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Developmental Changes in the Specificity of Memory Over the Second Year of Life

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Developmental changes in the specificity of memory were examined in five experiments with 12- to 21-month-old infants. In all experiments, infants were tested in a deferred imitation paradigm; the specificity of the cues necessary to retrieve the target memory was assessed after a delay. Changes in cues that disrupted performance at 12 months had no effect on performance at 18 months, and changes in cues that disrupted performance at 18 months had no effect on performance at 21 months. These findings indicate that one hallmark of memory development is an increase in the range of effective retrieval cues for a particular memory. We propose that this change in effective retrieval cues increases the range of situations in which early learning experiences are retrieved and expressed and may contribute to the decline of childhood amnesia during the third year of life.

memory deferred imitation encoding specificity

Many classic theories of memory share a number of common assumptions (Bower, 1972; Estes, 1976; Lewis, 1979; Medin & Schaffer, 1978; Spear, 1978; Tulving, 1983; Underwood, 1969; Wickens, 1970). First, all assume that a memory consists of a hypothetical collection of attributes that represent what the individual noticed at the time of original encoding. Second, all assume that these memory attributes reflect characteristics of the nominal event as well as information about the context in which that event originally occurred. Finally, all assume that the memory of the target event will be retrieved only if and when the individual re-encounters cues that match attributes stored as part of the original representation. This latter notion, the "encoding specificity hypothesis," has received considerable experimental support (Tulving, 1983, 1984; Tulving & Thomson, 1973). Studies of verbal learning with adults, for example, have shown that changes in either the stimulus materials (for reviews, see Spear, 1978; Tulving, 1983) or the environmental context (Godden & Baddeley, 1975; Smith, Glenberg, & Bjork, 1978) at the time of the retention test disrupt performance. These performance deficits are attributed to a retrieval failure engendered by a mismatch between the cues present at the time of encoding and those present at the time of retrieval.

A similar relation between encoding and retrieval has been described for 2- to 6-month-old infants tested in the mobile conjugate reinforcement paradigm (for reviews, see Rovee-Collier & Hayne, 1987; Rovee-Collier & Shyi, 1992). In this task, infants are trained to kick their feet to produce movement in a mobile. The effect of altered cues on memory retrieval has been assessed using three different procedures following training in the mobile paradigm—the delayed recognition procedure, the memory reactivation procedure, and the reforgetting procedure. The underlying assumption of studies of encoding specificity conducted with infants is identical to the underlying assumption of studies conducted with adults. That is, by assessing generalization to novel stimuli, it is possible to infer the conditions required to cue retrieval of the target memory (Tulving, 1984). Evidence supporting the encoding specificity hypothesis from studies using the mobile procedure is reviewed briefly below.

Delayed Recognition Procedure

In delayed recognition tests, the stimulus conditions necessary to cue retrieval of the target memory are assessed while that memory is still highly accessible. Depending on the age of the

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infant, the effect of altered retrieval cues at the time of the retention test is assessed after delays ranging from 1 to 14 days. Tests of delayed recognition have shown that memory retrieval is highly specific to the cues that were present at the time of original encoding (e.g., Greco, Hayne, & Rovee-Collier, 1990; Hayne & Findlay, 1995; Hayne, Greco, Earley, Griesler, & Rovee-Collier, 1986; Hayne, Rovee-Collier, & Perris, 1987; Rovee-Collier, Hankins, & Bhatt, 1992). For example, 2- and 3-month-olds exhibit excellent retention after a delay of 24 hours when they are tested with the same five-object mobile that had been present during original training. In contrast, they exhibit no retention whatsoever if more than a single novel object is substituted into the training mobile during the delayed recognition test (Hayne et al., 1986). Similarly, when 3-month-old infants are trained with a mobile composed of blocks displaying *As* or *2s*, they exhibit no evidence of retention after a 24-hour delay if either the color or the form of those characters is changed (Hayne et al., 1987). Studies with 6-month-old infants have also shown that memory retrieval is precluded by changes in the mobile after delays as long as 14 days (Hill, Borovsky, & Rovee-Collier, 1988). Furthermore, changes in the environmental context also disrupt memory retrieval at both 3 (Butler & Rovee-Collier, 1989; Rovee-Collier, Griesler, & Earley, 1985) and 6 (Borovsky & Rovee-Collier, 1990; Shields & Rovee-Collier, 1992) months of age.

Memory Reactivation Procedure

Numerous experiments with animal infants (Spear, 1973; Spear & Parsons, 1976), human infants (Hayne, 1990, 1996; Rovee-Collier & Hayne, 1987; Sheffield & Hudson, 1994), and children (Hoving & Choi, 1972; Hoving, Coates, Bertucci, & Riccio, 1972) have shown that, once forgetting has occurred, the target memory can be recovered by the presentation of a reminder. During a typical reminder treatment, the infant is briefly exposed to some component of the original event prior to the actual retention test. Presumably, reminders alleviate forgetting by priming or "reactivating" latent or dormant memory attributes, thereby increasing their accessibility (Spear, 1973). Studies of memory reactivation with human infants trained in the mobile paradigm have shown that once significant forgetting has occurred, retention can be restored if infants are briefly exposed to the original training mobile, moved noncontingently by the experimenter, well in advance of the long-term retention test. Following this reminder treatment, performance is restored to the level seen immediately after training. When infants are trained in a highly distinctive context, exposure to the context alone also alleviates forgetting (Hayne & Findlay, 1995; Rovee-Collier et al., 1985a). At 3 months, a single reminder treatment is highly effective in alleviating forgetting after retention intervals as long as 4 weeks (Hayne, 1990; Hayne & Findlay, 1995; Rovee-Collier, Sullivan, Enright, Lucas, & Fagen, 1980; Sullivan, 1982), and two reminder treatments alleviate forgetting for at least 6 weeks (Hayne, 1990).

To be effective, a reminder must reinstate the original encoding context fairly precisely. When 3-month-old infants are trained for 2 consecutive days with the same five-object mobile, for example, a mobile containing more than one different object is no more effective than no reminder at all (Rovee-Collier, Patterson, & Hayne, 1985b). Similarly, when infants are trained with a mobile composed of blocks displaying *As* or 2s, changes in either the color or the form of those characters on the reminder mobile also preclude retrieval of the training memory (Hayne et al., 1987). Changes in the environmental context at the time of the reminder treatment also eliminate its effectiveness even though infants are reminded and tested with the original mobile (e.g., Borovsky & Rovee-Collier, 1990; Butler & Rovee-Collier, 1989; Hayne, Rovee-Collier, & Borza, 1991; Rovee-Collier & DuFault, 1991; Shields & Rovee-Collier, 1992). These effects are not task-specific: When 6-month-old infants learn to press a lever to produce movement in a miniature train, changes in either the train or in the environmental context at the time of reminder preclude retrieval of the forgotten memory (Hartshorn & Rovee-Collier, 1997). Taken together, studies of memory reactivation have provided convergent evidence for the role of encoding specificity in memory retrieval during early infancy.

Reforgetting Procedure

Previous research on memory reactivation has shown that the effect of a reminder treatment on long-term retention is not transient. Once reactivated, the training memory remains accessible for several days (Hayne, 1990; Hayne & Rovee-Collier, 1995). The duration of retention following reactivation varies as a function of the age of the infant (Boller, Rovee-Collier, Borovsky, O'Connor, & Shyi, 1990) and the number of reminder treatments (Hayne, 1990). In studies of memory reactivation, memory retrieval is initiated at least twice. First, the reminder initiates retrieval of the inaccessible or forgotten memory, and second, the stimuli present at the time of the ensuing retention test cue retrieval of the memory made accessible through reminding. A third procedure for assessing the specificity of memory retrieval is to assess the effect of novel stimuli on performance following an effective reminder treatment. In this reforgetting procedure, infants are trained and reminded using the standard procedures described above, but they are tested with stimuli that differ from those present at the time of original encoding (Greco et al., 1990; Hayne & Findlay, 1995; Hayne & Rovee-Collier, 1995). The results of such studies have shown that retrieval of the reactivated memory, like retrieval of the original memory, is highly specific to the conditions present at the time of encoding. Changes in either the mobile (Greco et al., 1990; Hayne & Findlay, 1995; Hayne & Rovee-Collier, 1995) or the environmental context (Hayne & Rovee-Collier, 1995) at the time of the retention test disrupt memory performance.

In summary, mobile studies provide overwhelming support for the "encoding specificity hypothesis." Unless infants encounter different mobiles (Greco et al., 1990; Hayne et al., 1987; Merriman, Rovee-Collier, & Wilk, in press; Shields & Rovee-Collier, 1992) or different contexts (Amabile & Rovee-Collier, 1991; Rovee-Collier & Dufault, 1991) during the course of training, memory retrieval is disrupted by virtually any change in the cues between encoding and retrieval—even subtle changes that do not appear to disrupt memory performance by adults (Crowder, 1985; Fernandez & Glenberg, 1985). Although the results of these studies demonstrate that infants' memories are highly precise, they also suggest that the probability that infants will be able to retrieve and use their early memories might be quite limited. Given that memory retrieval only occurs when infants encounter stimuli that are virtually identical to those present during original encoding, developmental changes in perception and/or selective attention would significantly decrease the probability of retrieval after very long retention intervals. Furthermore, the specificity of the cues required to initiate memory retrieval indicates that it may be difficult if not impossible for potentially useful memories to be retrieved by cues (or in contexts) not previously encountered. One hallmark of memory development, however, may be an increase in the range of effective retrieval cues for a particular memory.

Recently, deferred imitation (Meltzoff, 1990) and reenactment (Bauer, 1996; Mandler, 1990) paradigms have been used to examine memory processing by infants 6 months of age and older. In these tasks, infants observe an experimenter performing an action on an object and their ability to reproduce that action is assessed after a delay. Traditionally, deferred imitation was considered to be a relatively late developmental milestone. Piaget (1952), for example, believed that infants were not capable of "true" deferred imitation until approximately 18 months of age. Meltzoff, however, found that 9-month-old infants could exhibit deferred imitation after a 24-hour delay (Meltzoff, 1988) and that 14-month-old infants could exhibit deferred imitation after a 4-month delay (Meltzoff, 1995). Recently, infants as young as 6 months of age have been shown to imitate novel actions after a 24-hour delay (Barr, Dowden, & Hayne, 1996). In the present experiments, we used a deferred imitation paradigm to assess potential age-related changes in effective retrieval cues over the second year of life.

EXPERIMENT 1

METHOD

Participants

Seventy-two infants were recruited through public birth records and by word-of-mouth. The majority of the infants were Pakeha (New Zealanders of European descent) and came from a wide range of socioeconomic backgrounds. Thirty-six infants (18 boys, 18 girls) were 12 months old (*M* age = 12.30 months, *SD* = .30), and 36 (18 boys, 18 girls) were 18 months old (*M* age = 18.36 months, *SD* = .26). Two additional 12-month-olds were excluded from the final sample due to refusal to remain seated during the test session or illness. Two additional 18-month-olds were excluded from the final sample due to refusal to remain seated during the test session or equipment failure.

Apparatus

Two hand puppets, a pastel pink rabbit and a pale grey mouse (see Figure 1), were constructed for these experiments. Both puppets were 30 cm in height and were made of soft, acrylic fur. A removable felt mitten (8 cm x 9 cm) was placed over the right hand of each puppet (see Figure 1). The mitten was either pink or grey and matched the color of the rabbit or the mouse, respectively. A large jingle bell was secured either to the back of the puppet (control condition) or to the inside of the mitten (demonstration condition). The puppets were counterbalanced across experimental conditions and test groups.

Procedure

The procedures used in the present experiments were identical to those used in our past research on deferred imitation with 6- to 24-month-old infants (Barr et al., 1996). All infants were tested in their own homes at a time of day when they were likely to be alert and playful. The demonstration session and the test session were separated by 24 hours (+/- 2). 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.

Demonstration Session

Infants were randomly assigned to either the demonstration condition or the control condition. For infants in the demonstration condition (n = 24 at each age), the jingle bell was attached to the inside of the mitten. The puppet was held at the infant's eye level, out of reach, for approximately 10 s. The experimenter then removed the mitten from the puppet's right hand, shook it three times to ring the bell inside, and replaced it on the puppet's right hand. This sequence was repeated two more times. Infants in the control condition (n = 12 at each age) were exposed to the puppet, the mitten, and the ringing bell for the same amount of time as infants the demonstration condition, however, the target actions were never modeled. For the infants in this condition, the jingle bell was secured to the back of the puppet's body. As before, the puppet was held in front of the infant, but out of reach, for approximately 10 s. The experimenter then shook the puppet three times ringing the bell attached to the puppet's back. This procedure was repeated two more times. Both the demonstration and the control procedure lasted approximately 20 to 30 s.

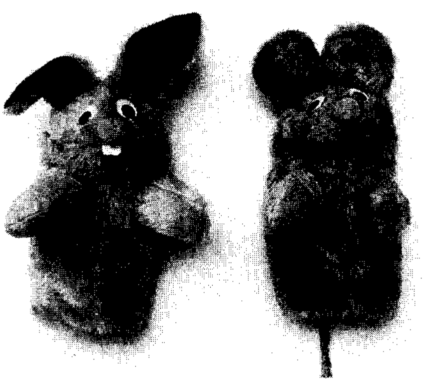

Figure 1. The rabbit (left) and mouse (right) puppets used in Experiment 1.

Test Session

The test session occurred 24 hours (+/- 2) later and was identical for infants in both conditions. The bell was removed from the puppet during the test. Half of the infants in the demonstration condition were tested with the same puppet that they had seen the day before (*demonstration/same* group), and half were tested with the novel one (*demonstration/different* group). All infants in the control condition were tested with the same puppet they had seen the day before (*control* group).

During the test, the infant was again seated on the caregiver's knee, and the puppet was placed, within the infant's reach, approximately 30 cm in front of the infant. The infant was allowed 90 s from the time he or she first touched the puppet in which to imitate the modeled actions.

RESULTS AND DISCUSSION

Each videotaped test session was scored by two independent observers, one of whom was blind to the infant's group assignment. Both observers scored the presence or absence of the three target behaviors during the 90-s period: (1) remove the mitten, (2) shake the mitten, and (3) put the mitten back on the puppet (or attempt to put the mitten back on). Interobserver reliability was expressed as the number of agreements divided by the total number of behaviors recorded. This calculation yielded an interobserver reliability score of 94% (κ = .86).

An imitation score was calculated for each infant by summing the number of target behaviors produced during the test (range = 0–3). The mean imitation score of the infants in the demonstration and control conditions is shown in Figure 2 as a function of age and test stimulus (same or different). A 2 (Age) × 3 (Group) analysis of variance (ANOVA) yielded significant main effects of Age, $F(1, 66) = 11.88, p < .001$, and Group, $F(2, 66) = 19.89, p < .01$. These main effects, however, were qualified by a significant Age x Group interaction, $F(2, 66) = 5.55, p < .01$.

To examine the interaction, separate one-way ANOVAs across Group were conducted at each age, and significant effects were further analyzed using post-hoc Tukey tests ($p < .05$). At both ages, there was a significant effect of Group (12-month-olds: $F(2, 33) = 7.78$, $p < .002$; 18-month-olds: $F(2, 33) = 17.48$, $p < .001$). Post-hoc tests confirmed that 12- and 18-month-old infants exhibited deferred imitation: At both ages, infants in the *demonstration/same* group had significantly higher mean imitation scores than those of the age-matched *control* group. Generalization to the novel test puppet, however, varied as a function of age. At 12 months, the *generalization/different* group exhibited no deferred imitation during the test. Its mean imitation score was significantly lower than that of the *demonstration/same* group and was not different from that of the age-matched *control* group. In contrast, at 18 months, changing the puppet had no effect on imitation performance whatsoever. The mean imitation score of the *demonstration/different* group was not different from the score of the *demonstration/same* group, and both scores were significantly greater than that of the age-matched *control* group.

As shown in Figure 2, spontaneous production of the target behaviors was rare at both ages. In fact, only 4 of the 24 infants in the control condition removed the mitten during the test. A *t* test yielded no difference in the spontaneous production of target behaviors as a function of age. To ensure that infants in the control condition were no less willing than infants in the demonstration condition to interact with the puppet during the test, the latency (in seconds) for infants to first touch the puppet were scored from videotape. These latency scores were subjected to a 2 (Age) × 2 (Condition) ANOVA. This analysis yielded no main effects and no interaction. These results indicate that infants in the control condition were no more inhibited than infants in the demonstration condition from touching the puppet during the test. Despite their willingness to interact with the puppet, however, infants in the control condition produced almost no target behaviors.

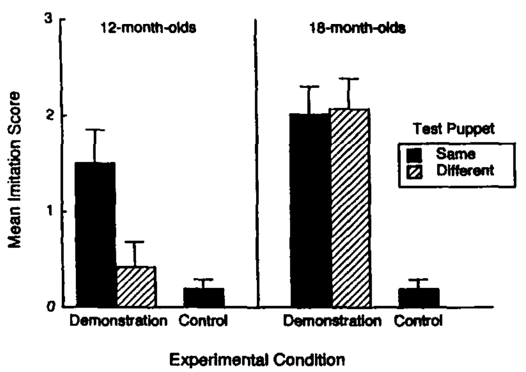

Figure 2. The mean imitation scores (+ 1 *SE*) of the 12- and 18-month-old infants in Experiment 1 as a function of experimental condition (demonstration or control) and test cue (same or different puppet).

The results of Experiment 1 demonstrate clear age-related changes in generalization. When tested with a novel puppet, 18-month-old infants exhibited excellent retention. In fact, their performance was not different from that of infants tested after the same delay with the same puppet that had been present during the original demonstration session. The 12-month-olds, on the other hand, exhibited no retention whatsoever when tested with a novel puppet after a 24-hour delay, despite the fact that many aspects of the demonstration session and the test session were the same (e.g., the context, and the experimenter). Thus, the performance of the 12-month-olds in the present experiment was like that of 2- to 6-month-olds who exhibit no retention during delayed recognition tests with a novel mobile.

In Experiment 1, deferred imitation by 12-month-old infants was completely precluded when the puppet presented at the time of the test was different from the puppet present at the time of the original demonstration. In Experiment 2, we attempted to replicate this basic finding. In addition, we asked whether the 12-month-olds' discrimination was affected by the type of test cue that was changed. To this end, we also tested groups of infants with a puppet that was novel only in color or only in form from the puppet present during the original demonstration.

EXPERIMENT 2

METHOD

Participants

Sixty (30 boys, 30 girls) 12-month-olds (M age = 12.34 months, SD = .15) were recruited as before. Additional infants were excluded from the final sample due to refusal to remain seated during the test session (n = 3) or maternal interference during the test (n = 1).

Apparatus

In addition to the pink rabbit and grey mouse puppets, two other puppets were used. These puppets were identical in form to the puppets used in Experiment 1, but the colors of the forms were reversed (i.e., grey rabbit and pink mouse). Both the form (mouse or rabbit) and color (pink or grey) of the puppets were counterbalanced across groups.

Procedure

The demonstration and test procedures were identical to those used in Experiment 1. Within the demonstration condition, four test groups were defined by the puppet used during the test. For the *no change* group, the test puppet was the same puppet used during the original demonstration. For the *color change* group, the form (rabbit or mouse) of the test puppet was the same as the puppet used during the demonstration, but its color was different. For the *form change* group, the color of the test puppet was the same, but its form was different. Finally, for the *color and form change* group, both the color and the form of the puppet differed during the test (this group was equivalent to the *demonstration/different* group in Experiment 1). As in Experiment 1, infants in the control condition (n = 12) were tested with the same puppet they had seen the day before.

RESULTS AND DISCUSSION

As in Experiment 1, infants were given 90 s from the time they first touched the puppet in which to respond. Two observers again independently scored 100% of the sessions from videotape. The interobserver reliability for the three target behaviors was 96% (κ = .86). The mean imitation score of the infants in each condition (demonstration or control) is shown in Table 1 as a function of test group. A one-way ANOVA yielded a significant effect of Test Group, $F(4, 55) = 3.47$, $p < .01$. A post-hoc Tukey test ($p < .05$) revealed that only the *no change* group had a significantly higher mean imitation score than the *control* group. The mean imitation scores of all other groups were not significantly different from that of the *control* group.

TABLE 1
The Mean Imitation Scores of the 12-Month-Old Infants Tested After a 24-Hour (Experiment 2) or a 10-min (Experiment 3) Delay as a Function of Test Group. The Standard Errors are Shown in Parentheses.

Test Group	24-hr Delay	10-min Delay
No Change	1.33 (.33)*	1.42 (.38)*
Color Change	0.42 (.23)	1.00 (.37)*
Form Change	0.42 (.23)	0.58 (.26)
Color and Form Change	0.25 (.18)	0.50 (.26)
Control	0.33 (.19)	0.08 (.08)

*An asterisk indicates that the mean imitation score was significantly greater than the mean imitation score of the control group (p < .05).

Taken together, the results of Experiments 1 and 2 confirm that 12-month-olds do not generalize to a novel test puppet after a 24-hour delay. Moreover, even when the test puppet differed from the demonstration puppet only in color or only in form, 12-month-olds did not imitate the target actions. Recently, Barnat, Klein, and Meltzoff (1996) reported that slightly older infants exhibited some evidence of deferred imitation when tested with novel stimuli after a relatively brief delay. In their study, 14-month-olds observed an experimenter perform a series of 1-step actions with a number of props. After a 10-min delay, independent groups were presented with either the original props (same props) or with props different in size and color (different props) from those used during the original demonstration. Infants tested with the same props performed more target actions than infants tested with different props; however, infants tested with different props performed more target actions than infants in the control group, who had never seen the actions modeled in the first place.

Experiments 1 and 2 of the present study reveal that 12-month-olds will exhibit deferred imitation after a 24-hour delay only if the cues present at the time of the test are virtually identical to the cues present at the time of the original demonstration. Even minor changes in the color or the form of the test cue will disrupt performance. The findings reported by Barnat et al. (1996), however, raise the possibility that generalization might vary as a function of the time since the original demonstration. That is, 12-month-olds, like 14-month-olds, might generalize to novel test stimuli after a brief delay, when the memory of the original demonstration is presumably still highly accessible. To examine this possibility, we tested 12-month-old infants in our imitation task after a 10-min delay with the stimuli used in Experiment 2.

EXPERIMENT 3

METHOD

Participants

Sixty (30 boys, 30 girls) 12-month-olds (M = 12.23 months, SD = .15) were recruited as before. Additional infants were excluded from the final sample due to refusal to remain seated during the test session ($n = 3$), crying ($n = 2$), experimenter error ($n = 2$), or sibling interference ($n = 1$).

Apparatus and Procedure

The apparatus and procedure were the same as in Experiment 2 except that the deferred imitation test occurred after a 10-min delay. As before, infants were given 90 s from the time they first touched the puppet in which to respond.

RESULTS AND DISCUSSION

Two observers again independently scored 100% of the sessions from videotape. The interobserver reliability for the target behaviors was 95% ($\kappa = .84$). The mean imitation scores (see Table 1) were subjected to a one-way ANOVA. This analysis yielded a significant effect of Test Group, $F(4, 55) = 3.07$, $p < .02$. A post-hoc Tukey test ($p < .05$) revealed that the mean imitation scores of the *no change* and the *color change* test groups were significantly higher than the score of the *control* group. Infants tested with a puppet that differed only in form or in both color and form, however, performed no better than the control group. Consistent with the results of Barnat et al. (1996), therefore, Experiment 3 demonstrated that 12-month-old infants would generalize to a novel stimulus after a 10-min delay under certain conditions. Although imitation by 12-month-olds was disrupted by a change in form, they generalized to a puppet that differed only in color relative to the puppet that had been present during the original demonstration.

In the preceding experiments, the demonstration and test puppets shared many features in common—both the mouse and the rabbit had the same overall shape (except for the ears), both were pastel in color, and both had identical plastic eyes and small pink noses. The relative similarity between the puppets raises an important question about the extent and limits of the excellent generalization performance exhibited by the 18-month-olds in Experiment 1. That is, would the performance of 18-month-olds be disrupted if the differences between the encoding and testing puppets were greater? To answer this question, we constructed two new puppets that differed substantially in overall shape, color, and in a number of facial features including the eyes, ears, nose, and mouth. We then used these puppets to assess generalization by 18-month-olds after a 24-hour delay.

EXPERIMENT 4

METHOD

Participants

Thirty-six (18 boys, 18 girls) 18-month-olds (M age = 18.07 months, $SD = .38$) were recruited as before. Additional 18-month-olds were excluded from the final sample due to refusal to remain seated during the test session ($n = 2$), sibling interference during the test ($n = 1$), or experimenter error ($n = 1$).

Apparatus and Procedure

Two new puppets were constructed for the present experiment (see Figure 3). One was a black-and-white cow, and the other was a yellow-and-orange duck. The presentation of these puppets was counterbalanced across all groups.

The demonstration and test procedures were identical to those used in Experiment 1. Half of the infants in the demonstration condition were tested with the same puppet that they had seen the day before (*demonstration/same* group), and half were tested with the other one (*demonstration/different* group). All infants in the control condition were tested with the same puppet they had seen the day before (*control* group). As before, infants were given 90 s from the time they first touched the puppet in which to respond.

RESULTS AND DISCUSSION

Two observers again independently scored 100% of the sessions from videotape. The interobserver reliability was 99% ($\kappa = .98$). A one-way ANOVA indicated that there was a significant difference between the test groups, $F(2, 33) = 11.89$, $p < .0001$ (see Figure 4, left panel). A post-hoc Tukey test ($p < .05$) revealed that, as in Experiment 1, the mean imitation score of the *demonstration/same* group was significantly higher than that of the *control* group. However, in contrast to Experiment 1, the *demonstration/different* group exhibited no deferred imitation when tested with a novel test puppet. Its mean

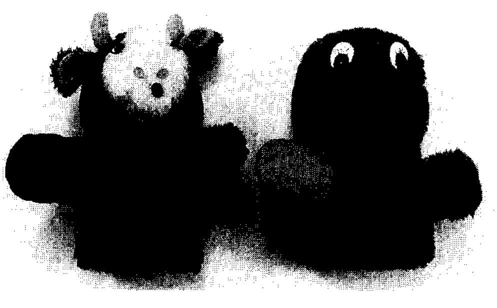

Figure 3. The cow (left) and duck (right) puppets used in Experiments 4 and 5.

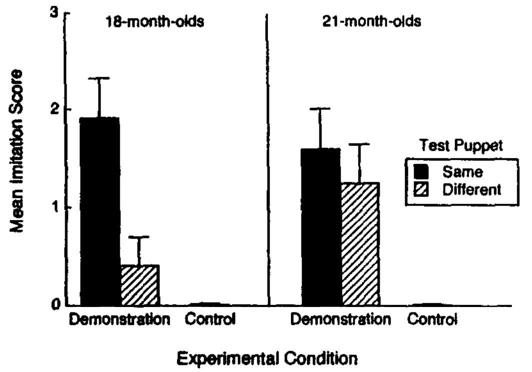

Figure 4. The mean imitation scores (+ 1 SE) of 18-month-old (Experiment 4) and 21-month-old (Experiment 5) infants as a function of experimental condition (demonstration or control) and test cue (same or different puppet).

imitation score was significantly lower than that of the *demonstration/same* group and was not different from that of the *control* group.

Considered jointly, Experiments 1 and 4 clearly show that generalized imitation by 18-month-old infants was influenced by the physical similarity of the demonstration and test stimuli. In Experiment 1, when there was a high degree of physical similarity between the puppets, 18-month-olds responded to a novel puppet during the test. In Experiment 4, however, when the similarity of the puppets was less, 18-month-olds failed to respond to a novel test puppet. This latter finding was not due to differences in the memorability of the two sets of puppets: In both experiments, the mean imitation score of infants tested with the same puppet they had seen during the demonstration session was virtually identical.

The preceding experiments demonstrate that generalization of deferred imitation changes as a function of age. Given the present demonstration and testing parameters, 12-month-olds fail to generalize to novel cues (color, form, or both) after a delay of 24 hours (Experiments 1 and 2). In contrast, 18-month-olds generalize to these same novel test cues (color and form) after the same delay (Experiment 1), but they fail to generalize to novel test cues that differ more substantially in both color and form (Experiment 4). As a final test of the hypothesis that generalization increases with age, we tested 21-month-olds with the same puppets that were used in Experiment 4.

EXPERIMENT 5

METHOD

Participants

Thirty-six (18 boys, 18 girls) 21-month-olds (M age = 21.13 months, SD = .22) were recruited as before. Four additional infants were excluded from the final sample due to failure to touch the puppet during the test.

Apparatus and Procedure

The apparatus and procedure were identical to those used in Experiment 4. As in all of the preceding experiments, infants were given 90 s in which to respond.

RESULTS AND DISCUSSION

The interobserver reliability for the target behaviors was 99% (κ = .98). A one-way ANOVA indicated that there was a significant difference between the test groups, $F(2, 33) = 6.39, p < .005$ (see Figure 4, right panel). A post-hoc Tukey test ($p < .05$) revealed that, as expected, infants in the demonstration condition exhibited deferred imitation after a 24-hour delay. The mean imitation score of the *demonstration/same* group was significantly higher than that of the *control* group. This time, however, a change in the puppet did not disrupt test performance. The mean imitation score of the *demonstration/different* group was not significantly different from that of the *demonstration/same* group and was significantly higher than that of the *control* group. Thus, whereas 18-month-olds had failed to generalize between the highly dissimilar puppets shown in Figure 3 (Experiment 4), 21-month-olds performed equivalently whether they were tested with the original puppet or with the novel one.

GENERAL DISCUSSION

Taken together, the present findings demonstrate developmental differences in the specificity of memory between 12 and 21 months of age. Changes in the test stimulus that disrupted performance at 12 months of age had no effect on performance at 18 months, and changes in the test stimulus that disrupted performance at 18 months of age had no effect on performance at 21 months. These age-related changes in generalization reflect age-related changes in the specificity of memory retrieval: Over the course of their second year of life, infants become increasingly able to use novel cues to retrieve their memory for a prior event.

The finding that older infants were able to retrieve and use information gleaned during the demonstration session even when tested with highly dissimilar stimuli is consistent with findings from other imitation studies. In Bauer and Dow (1994), for example, 16- and 20-month-old infants observed an experimenter perform a series of 3-step sequences with a number of props. Immediately following the demonstration, infants were allowed to re-enact each sequence using the original props. One week later, infants were presented with either the original props or with novel props. Although infants tested with the original props exhibited better retention than infants tested with different props, infants tested with different props still performed more target actions than they had prior to the demonstration 1 week earlier.

In addition to deferred imitation across changes in test stimuli, older infants have been reported to exhibit deferred imitation across changes in context. Meltzoff and his colleagues, for example, have shown that 12- to 18-month-old infants exhibit deferred imitation even when tested in contexts that differ from the one in which the target actions were originally modeled (Barnat et al., 1996; Hanna & Meltzoff, 1993; Klein & Meltzoff, 1996).

As described earlier, memory retrieval by 2- to 6-month-olds tested in the mobile conjugate reinforcement paradigm requires an exact match between the conditions present at the time of original encoding and those present at the time of retrieval. In contrast, memory retrieval by 12- to 20-month-old infants tested in deferred imitation paradigms is apparently less constrained; that is, retrieval of the target memory occurs in the presence of props or in contexts different from those present at the time of original encoding (Barnat et al., 1996; Hanna & Meltzoff, 1993; Klein & Meltzoff, 1996). Two explanations have been offered to account for the different pattern of findings obtained in the mobile conjugate reinforcement paradigm with 2- to 6-month-olds and those obtained in imitation paradigms with 12- to 20-month-olds (see Bauer & Dow, 1994; Hanna & Meltzoff, 1993). One account holds that the memorial requirements of the mobile conjugate reinforcement and imitation paradigms differ. It is commonly assumed, for example, that memory processing involves multiple neural systems that mature at different rates (Bachevalier, 1990; Nadel & Zola-Morgan, 1984; C. Nelson, 1995; Schacter & Moscovitch, 1984). It has been argued, for example, that the memory skills of young infants are restricted to motor procedures or habits (procedural memory) without explicit recollection of the event in which the memory was originally established (declarative memory). It is also commonly assumed that tasks that require individuals to remember actions they have performed in the past require less sophisticated memory skills than tasks that require individuals to remember actions they have merely observed. Within this framework, the mobile conjugate reinforcement paradigm is thought to reflect only procedural or motor memory while deferred imitation paradigm is thought to reflect declarative memory (Bauer, 1996; Meltzoff, 1990, 1995). From this perspective, the different pattern of findings in mobile studies and imitation studies is interpreted as a reflection of the underlying differences in procedural (implicit) and declarative (explicit) memory. Previous studies conducted with both humans and animals, for example, have suggested that procedural memory is more constrained by physical changes in potential retrieval cues than declarative memory (Diamond, 1990).

These studies, however, suggest a more parsimonious account, namely that differences in results obtained with the two paradigms is a function of age differences in the infants studied in each. In mobile studies of encoding specificity, infants have ranged from 2 to 6 months of age, while in imitation studies, infants have ranged from 12 to 20 months of age. It is likely that the different findings obtained in studies using these two paradigms reflect a *developmental increase in the flexibility of memory processing per se, irrespective of the paradigm used to assess it.* In this study, when infants of various ages were tested in the same deferred imitation paradigm, large age-related differences in the specificity of memory retrieval were found. Furthermore, within a given age, increasing or decreasing the similarity between the training and test cues had a predictable effect on memory performance (see "principle of encoding specificity," Tulving & Thomson, 1973).

A developmental account is highly consistent with a growing body of research using both infants and children tested using a wide variety of procedures. First, Aaron, Hartshorn, Klein, Ghumman, and Rovee-Collier (1994) found a developmental decrease in the specificity of effective retrieval cues for infants tested in a delayed recognition procedure. In their study, 6-, 9-, and 12-month-old infants learned to press a lever to produce movement in a miniature train. Independent groups of infants at each age were tested with either the same train set or a different one. Consistent with past studies using the mobile paradigm, 6-month-olds exhibited no retention whatsoever when tested with a different train set. The 9- and 12-month-olds, on the other hand, generalized to a novel train set after a 24-hour delay but not after longer delays. These data are similar to the data in Experiments 2 and 3, when 12-month-old infants generalized to a puppet of a novel color after a 10-min delay but not after 24 hours. Second, Sheffield and Hudson (1996) found that the specificity of effective reminders in a reenactment paradigm also decreased as a function of age. In their study, 18- and 24-month-olds learned to perform a series of activities and were tested 8 or 10 weeks later, after significant forgetting had occurred. Forgetting by 24-month-old infants was alleviated by both a video and a photograph reminder, but at 18 months of age, only a video reminder was effective; the performance of infants given a photograph reminder was no better than that of infants given no reminder at all. Finally, Fivush, Kuebli, and Clubb (1992), reported age-related changes in the specificity of memory retrieval by preschool children. In their study, 3½- and 5½-year-old children participated in a unique event, and their ability to reenact that event was assessed after a 2- to 4-day delay. Although 5½-year-olds could readily use novel props to reenact the target event, 3½-year-olds could not. Once they were given explicit experience with various props, however, 3½-year-olds were also able to retrieve and use their prior knowledge in novel situations.

Taken together, the results of these studies provide overwhelming support for the conclusion that one hallmark of memory development is an increase in the range of stimuli that can serve as effective retrieval cues for a particular memory. Irrespective of the task used to assess memory performance, the specificity of effective retrieval cues decreases as a function of age and experience. Furthermore, the consistent pattern of findings outlined above indicates that the most productive approach to the study of memory development will include a synthesis of findings across paradigms in an attempt to uncover the large number of continuities that undoubtedly exist (Barr et al., 1996; Hayne, 1996; Rovee-Collier, in press).

Finally, the present findings have implications for the understanding of childhood amnesia. Childhood amnesia refers to the inability of adults to report autobiographical information from the period prior to the age of 3 or 4. Although a number of accounts of this phenomenon have been proposed (for reviews, see Campbell & Spear, 1972; Howe & Courage, 1993; Pillemer & White, 1989), no single account can explain all of the available data. K. Nelson (1993) has argued that the decline of childhood amnesia is due, at least in part, to a child's emergent ability to use language as a retrieval cue for a particular experience. Nelson proposed that during the preschool period, children begin to gain access to their memories through conversations about the past; repeated retrieval of those memories in the course of repeated conversation preserves those memories over time (see also, Hudson, 1990).

Although the mechanism of memory retrieval central to Nelson's theory resembles the mechanism previously described for the long-term maintenance of memories in studies with preverbal infants (Hayne, 1990; Rovee-Collier & Hayne, 1987; Sheffield & Hudson, 1994, 1996), Nelson has argued that the increased efficacy of verbal retrieval cues in particular leads to a *dramatic shift in the range of situations in which memory retrieval is likely to occur.* The present findings provide evidence that age-related decreases in the specificity of memory retrieval facilitate the accessibility of particular memories over the long term. The present findings also suggest that the increased effectiveness of a large number of retrieval cues (i.e., in addition to language) undoubtedly contribute to the decline of infantile amnesia during the third year of life.

AUTHORS' NOTES

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