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Article *in* Child Development · November 2003

DOI: 10.1046/j.1467-8624.2003.00627.x · Source: PubMed

3 authors:


Harlene Hayne
University of Otago


Rachel Barr
Georgetown University


Jane S Herbert
University of Wollongong

Child Development, November/December 2003, Volume 74, Number 6, Pages 1615–1627

The Effect of Prior Practice on Memory Reactivation and Generalization

Harlene Hayne, Rachel Barr, and Jane Herbert

Three experiments examined the effect of practice on memory performance by 18-month-old infants. Infants were tested using an imitation paradigm; an adult demonstrated a series of actions with objects and infants were given the opportunity to reproduce those actions following a delay. Some infants practiced the target actions before the retention interval (practice) and some did not (no practice). In Experiment 1, a reminder treatment alleviated forgetting by infants who practiced but failed to alleviate forgetting by infants who did not practice. In Experiments 2A and 2B, infants who practiced generalized to novel test stimuli after a 24-hr delay, whereas infants without practice did not. Results suggest practice influences the accessibility and generality of infants' memories.

Over the last decade, imitation has reemerged as a valuable tool for examining memory processing by 1- to 2-year-old infants (for review, see Barr & Hayne, 2000; Meltzoff, 1990). In imitation tasks, an experimenter performs an action or actions and the infant's ability to reproduce that action or actions is assessed following a delay. When this task is used to study memory, a delay is inserted between the end of the demonstration and the test session. Under these conditions, the modeled information must be stored in long-term memory to be retrieved and used at the time of the test (Meltzoff, 1990; Piaget, 1927/1962).

In general, two imitation procedures have been used to study memory development. In the deferred imitation procedure (e.g., Meltzoff, 1985), the experimenter does not verbally label the objects, the actions, or the goal of the sequence, and the infant is not allowed to touch the objects or practice the actions before the test. In the elicited imitation procedure (e.g., Bauer & Mandler, 1989), on the other hand, the demonstration is accompanied by a verbal description of the objects and actions and the infant is allowed to practice the actions at the end of the demonstration before the retention interval. If infants do not spontaneously imitate the target actions, the entire sequence is often remodeled and the infant is given a second opportunity to practice the target actions (Bauer & Hertsgaard, 1993; Bauer, Hertsgaard, & Wewerka, 1995; Bauer & Mandler, 1992).

Thus, there are two critical differences between the deferred imitation and elicited imitation procedures. First, verbal information accompanies the demonstration and the test in the elicited imitation paradigm but not in the deferred imitation paradigm. Second, infants have the opportunity to practice the target actions before the retention interval in the elicited imitation paradigm but not in the deferred imitation paradigm. Although some researchers have considered these procedural differences to be inconsequential to infants' performance, others have argued that narration and practice may influence estimates of infant memory.

There is mounting evidence, for example, that one difference between the elicited and deferred imitation procedures, the inclusion of verbal cues, influences at least two basic memory processes: generalization and long-term retention. That is, infants who are provided with verbal cues are more likely to generalize to novel test stimuli (Herbert & Hayne, 2000a) and to exhibit retention when tested with the original stimuli after a long delay (Herbert, Barr, & Hayne, 2000). Furthermore, infants' ability to exploit verbal cues varies as a function of age. In the study by Herbert and Hayne (2000a), for example, verbal cues increased generalization by 24-month-olds, but they had no effect on generalization by 18-month-olds. These findings raise the distinct

Harlene Hayne, Psychology Department, University of Otago; Rachel Barr, Department of Psychology, Georgetown University; Jane Herbert, Department of Psychology, University of Sheffield.

This research was supported by a Marsden Grant from the Royal Society of New Zealand to Harlene Hayne. Experiments 1 and 2A were part of a Ph.D. thesis completed by Rachel Barr under the direction of Harlene Hayne. The authors would like to thank Gabrielle Simcock and Julien Gross for providing interobserver reliability, and Jacqueline Clearwater and Brendon Sturgeon for constructing the stimuli. The authors would also like to thank the parents and their infants who made this research possible.

Correspondence concerning this article should be sent to Harlene Hayne, Psychology Department, University of Otago, Dunedin, New Zealand. Electronic mail may be sent to hayne@psy.otago.ac.nz.

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possibility that age-related differences in infants' performance on tasks that include verbal cues are due to changes in their ability to exploit linguistic information rather than to changes in retention, per se (cf. Liston & Kagan, 2002). To avoid this confound in the present research, the demonstration and test sessions did not include a verbal description of the stimuli, the target actions, or the goal of the sequence.

Researchers have also examined the effect of prior practice on long-term retention. In contrast to the effect of verbal cues, several studies have shown that practice has no effect on retention after delays ranging from 10 min to 4 months (Abravanel, 1991; Barr & Hayne, 1996; Meltzoff, 1995). Meltzoff (1995), for example, compared retention by groups of 14- and 16-month-old infants who had the opportunity to practice four single-step actions with that of infants who were not given the opportunity to practice. For infants in the no-practice group, the actions were modeled three times. For infants in the practice group, the actions were modeled once, the infant was given the opportunity to imitate the action for 20 s, and the action was modeled a second time. In this way, the total exposure to the test stimuli was equated across the practice and no-practice groups. The memory performance of infants in both practice groups was compared with the performance of infants in the age-matched baseline control group who had not seen the target actions before the retention test. Infants were tested following either a 2- or a 4-month delay. Although uniformly low, the performance by infants in both the practice and no-practice groups was significantly different from the performance of infants in the baseline control group, and there was no difference in performance as a function of practice at either delay.

In the present series of experiments, we continued to explore the effect of practice on infants' performance in imitation paradigms. In particular, the research addressed two questions. First, does practice facilitate the accessibility of the target memory once it has been forgotten? Past studies with both human and nonhuman infants have shown that memories that have been forgotten are not always permanently lost but can sometimes be retrieved and expressed if the infant is exposed to a reminder before the retention test (for review, see Rovee-Collier & Hayne, 1987). In the present research, we compared the effectiveness of a reminder treatment on the alleviation of forgetting in groups of infants with and without practice before the retention interval.

Second, does practice facilitate generalization to novel test stimuli? Past research has shown that, in the absence of prior practice, young infants do not generalize to novel stimuli when they are tested immediately or after a delay (Barr, Dowden, & Hayne, 1996; Hayne, Boniface, & Barr, 2000; Hayne, MacDonald, & Barr, 1997). When infants are given verbal labels for the novel stimuli, however, generalization is enhanced (Herbert & Hayne, 2000a). In the present research, we examined whether practice, like narration, might facilitate generalization.

Experiment 1: Effects of Practice on Memory Reactivation

Past studies with both human and nonhuman infants have shown that memories that are forgotten are not lost but can be retrieved and expressed if the participant is exposed to some aspect of the original training event before the retention test. In the first experiment of this kind, Campbell and Jaynes (1966) periodically exposed weanling rat pups to a portion of the original fear-conditioning procedure during a 4-week retention interval. Pups who received this reminder treatment exhibited excellent retention, whereas pups that had been trained but not reminded did not. Furthermore, pups that received only the four brief reminder treatments in the absence of original fear conditioning exhibited no retention during the test. Campbell and Jaynes proposed that the brief reminder treatments forestalled forgetting of the original training experience. They referred to this process as reinstatement. In subsequent experiments, Spear and Parsons (1976) found that a reminder administered at the end of the retention interval could also alleviate forgetting that had already occurred. Spear and Parsons referred to this process as reactivation.

Given the effect of reminder treatments on retention in infant rats, Rovee-Collier and her colleagues (Rovee-Collier, Sullivan, Enright, Lucas, & Fagen, 1980; Sullivan, 1982) examined the effect of analogous reminder treatments on long-term retention by human infants. In their original adaptation of the reminder procedure for use with 3-month-olds, Rovee-Collier et al. (1980) trained infants in the mobile conjugate reinforcement paradigm and tested them after a 2-week delay. Twenty-four hours before the long-term retention test, some infants were briefly exposed to the training mobile that was moved noncontingently by the experimenter. Only infants who received both original training and the reminder exhibited retention during the test. Infants who had been trained but not reminded, and infants who had been reminded but never trained responded at baseline during the test.

Literally dozens of studies using the mobile conjugate reinforcement paradigm have confirmed this seminal finding. That is, once substantial forgetting appears to have occurred, retention can be restored through the presentation of a reminder treatment (for review, see Rovee-Collier & Hayne, 1987). Reminder effects have also been demonstrated in a wide range of other memory paradigms used with both infants (Cornell, 1979; Hudson & Sheffield, 1998; Sheffield & Hudson, 1994) and children (Hoving & Choi, 1972; Hoving, Coates, & Bertucci, 1972; Howe, Courage, & Bryant-Brown, 1993; Priestley, Roberts, & Pipe, 1999). In most of the reminder studies, participants have been allowed to practice the target response or rehearse the target information before the retention interval. The long-term accessibility of memories based on observation alone is much less certain. Although prior practice may not influence the absolute duration of retention in tests of simple forgetting (Abravanel, 1991; Barr & Hayne, 1996; Meltzoff, 1995), it may influence whether the memory remains accessible to reminding over the long term. The present experiment was designed to assess the effects of prior practice on memory reactivation in 18-month-old human infants using an imitation paradigm.

Method

Participants. Sixty infants (30 male, 30 female) were recruited from published birth announcements and by word of mouth. All infants were tested within 2 weeks of their 18-month-old birthday. The sample was predominantly Pakeha (New Zealanders of European descent) and came from a wide range of economic backgrounds. Seven additional 18-month-olds were excluded from the final sample because of scheduling difficulties ($n = 2$), maternal interference ($n = 1$), or failure to touch the stimuli during the test ($n = 4$).

Apparatus. Two hand puppets, a pastel pink rabbit and a pale grey mouse, were constructed for these experiments and were not commercially available (see Figure 1). Both puppets were 60 cm in height and were made of soft, acrylic fur. A removable felt mitten (8 cm × 9 cm) was placed over the right hand of each puppet. The mitten was either pink or grey and matched the color of the rabbit or mouse, respectively. A large jingle bell was secured to the back of the puppet or inside the mitten itself, depending on the experimental group. The puppets (mouse or rabbit) were counterbalanced within and between groups.

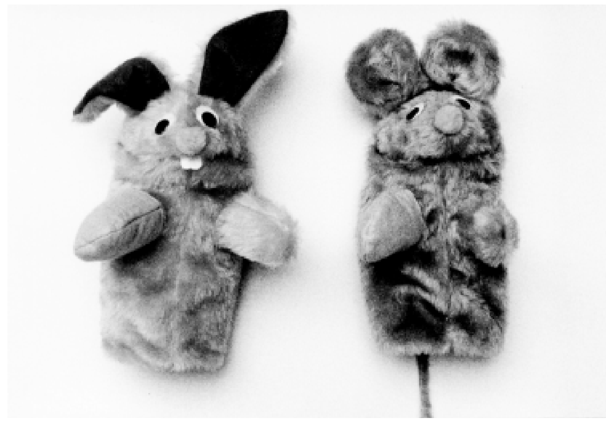

Fig. 1. The rabbit (left) and mouse (right) puppets used in Experiment 1.

Procedure. The procedures used in the present experiment were identical to those used in our past research on the development of deferred imitation (e.g., Barr et al., 1996; Barr & Hayne, 2000; Hayne et al., 1997; Hayne et al., 2000). All infants were tested in their own homes at a time of day defined by their caregiver as an alert play period. The purpose of the study and details of the procedure were explained to the caregiver and informed consent was obtained. At the beginning of each session, the infant was placed on the caregiver's knee and was held firmly by the hips. The experimenter interacted with the infant for approximately 5 min or until a smile was elicited.

Demonstration session. Independent groups of 18-month-old infants were randomly assigned to one of three conditions: practice ($n = 24$), no practice ($n = 24$), or nondemonstration control ($n = 12$). During the demonstration session, the female experimenter, kneeling at the caregiver's feet, placed the puppet over her right hand. The puppet was positioned at the infant's eye level but was out of reach. Infants in the no-practice condition watched the experimenter perform three specific actions with the puppet. The experimenter removed the mitten from the puppet's right hand, shook it three times ringing the jingle bell that was pinned inside, and replaced it on the puppet's right hand. This sequence was demonstrated a total of six times. Infants in the practice condition watched the experimenter perform the same specific actions with the puppet; however, these actions were demonstrated a total of three times, after which the infants had the opportunity to imitate the target actions three times. In this way, exposure to the target actions was equated across the practice and no-practice conditions.

Infants in the nondemonstration control condition were exposed to the puppet, the mitten, the ringing of the bell, and the experimenter for the same amount of time as infants in the practice and no-practice conditions; however, the target actions were never modeled. For infants in the control condition, the jingle bell was attached to the back of the puppet's body. As before, the puppet was held in front of the infant but was out of reach. The experimenter then shook the puppet three times ringing the bell attached to the puppet's back. This procedure was repeated five more times. For infants in all three conditions (practice, no practice, and control), the demonstration session lasted approximately 50 to 60 s.

To maintain the infant's attention during the demonstration, the experimenter used phrases such as, ''Isn't this fun?'' or ''Are you still watching?'' or ''Shall we have another look?'' In no instance, however, were the target actions or the puppet verbally described.

Reminder treatment. Twenty-four hours before the test, half of the infants in the practice and the no-practice conditions were given a reminder treatment (reminder group) and the remaining infants were not (no reminder group). The 24-hr delay between the presentation of the reminder and the test session was selected because it represents the modal delay between reminding and test in prior studies conducted with human infants (for reviews, see Rovee-Collier & Hayne; 1987; Rovee-Collier, Hayne, & Colombo, 2001) and toddlers (Sheffield & Hudson, 1994).

During the reminder treatment, infants were briefly exposed to the puppet; however, the target actions were not demonstrated. The bell was pinned to the back of the puppet and the experimenter shook the puppet to ring the bell. The reminder treatment lasted 30 s. This procedure is identical to the nondemonstration control procedure used in all of our prior studies. Our past research has shown that, in the absence of a prior demonstration, this procedure does not elicit the target responses.

Test session. The test session occurred 6 weeks ($\pm$5 hr) after the demonstration session (24 hr after the reminder treatment) and was identical for all infants. The 6-week delay was selected on the basis of prior research with this task showing that 18-month-old infants exhibit no evidence of retention when tested after a 6-week delay (Barr & Hayne, 2000).

During the test, the bell was removed from the puppet. The infant was again placed on the caregiver's knee and the puppet was placed within reach, approximately 30 cm in front of the infant. During the test, infants were allowed 90 s from the time that they first touched the puppet in which to imitate the target actions.

Results

Two independent observers scored each videotaped test session. One observer was blind to the infants' group assignments. Both observers noted the presence or absence of three target behaviors during the test: (a) remove the mitten, (b) shake the mitten, and (c) put the mitten back on the puppet (or attempt to put the mitten back on). Both percent reliability and kappa were calculated, yielding an interobserver reliability of 93.7% (kappa = 0.87). Preliminary analyses indicated that there was no main effect of infant gender, and gender did not enter into any significant interaction. As such, the data were collapsed across gender for all subsequent analyses.

The mean imitation scores are shown in Figure 2 as a function of experimental condition and reminder group. The data in Figure 2 were subjected to a one-way analysis of variance (ANOVA). This analysis yielded a main effect of group, $F(4, 55) = 3.55$, $p < .01$. Post hoc Student-Newman-Keuls tests ($p < .05$) highlighted two important findings. First, in the absence of a reminder treatment, infants exhibited no retention of the target actions 6 weeks after the demonstration, irrespective of their practice

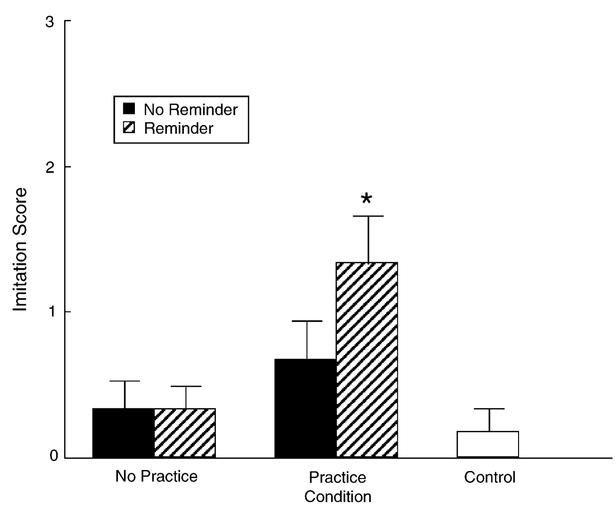

Fig. 2. The mean imitation scores (+1 *SE*) of 18-month-old infants tested after a 6-week delay as a function of practice condition and reminder group. The mean imitation score (+1 *SE*) of infants in the nondemonstration control condition is shown by the open bar.

condition (see Figure 2, no-reminder groups). The mean imitation scores of these two groups were not significantly greater than that of the nondemonstration control group. Second, for infants in the reminder groups, only infants who were given the opportunity to practice the actions before the retention interval exhibited retention during the test. The mean imitation score of the practice and reminder group was significantly greater than that of the nondemonstration control group (see Figure 2, asterisk). The imitation score of the no-practice and no-reminder group, on the other hand, was not.

Discussion

Consistent with our prior findings, practice alone was not sufficient to sustain retention of this task over the 6-week delay (Barr & Hayne, 2000). Infants in both the practice and the no-practice condition who did not receive a reminder treatment exhibited no retention during the test. Although infants who are 18 months old and younger have been shown to exhibit retention of some single-step actions following delays as long as 4 months (Meltzoff, 1995), our prior studies have shown that forgetting of multistep sequences occurs following a much shorter delay (Barr & Hayne, 2000; Herbert & Hayne, 2000b).

Consistent with prior findings obtained in the mobile conjugate reinforcement paradigm, forgetting in the present experiment was alleviated by the presentation of a reminder treatment before the long-term test. The effect of the reminder, however, varied as a function of prior practice. Forgetting was only alleviated in the group that was given the opportunity to practice the target actions before the retention interval. This finding suggests that, despite equivalent rates of original forgetting, memories based on prior practice may remain more accessible to retrieval over the long term than memories based on observation alone.

Experiment 2: Effects of Practice on Generalization

Several theorists concur that a memory consists of a collection of attributes that represent portions of the event and the context in which the event occurred (e.g., Estes, 1973, 1976; Spear, 1973, 1978; Tulving, 1983, Underwood, 1969). For example, Estes (1973, 1976) originally proposed that a memory could be retrieved if and only if the participant reencountered stimuli that matched attributes stored as part of the original representation. Furthermore, a threshold number of attributes had to be reactivated to enable retrieval to occur. This notion was subsequently elaborated by Tulving (1983) and is commonly referred to as the encoding specificity hypothesis.

The encoding specificity hypothesis has important implications for memory retrieval in situations in which either the context or objects differ from those that were present during original encoding. For a novel object to cue retrieval, the individual must recognize the similarity between that object and attributes stored as part of the memory representation. This task may be extremely difficult early in development simply because infants and young children have acquired fewer associations between memory attributes than older children and adults (Hayne et al., 2000; Herbert & Hayne, 2000a; Rovee-Collier, 1996).

Hayne and her colleagues (Hayne et al., 1997; Hayne et al., 2000; Herbert & Hayne, 2000a) have examined developmental changes in the effect of novel retrieval cues on memory performance by 6- to 30-month-old infants using the deferred imitation paradigm. In one series of studies, infants were tested following a 24-hr delay with either the same puppet that was present during the demonstration session or with a different puppet (Hayne et al., 1997; Hayne et al., 2000). Although infants of all ages exhibited deferred imitation of the target actions when the test puppet was the same as the puppet present during the original demonstration, there were clear age-related differences in performance when the puppet was different. In fact, infants less than 18 months of age exhibited no generalization whatsoever.

In addition to age, several procedural variables also influence generalization performance. First, the discrepancy between the demonstration and test stimuli have been shown to alter performance. For example, 18-month-olds will generalize between the puppets shown in Figure 1, but if the discrepancy between the puppets is increased (see Figure 3), generalization does not occur until 21 months of age (Hayne et al., 1997). Second, the complexity of the imitation task, per se, also influences performance. Although 21-month-olds generalize between the puppets shown in Figure 3, if they are tested with more complex stimuli that require different target actions, generalization does not occur until 30 months of age (Herbert & Hayne, 2000a). Presumably, increasing the discrepancy between the demonstration and the test stimuli or the difficulty of the task even further would continue to increase the age at which infants first solve the generalization task.

Fig. 3. The cow (left) and duck (right) puppets used in Experiment 2A.

Third, as described earlier, verbal cues facilitate generalization to novel test stimuli (Herbert & Hayne, 2000a; see also Nelson, 1990, 1993). In the Herbert and Hayne (2000a) experiment, for example, 24-month-olds who were provided with the same unique verbal label at the time of the demonstration and again at the time of the test generalized responding when tested with physically dissimilar objects.

Finally, Rovee-Collier and her colleagues (Fagen, Morrongiello, Rovee-Collier, & Gekoski, 1984; Greco, Hayne, & Rovee-Collier, 1990; Hayne, Rovee-Collier, & Perris, 1987; Rovee-Collier, Greco-Vigorito, & Hayne, 1993) have shown that generalization, even by very young infants, is facilitated by exposure to multiple exemplars at the time of original encoding. Similar findings have also been obtained by Fivush, Kuebli, and Clubb (1992) in studies with 3-year-old children tested in a behavioral reenactment procedure and by DeLoache (1987, 1991) in studies with 2- to 3-year-olds tested in a standardized search paradigm. In both the reenactment and search paradigms, children given exposure to multiple instantiations of the relevant stimuli during original encoding are more likely to generalize to novel stimuli or more difficult problems encountered at the time of the test.

In sum, several procedural factors have been shown to influence the probability that infants will exploit novel retrieval cues at the time of the test and generalize responding to novel stimuli. We hypothesized that the opportunity to practice the target actions before the retention interval might also facilitate infants' ability to exploit novel retrieval cues. In the next two experiments, we tested this hypothesis using two different sets of stimuli that have been used in prior research on generalization.

Experiment 2A

Method

Participants. Sixty infants (30 male, 30 female) were recruited, as before. All infants were tested within 2 weeks of their 18-month-old birthday. The sample was predominantly Pakeha and came from a wide range of socioeconomic backgrounds. Six additional 18-month-olds were excluded from the final sample because of scheduling difficulties ($n = 1$), procedural error ($n = 2$), or a failure to touch the puppet during the practice session ($n = 1$) or during the test ($n = 2$).

Apparatus. Two hand puppets, a black-and-white-cow and a yellow-and-orange duck, were constructed for these experiments and were not commercially available (see Figure 3). Both puppets were 60 cm in height and were made of soft, acrylic fur. A removable felt mitten (8 cm $\times$ 9 cm) was placed over the right hand of each puppet. The mitten was either black or yellow and matched the color of the cow and the duck, respectively. A large jingle bell was secured to the back of the puppet or to the inside of the mitten itself, depending on the experimental group. The puppets (cow or duck) were counterbalanced within groups.

Procedure. The demonstration and test procedures were identical to those used in Experiment 1. Infants were randomly assigned to one of three conditions: practice ($n = 24$), no practice ($n = 24$), or nondemonstration control ($n = 12$). The test session, identical to that used in Experiment 1, was scheduled 24 hr ($\pm$5 hr) after the demonstration session and was identical for all infants. During the test, half of the infants in the practice condition and no-practice condition and all of the infants in the nondemonstration control condition were presented with the same puppet that they had seen during the demonstration (same group) and half of the infants in the practice condition and no-practice condition were tested with a different puppet (different group). As in Experiment 1, the bell was removed from the puppet during the test.

Results

An imitation score was calculated for each infant by summing the number of target behaviors that he or she produced during the test (*range* = 0–3). Both percent reliability and kappa were calculated yielding an interobserver reliability of 94.8% (kappa = 0.89). Preliminary analyses indicated that there was no main effect of infant gender, and gender did not enter into any significant interaction. As such,

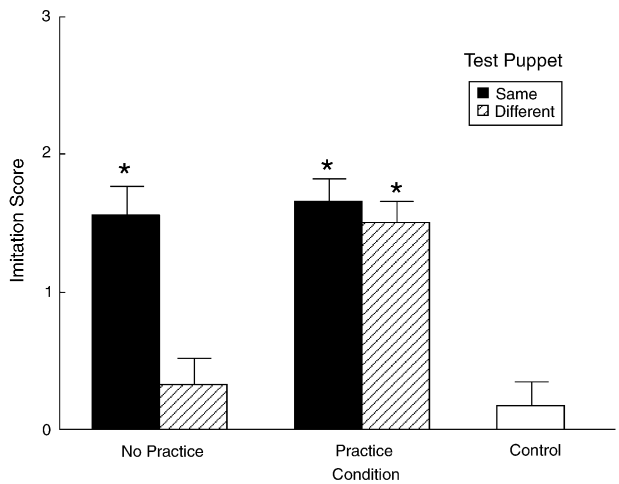

Fig. 4. The mean imitation scores (+1 *SE*) of 18-month-old infants tested after a 24-hr delay as a function of practice condition and test stimulus. The mean imitation score (+1 *SE*) of infants in the nondemonstration control condition is shown by the open bar.

the data were collapsed across gender for all subsequent analyses.

The mean imitation scores are shown in Figure 4 as a function of experimental condition and test stimulus. The data in Figure 4 were subjected to a one-way ANOVA. This analysis yielded a main effect of group, $F(4, 55) = 6.95$, $p < .01$. Post hoc Student-Newman-Keuls tests ($p < .05$) indicated that, consistent with our prior research, infants in the no-practice condition who were tested with the same puppet exhibited imitation scores that were significantly greater than those of infants in the nondemonstration control condition, whereas infants in the no-practice condition who were tested with a different puppet did not. In contrast, infants in the practice condition exhibited significantly higher imitation scores than infants in the nondemonstration control condition irrespective of whether they were tested with the same or a different puppet. Furthermore, within the practice condition, there was no difference in the imitation scores when infants were tested with the same or a different puppet.

Experiment 2B

The results of Experiment 2A supported our hypothesis that practice would facilitate generalization. In Experiment 2B, we attempted to replicate and extend this finding using a different imitation task and a within-subject rather than a between-subject design.

Method

Participants. Thirty-six infants (18 male, 18 female) were recruited as before. All infants were tested within 2 weeks of their 18-month-old birthday. The sample was predominantly Pakeha and came from a wide range of socioeconomic backgrounds. Three additional 18-month-olds were excluded from the final sample because of scheduling difficulties ($n = 2$) or illness on the test day ($n = 1$).

Apparatus. The stimuli used in the present experiment were identical to those used by Herbert and Hayne (2000a, 2000b). There were two types of stimuli (rattle and animal) and two versions of each type. The stimuli were constructed in such a way that the exact same target actions could be performed with each version (see Table 1).

The stimuli for the green rattle (see Figure 5, Panel A) consisted of a green stick (12.5 cm long) attached to a white plastic lid (9.5 cm in diameter) with Velcro attached to the underside of the lid, a round green block (3 cm in diameter × 2.5 cm in height), and a clear plastic square cup with Velcro around the top (5.5 cm in diameter × 8 cm in height). The opening of the plastic cup (3.5 cm in diameter) was covered with a 1-mm black rubber diaphragm, with 16 cuts radiating from the centre.

Table 1
The Three Target Actions of Each Set of Stimuli

Stimulus set	Step 1	Step 2	Step 3
Green rattle	Push block through diaphragm into jar	Put stick on jar attaching with Velcro	Shake stick to make noise
Red rattle	Put the block in the jar	Push the stick into the top of the jar	Shake stick to make noise
Rabbit	Pull lever in a circular motion to raise ears	Place eyes on face attaching with Velcro	Put the carrot in the rabbit's "mouth"
Monkey	Pull lever in a circular motion to raise ears	Place eyes on face attaching with Velcro	Put the banana in the monkey's "mouth"

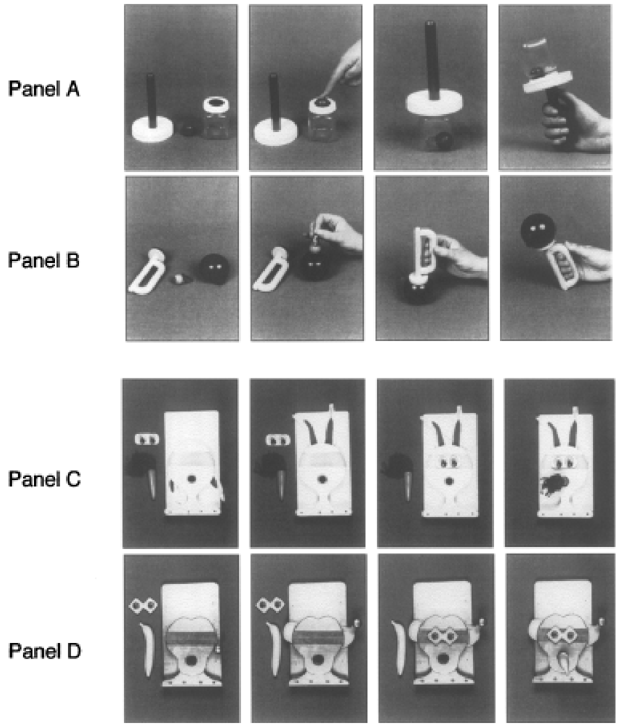

Fig. 5. The green rattle (Panel A), red rattle (Panel B), rabbit (Panel C), and monkey (Panel D) stimuli that were used in Experiment 2B.

The stimuli for the red rattle (see Figure 5, Panel B) consisted of a yellow D-shaped handle (gap between stick and handle = 1.5 cm × 8 cm) attached to a yellow wooden stick (12.5 cm long) with a plug on the end that fit into a red plastic ball with a hole cut in the top (4 cm in diameter), and a blue plastic bead (2 cm in diameter) attached to the underside of a silver metal bell (2.5 cm in width, 2 cm long).

The stimuli for the rabbit (see Figure 5, Panel C) consisted of two plastic eyes (3 cm × 2 cm) attached to a 9 cm × 6 cm piece of plywood with Velcro on the back, a 12-cm orange wooden carrot with green string attached to the top, and a white circle of wood (the head, 15 cm in diameter) mounted horizontally on a white rectangular wooden base (30 cm 20 cm). A 3-cm (in diameter) hole was drilled at the bottom of the head and a 5 cm × 15 cm piece of white Velcro was attached to the top of the head. Two white "ears" (20 cm × 5 cm) decorated with stripes of pink felt were hidden behind the head. A 10-cm wooden stick attached to the top of the right ear allowed the ears to be pulled up from behind the head in a circular motion to a point above the head.

The stimuli for the monkey (see Figure 5, Panel D) consisted of two plastic eyes (2.5 cm in diameter) with eyelashes that were attached to a piece of brown plywood in the shape of two diamonds joined at the center (11.5 cm in width, 6.5 cm in height), with brown Velcro on the back, a 20.5-cm yellow plastic banana, and a brown wooden head and shoulders shape mounted horizontally on a brown rectangular wooden base (22 cm × 38 cm). A 4-cm hole was drilled at the bottom of the head and a 5 cm × 18 cm piece of brown Velcro was attached to the top of the head. Two brown ears (3.5 cm × 7 cm) decorated with a piece of yellow felt were hidden behind the head. A 3-cm lever with a wooden button (3.5 cm in diameter) on the top, attached to the right ear, allowed for the ears to be pulled up from behind the head in a circular motion to the side of the head.

Procedure. As before, infants were tested in their homes at a time of day that the caregiver identified as an alert play period. During the initial visit, the purpose of the study and details of the procedure were explained to the caregiver, and informed consent was obtained. Throughout each session, the infant and the experimenter were seated facing each other on the floor; the caregiver was seated behind the infant and held him or her gently by the hips. At the beginning of each session, the experimenter interacted with the infant for approximately 5 min or until a smile was elicited.

Infants were randomly assigned to the practice or no-practice conditions with the proviso that there were an equal number of males and females in each condition. Infants in the practice condition ($n = 12$) were allowed to practice the target actions following the demonstration before the retention interval. Infants in the no-practice condition ($n = 12$), on the other hand, were not allowed to touch the stimuli until the long-term retention test 24 hr later.

For infants in both the practice and no-practice conditions, the experimenter modeled a three-step sequence for one of the rattles and one of the animal stimuli. The experimental stimuli are shown in Figure 5 and the target actions for each set of stimuli are listed in Table 1. The order of presentation of the stimulus sets was counterbalanced across participants. For infants in the no-practice condition, the three-step sequence was modeled six times in succession. For infants in the practice condition, on the other hand, the three-step sequence was modeled three times in succession and then infants had the opportunity to imitate the target actions three times.

The test session was scheduled 24 hr (±5 hr) after the demonstration session and was identical for all infants. During the test, infants were tested with one set of stimuli that had been used during the demonstration (same) and one set of stimuli that was perceptually different to the one seen during the demonstration (different) but that required the same target actions (see Table 1). The two types of stimuli (rattle or animal) and the order of presentation (same or different) were counterbalanced across infants.

To assess the spontaneous production of the target actions in the absence of adult demonstration, an independent group of infants in the nondemonstration control condition ($n = 12$) was presented with the stimuli for the first time at the time of the test.

Results

Each videotaped session was coded by two independent observers, one of whom was blind to the infants' group assignment. Each observer scored the presence or absence of each target behavior during the 60-s test period. Both percent reliability and kappa were calculated, yielding an interobserver reliability of 92% (kappa = 0.84). An imitation score was calculated for each infant by summing the number of target actions produced during the test with each set of stimuli (*range* = 0–3). Preliminary analyses indicated that there was no difference in infants' performance with the two sets of stimuli; therefore, the data were averaged across both sets for all subsequent analyses. Preliminary analyses also indicated that there was no main effect of infant gender, and gender did not enter into any significant interaction. As such, the data were collapsed across gender for all subsequent analyses.

The mean imitation scores are shown in Figure 6 as a function of experimental condition and test stimulus. The data from infants in the practice and no practice conditions were initially subjected to a 2 (practice) × 2 (test stimuli) ANOVA with repeated measures across test stimuli. This analysis yielded a main effect of practice, $F(1, 22) = 4.46$, $p < .05$, and test stimuli, $F(1, 22) = 18.73$, $p < .01$, and a Practice × Test Stimuli interaction, $F(1, 22) = 5.14$, $p < .05$.

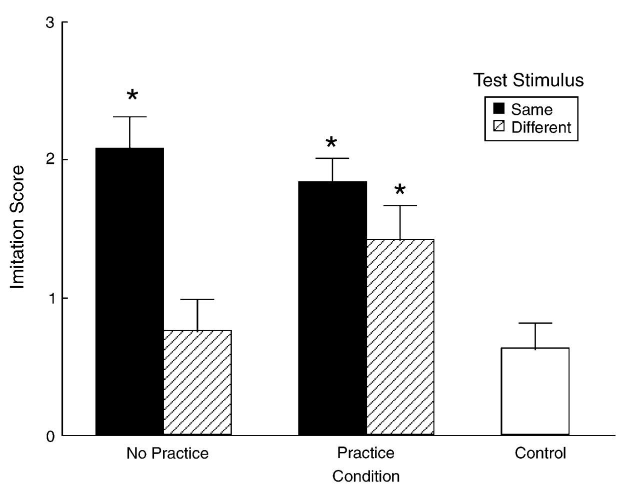

Fig. 6. The mean imitation scores (+1 *SE*) of 18-month-old infants tested after a 24-hr delay as a function of practice condition and test stimulus. The mean imitation score (+1 *SE*) of infants in the control condition is shown by the open bar.

To evaluate the interaction and to assess whether the performance of any group exceeded that of infants in the control condition, the data for each test stimulus (same, different) were subjected to separate one-way ANOVAs across practice condition. Each of these analyses also included the data from the nondemonstration control condition. Both analyses yielded a significant main effect of condition: same test stimulus, $F(2, 33) = 12.26$, $p < .0001$; different test stimulus, $F(2, 33) = 3.93$, $p < .05$. These main effects were then evaluated using Student-Newman-Keuls post hoc tests ($p < .05$).

The results of the post hoc analyses indicated that when infants were tested with the same stimulus that had been used during the original demonstration, practice had no effect on performance. That is, the mean imitation scores of infants in both the practice and no-practice conditions were significantly greater than those of infants in the control condition and they did not differ from each other. When infants were tested with a different stimulus, however, practice did influence performance. The mean imitation scores of infants in the practice condition were significantly greater than those of infants in the control condition, but the mean imitation scores of the infants in the no-practice condition were not. These findings are identical to those reported in Experiment 2A.

General Discussion

Although research has failed to demonstrate an effect of prior practice on long-term retention in imitation paradigms, the present findings show that practice does influence at least two other aspects of infant memory: memory reactivation and generalization to novel test cues. In Experiment 1, only infants who practiced the target actions before the retention interval were successfully reminded 6 weeks later. In Experiments 2A and 2B, only infants who practiced the target actions exhibited retention when they were tested with stimuli that differed from those present at the time of the original demonstration. On the basis of these findings, we concluded that prior practice facilitates both the accessibility and generality of infants' memories.

The results of Experiment 1 add to a well-established body of literature on reminder effects in human infants. That is, although infants typically forget rapidly, some of their early memories may not be permanently lost. Instead, memories that appear to be forgotten can be reactivated given the appropriate retrieval cues. Several factors, including the age of the infant (Greco, Rovee-Collier, Hayne, Griesler, & Earley, 1986), the nature of the reminder stimuli (Hayne & Rovee-Collier, 1995; Hayne, Rovee-Collier, & Borza, 1991; Rovee-Collier, Patterson, & Hayne, 1985), and the number of prior reminder treatments (Hayne, 1990), have been shown to influence if and when a memory is accessible to reminding. The present findings demonstrated that practice at the time of original encoding also influences the effectiveness of a reminder. Although memories based on observation alone may also be retrieved through reminding (Cornell, 1979; Richardson, Wang, & Campbell, 1993), we predict that the nature of an effective reminder treatment may vary as a function of prior practice. We are currently exploring this possibility.

The results of Experiments 2A and 2B are consistent with a growing body of research showing that infant memory retrieval, perhaps even more than adult memory retrieval, follows the principles outlined in Tulving's (1983) encoding specificity hypothesis. Systematic studies conducted with 2- to 6-month-old infants trained in the mobile conjugate reinforcement paradigm have indicated that the proximal cues present at the time of the test must be virtually identical to those present at the time of original training if the target memory is to be retrieved and expressed (e.g., Greco et al., 1990; Hayne & Findlay, 1995; Hayne, Greco, Earley, Griesler, & Rovee-Collier, 1986; Hayne et al., 1987; Rovee-Collier, Hankins, & Bhatt, 1992). Hayne et al. (1986) demonstrated, for example, that if more than one object on a five-object mobile was changed at the time of the 24-hr retention test, retrieval by 2- and 3-month-olds was precluded.

In contrast to data obtained using the mobile conjugate reinforcement paradigm, initial research using the imitation paradigm demonstrated that memory retrieval might occur in spite of substantial changes in the stimuli or in the context between original encoding and the test (Barnat, Klein, & Meltzoff, 1996; Bauer & Dow, 1994; Hanna & Meltzoff, 1993). For example, Bauer and Dow (1994) found that 16- and 20-month-old infants generalized when tested with different objects after a 1-week delay. Similarly, Hanna and Meltzoff (1993) found that 14- to 18-month-old infants generalized when tested in an environmental context that differed from that during the original demonstration.

What factors might account for the difference in the performance of infants tested using the mobile conjugate reinforcement and imitation paradigms? Initially, investigators attributed the difference to the underlying memory systems that they thought were required to complete the two tasks (Bauer & Dow, 1994; Hanna & Meltzoff, 1993; Meltzoff, 1995). It was generally assumed, for example, that the mobile conjugate reinforcement paradigm required procedural memory whereas the imitation paradigm required declarative memory (Bauer, 1995; Mandler, 1984, 1990a, 1990b; Meltzoff, 1990, 1995; Nelson, 1995, 1997). Based on this assumption, it was argued that the differences in generalization performance in these two tasks reflected fundamental differences in the functioning of the procedural and declarative memory systems, per se. Studies using procedural memory tasks have typically found that memory performance is often concrete, context specific, and object bound, whereas studies using declarative tasks have found that memory performance is more abstract and flexible (for reviews, see Diamond, 1990; Rovee-Collier et al., 2001; Schachter, 1987).

More recent research has challenged the view that mobile conjugate reinforcement and imitation paradigms tap different memory processes (for review, see Rovee-Coller et al., 2001). In fact, when the same infants are tested in both procedures, their performance is identical (Gross, Hayne, Herbert, & Sowerby, 2002). Given this, how can we account for the differences in infants' generalization performance? Hayne et al. (1997; Hayne et al., 2000) have argued that the difference in infants' generalization performance in the mobile conjugate reinforcement and imitation paradigms is due to the age of the infants who are typically tested in each procedure. For example, the mobile conjugate reinforcemernt paradigm is typically used with infants 6 months old and younger, whereas imitation tasks are typically used with infants 12 months old and older (but see Barr et al., 1996; Hayne et al., 2000). In support of this view, when infant age is held constant in both paradigms, generalization performance is the same (Hayne et al., 1997). Furthermore, when infants of different ages are tested in both procedures, generalization in both increases as a function of age (cf. Hartshorn et al., 1998; Hayne et al., 1997; Hayne et al., 2000).

Hayne et al.'s (1997; Hayne et al., 2000) explanation based on age differences accounts for prior discrepancies in findings obtained in the mobile conjugate reinforcement and imitation paradigms, but it does not account for discrepancies in findings obtained within the imitation paradigm. For example, recall that 16- and 20-month-old infants readily generalized to changes in test stimuli in the study conducted by Bauer and Dow (1994). Despite their overlapping age range, the 18-month-old infants in the study conducted by Hayne et al. (1997) did not. Given this, some factor other than age may also influence the conditions under which infants generalize knowledge acquired with one object when tested with another. On the basis of the present findings, we hypothesize that prior practice is one of these factors. In the Bauer and Dow study, for example, infants were allowed to practice the actions before the test (elicited imitation), but in the Hayne et al. (1997; see also Herbert & Hayne, 2000a) study, they were not (deferred imitation).

How does practice alter the accessibility and generality of infants' memories? We hypothesize that practice influences memory performance by enhancing both the content and the strength of the underlying memory representation. That is, infants without practice can encode information about the visual features of the objects and the experimenter's actions as well as information about the goal or end state of the target event. In addition to this information, infants with practice have the opportunity to encode other information about the characteristics of the stimuli (e.g., the weight and texture of the objects in their hands) and the target actions as well as affective information that may arise while playing with the objects (e.g., joy, interest, or feelings of success). As such, the representation formed by infants who are given the opportunity to practice would contain more total attributes, and the connections between individual attributes might also be stronger. Either of these outcomes would make the memory more accessible to subsequent retrieval when an infant encounters a reminder after a long delay or when he or she encounters novel retrieval cues following a shorter delay (e.g., Brainerd, Reyna, Howe, & Kingma, 1990; DeLoache, Miller, & Pierroutsakos, 1998; Vander Linde, Morrongiello, & Rovee-Collier, 1985). In this way, we hypothesize that practice influences memory performance in a manner analogous to other forms of rehearsal.

Within the infant memory literature, it has been repeatedly argued that paradigms that provide opportunities for practice recruit different memory processes than paradigms that do not. Historically, this argument has been marshaled to draw a distinction between the mobile conjugate reinforcement and imitation paradigms. Over the last decade, however, empirical research has clearly shown that these procedures share more similarities than differences. Ironically, the presence or absence of practice is rarely used to distinguish between different imitation procedures even though one version of the task involves practice (elicited imitation) and the other does not (deferred imitation). Despite the common claim that deferred and elicited imitation procedures yield similar measures of memory, the results of the present experiments demonstrate that prior practice leads to systematic differences in memory performance.

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