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Developmental Changes in Deferred Imitation by 6- to 24-Month-Old Infants

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Developmental changes in imitation were examined in three experiments with 6- to 24-month-old infants. In all experiments, infants in the demonstration condition observed an experimenter perform three specific actions with a puppet. Their ability to reproduce those actions was assessed for the first time during the test in the absence of prior practice. Infants in the control condition received equivalent exposure to the puppet and the experimenter but were not shown the target actions. The results of Experiment 1 showed that 12-, 18-, and 24-month-old infants exhibited clear evidence of imitation following a 24-hour delay (deferred imitation). In addition, the findings of Experiment 1 demonstrated that the 18- and 24-month-old infants reproduced more of the target actions during the test than the 12-month-olds. The results of Experiment 2 showed that 6-month-olds performed as well as 12-month-olds when they were tested in the absence of a delay (immediate imitation). Finally, the results of Experiment 3 showed that, with additional exposure to the target actions, even 6-month-old infants exhibited deferred imitation following a 24-hour delay. Taken together, these findings have important implications for current theories of the development of imitation and memory during the first 2 years of life.

memory development deferred imitation infancy

Imitation and observational learning are important ways by which children acquire a wide range of new behaviors (Abravanel & Sigafos, 1984; Meltzoff, 1993; Parker, 1993; Piaget, 1962). It has been argued that learning through imitation is more efficient than either trial and error learning or independent problem solving and that the process is made easier for children by adults, who typically decompose complex behaviors and demonstrate actions that are appropriate to the child's age and motor capacity (Meltzoff, 1993; Parker, 1993). In many instances, a child's response to a modelled behavior does not occur immediately. In these instances, the modelled information must be stored in long-term memory to be retrieved and used in the future. From this perspective, the development of imitation is critically linked to the development of memory (Meltzoff, 1990, 1993; Piaget, 1962).

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The developmental course of imitation and its social, cognitive, and evolutionary functions have recently been discussed by a number of investigators (e.g., Masur, 1993; Meltzoff, 1990, 1993; Parker, 1993; Uzgiris, 1981), however, the most extensive developmental theory remains the one originally proposed by Piaget (1962). According to Piaget, the development of imitation occurs in six discrete stages culminating at approximately 18 to 24 months of age with three important changes. First, infants imitate novel behaviors almost immediately without extensive trial and error. Second, infants imitate nonhuman and inanimate objects. Third, and most importantly, infants exhibit deferred imitation; that is, the target action can be reproduced in the absence of the model after a delay. Piaget argued that deferred imitation was one hallmark of mental representation; the emergence of deferred imitation signalled the infant's ability to form a mental representation of the model's behavior at the time of demonstration and to recall that image following a retention interval.

Traditional Piagetian theory is remarkably consistent with current multiple-system accounts of memory development. In the last decade, an increasing number of theorists have proposed that memory is not a unitary phenomenon, but rather is comprised of multiple neural systems that mature at different rates (e.g.,

Bachevalier, 1990, 1992; Nadel & Zola-Morgan, 1984; Schacter & Moscovitch, 1984). It has been argued, for example, that the memory skills of infants are restricted to motor procedures (Nadel & Zola-Morgan, 1984; Schacter & Moscovitch, 1984) or habits (Bachevalier & Mishkin, 1984) without conscious recollection of the event in which the memory was originally established (Mandler, 1990). Because these memory skills resemble those typically exhibited by human adults with temporal-lobe amnesia (Nadel & Zola-Morgan, 1984; Schacter & Moscovitch, 1984), it has been hypothesized that immaturity of the limbic system (Bachevalier & Mishkin, 1984; Nadel & Zola-Morgan, 1984; Rudy, 1991; Rudy & Sutherland, 1989; Schacter & Moscovitch, 1984) or the prefrontal cortex (Bachevalier, Brickson, & Hagger, 1993; Diamond, 1990; Diamond, Towle, & Boyer, 1994) early in development precludes infants from demonstrating the more sophisticated memory skills exhibited by normal adults. Broadly defined, Piaget also viewed memory development as a two-stage process. He drew a sharp distinction, for example, between *sensorimotor memory*, or memory for primitive, adaptive actions, and *symbolic memory*, or memory based on mental representation (Piaget, 1952). According to Piaget, sensori-motor memories could be expressed only through behavioral routines, whereas symbolic memories could be reflected upon, combined, integrated, and used to solve novel problems. Piaget's distinction between *knowing how* and *knowing that* is common to almost all current multiple-memory theories including Squire's (1992) nondeclarative/declarative distinction, Bachevalier and Mishkin's (1984) habit/memory distinction, and Schacter's (1987) implicit/explicit distinction (for reviews, see McKee & Squire, 1993; Schacter & Tulving, 1994).

Given the similarity between Piaget's account of cognitive development and the more recent views expressed by behavioral neuroscientists, it has been argued that the emergence of deferred imitation may provide a conduit for integrating these two fields of research (Mandler, 1990; Meltzoff, 1990, 1995). Meltzoff (1990, 1995) has argued, for example, that deferred imitation requires declarative memory. His argument is based on the fact that in deferred imitation paradigms, infants acquire

information on the basis of very brief exposure to relatively novel behavior and can reproduce that behavior following a delay in the absence of prior practice. Meltzoff's argument that deferred imitation provides a measure of declarative memory in infancy is strengthened by the finding that amnesic patients are impaired on tasks that require deferred imitation (McDonough, Mandler, & Squire, 1995).

Historically, the emergence of deferred imitation was thought to be a relatively late developmental milestone. From a functional perspective, Piaget argued that deferred imitation did not contribute new behaviors to an infant's repertoire prior to approximately 18 months of age. Some empirical work on the development of imitation has supported Piaget's stage theory (e.g., Abravanel, 1991; Abravanel, Levan-Goldschmidt, & Stevenson, 1976; Killen & Uzgiris, 1981; Masur, 1988, 1993; McCabe & Uzgiris, 1983; McCall, Parke, & Kavanaugh, 1977). In most of these studies, however, imitation was assessed after very brief delays (e.g., minutes), and critical control groups were absent from the experimental designs. Recent work by Meltzoff and his colleagues has challenged many of our basic assumptions about the emergence of imitation during development (for review, see Meltzoff, 1990). In a number of studies, for example, Meltzoff and Moore (1977, 1983, 1989, 1994) have examined imitation by infants during the first month of life. They reported that infants of this age can imitate a range of behaviors including mouth opening, tongue protrusion, and head movement displays. In addition, Meltzoff has provided evidence for deferred imitation following a 24-hour delay in infants as young as 6 weeks (Meltzoff & Moore, 1994) and following a 4-month delay in infants as young as 14 months (Meltzoff, 1995). Taken together, these studies raise questions about the discrete, stage-like nature of the development of imitation originally proposed by Piaget. Given that deferred imitation is thought to be a valid index of declarative memory, these studies also raise questions about the discrete, stage-like nature of memory development proposed by current multiple-memory theorists.

Although past research has shown that the capacity for deferred imitation may be present at birth, we know very little about possible developmental changes in the extent or limits

of this cognitive ability. Despite the finding that very young infants may be able to represent and reproduce some actions, the range of situations in which this is likely to occur may change dramatically over the course of development. Meltzoff has argued that deferred imitation exhibited before 18 months of age may be a "sharply constrained phenomenon—severely limited in the number of acts that can be retained for later reproduction" (Meltzoff, 1988b, p. 218). With a few notable exceptions (Meltzoff, 1988a; Meltzoff & Moore, 1994), however, most of the current work on deferred imitation has focused on infants who are at least 14 months old (e.g., Hanna & Meltzoff, 1993; Meltzoff, 1985, 1988b, 1988c, 1995). Comparably little work has examined deferred imitation by infants during the 1st year of life. The purpose of this study, therefore, was to assess age-related differences in imitative ability by infants between 6 and 24 months of age.

The most accurate way to assess deferred imitation is to demonstrate the target behavior(s) without allowing the infant an opportunity to imitate until the time of the test. This procedure not only respects Piaget's original distinction between sensorimotor and symbolic memory, but it is also consistent with current neuropsychological views that there is a fundamental difference between memory for motor procedures and memory for other kinds of information. In many of Meltzoff's studies, for example, the experimenter showed the infant how to manipulate a novel toy or toys, and the infant was given no opportunity to touch these objects until the test which occurred either immediately or following a delay. In addition, deferred imitation of a particular behavior must be distinguished from spontaneous production of the same response by assessing baseline performance in the absence of explicit modelling (Meltzoff, 1985; Poulson, Nunes, & Warren, 1989). Meltzoff and Gopnik (1989) have argued that many of the early studies of imitation failed to include this critical control condition. As such, conclusions about developmental changes in imitation were based exclusively on the performance of infants shown the target behaviors without correcting for potential age-related differences in the spontaneous production of those same behaviors. The procedure used in the following experiments was designed with these methodological criteria in

mind. In particular, infants were given no opportunity to perform any of the target actions until the test, which occurred 24 hours after the demonstration session, and spontaneous production of the target behaviors was assessed in age-matched controls who were not shown the target actions prior to the test.

EXPERIMENT 1

Method

Subjects

The final sample consisted of 24 (12 males, 12 females) 6-month-olds (M age = 188 days, SE = 8.00), 24 (12 males, 12 females) 12-month-olds (M age = 343 days, SE = 3.32), 24 (13 males, 11 females) 18-month-olds (M age = 582 days, SE = 4.61), and 24 (12 males, 12 females) 24-month-olds (M age = 712 days, SE = 4.86) who were recruited from public birth records and by word of mouth. Infants were predominantly of European descent and came from a wide range of socioeconomic backgrounds. Four additional 12-month-old infants (2 males, 2 females) were tested but were not included in the final sample due to equipment failure (n = 3) or refusal to remain seated during the test session (n = 1). Six additional 18-month-old infants (2 males, 4 females) were tested but were not included in the final sample due to refusal to remain seated during the test session (n = 3), crying (n = 2), or maternal interference (n = 1). Two additional 24-month-olds were not included (1 male, 1 female) due to refusal to remain seated during the test session.

Apparatus

Each infant was tested with one of two hand-held puppets (counterbalanced across groups) which were constructed specifically for these experiments and were not commercially available. One puppet was a pastel pink rabbit and the other was a pale grey mouse. Both puppets were 30 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 pink or grey and was chosen to match the color of the rabbit and the mouse, respectively. A large jingle bell was secured to the back of the puppet or inside the mitten itself, depending on the experimental condition.

Procedure

Infants were tested in their own homes at a time of day when they were likely to be alert and playful. There were two sessions, a demonstration session and a test session, separated by 24 hours (\pm 2 hours). During each session, the infant was placed on the caregiver's knee, and he or she held the infant firmly by the hips. At the beginning of each session, the experimenter interacted with the infant for approximately 5 min.

Reaching Test. In order to imitate the target behaviors, infants had to be able to engage in visually guided reaching. This motor milestone is typically achieved by approximately 4 to 5 months of age (Bushnell, 1985). According to parental report, the 6-month-old infants in our sample had been reaching for objects for approximately 6 weeks (M = 44 days, SE = 4 days). To ensure that the infants in the youngest group could reliably reach for objects, we

assessed their reaching ability prior to the puppet demonstration. To do this, the experimenter held a brightly colored object within reach, approximately 25 cm in front of the infant and verbally encouraged him or her to reach out and grasp it. For all infants, the brightly colored object was a clown's head made of felt and secured to the end of a 30-cm dowel. This object was specifically constructed for these experiments: the clown's head was approximately the same size and shape as the felt mittens worn by the puppets. If an infant failed to reach out and grasp the clown within 60 s, he or she was excluded from the final sample. All infants passed this test.

Demonstration Session. Infants were randomly assigned to one of two conditions, the *demonstration condition* or the *control condition*. Once the infant appeared comfortable, the experimenter, kneeling at the caregiver's feet, placed the puppet over her right hand. The puppet was positioned at the infant's eye level in front of the experimenter's face. For infants in the demonstration condition, the jingle bell was attached to the inside of the mitten. The puppet was held in front of the infant, out of reach, for approximately 10 s, until the infant oriented to the puppet. The experimenter then removed the mitten from the puppet's right hand, shook it three times ringing the bell inside, and replaced it on the puppet's right hand. This sequence was repeated a total of three times. The entire demonstration procedure lasted approximately 20 to 30 s. Infants in the control condition were exposed to the puppet and the experimenter for the same amount of time as infants in the demonstration condition, however, the target actions were never modelled. For the infants in this condition, the jingle bell was secured, out of sight, to the back of the puppet's body. As before, the puppet was held in front of the infant, out of reach, for approximately 10 s, until the infant oriented to the puppet. The experimenter then shook the puppet three times ringing the bell attached to the puppet's back. This procedure was repeated a total of three times, and the entire control procedure lasted approximately 20 to 30 s.

Test Session. The test session occurred 24 hours (\pm 2 hours) after the demonstration session and was identical for infants in both conditions. Each infant was tested with the same puppet that he or she had seen the day before, however, the bell was no longer present. The infant was again seated 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 given 90 s from the time they first touched the puppet in which to respond. Each test session was videotaped.

Results

Each videotaped test session was scored by two independent observers, one of whom was blind to the infant's group assignment. Both observers noted the presence or absence of three target behaviors during the test: (1) remove the mitten, (2) shake the mitten, (3) put the mitten back on the puppet (or attempt to put the mitten back on). Interrater reliability was expressed as the number of agreements divided by the total number of behaviors recorded. This

calculation yielded an interobserver reliability score of 96.2% ($\kappa = .94$). Both observers also recorded the latency, in seconds, for the infant to touch the puppet and to remove the mitten. Pearson's product moment correlations were calculated for the latency to touch the puppet and the latency to remove the mitten. These calculations yielded interobserver reliabilities of .95 and .99, respectively.

An imitation score was calculated for each infant by summing the number of target behaviors he or she exhibited during the test (range = 0–3). The average imitation score of the infants in each condition (demonstration and control) as a function of age is shown in Figure 1. To determine whether or not any age group exhibited deferred imitation, separate *t* tests were calculated comparing each demonstration group with the age-matched control group. These analyses indicated that there was a significant difference between the two groups for the 12-month-olds, $t(22) = 3.05$, $p < .006$, the 18-month-olds, $t(22) = 4.43$, $p < .0001$, and the 24-month-olds, $t(22) = 4.47$, $p < .0001$. There was, however, no significant difference between the groups for the 6-month-olds.

To examine developmental differences in imitation, the data presented in Figure 1 were subjected to a 2 (condition) \times 4 (age) analysis of variance. This analysis yielded a significant main effect of condition, $F(1, 88) = 38.10$, $p < .0001$. Examination of the means indicated that, overall, infants in the demonstration condition exhibited significantly higher imitation scores than infants in the control condition. There was also a significant condition \times age interaction, $F(3, 88) = 6.50$, $p < .0005$. To examine this interaction, separate one-way ANOVAs across age were conducted within each experimental condition. This analysis yielded two important findings. First, there was no significant effect of age for infants in the control condition. That is, the spontaneous production of the target behaviors did not vary as a function of age. Second, there was a significant effect of age for infants in the demonstration condition, $F(3, 44) = 5.18$, $p < .004$. Post hoc analysis of this effect indicated that the 18- and 24-month-old infants in the demonstration condition exhibited significantly higher imitation scores than the 6-month-old infants, and the performance of the 12-month-olds was intermediate between these two extremes.

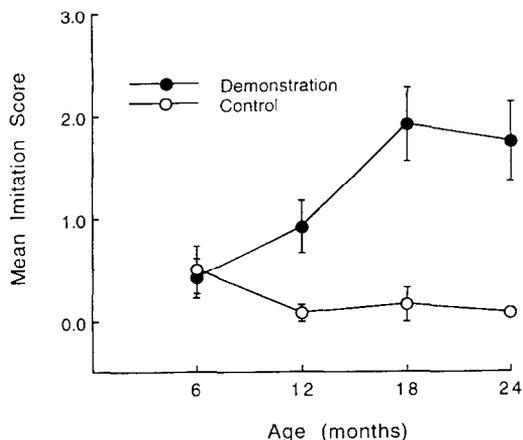


Figure 1. The mean imitation score (± 1 SE) of 6-, 12-, 18-, and 24-month-old infants tested 24 hours after the demonstration session as a function of experimental condition (Experiment 1).

As shown in Figure 1, the spontaneous production of the target behaviors was low for all age groups. This occurred even though infants in both the demonstration and control conditions were exposed to the puppet, the ringing sound, and the experimenter for an equivalent period of time 24 hours prior to the test session. The finding that few infants in the control condition exhibited any of the target behaviors during the test suggests that exposure to the puppet and the experimenter alone in the absence of explicit modelling did not elicit the behaviors in question when infants were tested 24 hours later. The low incidence of target behaviors by the control subjects, however, also raises the possibility that some aspect of the nondemonstration procedure actually suppressed the activity of infants in the control condition. To address this possibility, the latency (in seconds) for each infant to touch the puppet during the test was subjected to a 2 (condition) \times 4 (age) analysis of variance. This analysis yielded no significant main effect of condition and no interaction.¹ These results indicate that infants in the control condition were no more inhibited than infants in the demonstration condition to touch the puppet during the test. Despite their

willingness to interact with the puppet, however, infants in the control condition rarely produced the target behaviors.

The number of infants in the demonstration condition who removed the mitten is shown in Figure 2 as a function of age (see Figure 2, left panel). Because imitation of the other two target behaviors was dependent upon the infant first removing the mitten, the number of infants who shook the mitten or replaced it was expressed as a percentage of the number of infants in each age group who removed it (see Figure 2, right panel). Although the 12-month-olds were as likely as the 18- and 24-month-olds to remove the mitten, χ^2 (3, $N = 48$) = 3.08, $p < .40$, they were less likely to imitate the other two target behaviors (Fisher's Exact Test, range of p values = .006–.04).² As shown in the right panel of Figure 2, this age-related difference was most pronounced for replacing the mitten.

Discussion

This experiment provides the first opportunity to compare deferred imitation by infants across such a large developmental period. In past research, changes in tasks and procedures across age groups have made developmental comparisons of deferred imitation virtually impossible. In the few studies in which infants of different ages have been tested using the same procedures, age-related changes in spontaneous production of the target behaviors have made conclusions regarding age-related changes in imitation performance per se difficult (e.g., [Abravanel & Gingold, 1985](#); [Meltzoff, 1985](#)). In Experiment 1, on the other hand, 6- to 24-month-old infants were tested using exactly the same procedure, and spontaneous production of the target behaviors by infants in the control groups did not vary as a function of age. The results of Experiment 1 demonstrated that although 12-, 18-, and 24-month-old infants exhibited deferred imitation following a 24-hour delay, there was no evidence of deferred imitation by 6-month-olds; the performance of 6-month-old infants in the demonstration condition was indistinguishable

¹ These data and those reported in Experiments 2 and 3 were also analyzed by applying a square root transformation on the raw latency scores prior to submitting them to an analysis of variance. The pattern of results remained the same.

² The data were analyzed using the absolute number of infants exhibiting each target behavior. Due to the small number of observations in some cells, this analysis was conducted using the Fischer Exact Test.

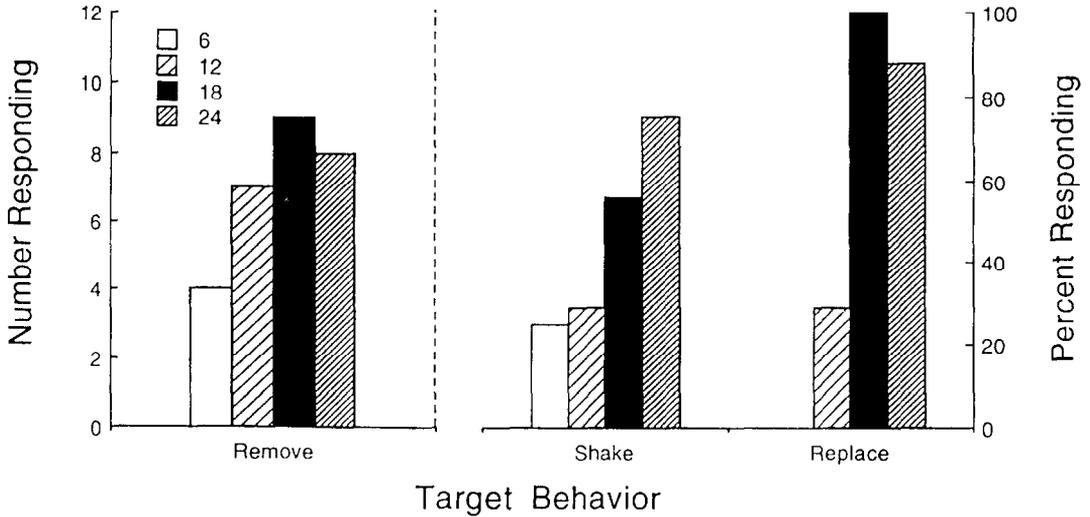


Figure 2. Left Panel: The number of infants (max = 12) in the demonstration condition who removed the mitten as a function of age. Right Panel: The percentage of infants removing the mitten who also shook it or replaced it as a function of age (Experiment 1).

from that of their age-matched controls. These findings suggest that although very young infants may exhibit deferred imitation of some facial gestures (Meltzoff & Moore, 1994), they may be unable to exhibit deferred imitation of object-related play behaviors similar to those readily imitated by infants during the 2nd year of life (Tomasello, Savage-Rumbaugh, & Kruger, 1993). Before we can conclude that the 6-month-olds in Experiment 1 exhibited a deficit in deferred imitation *per se*, however, it is necessary to rule out an alternative explanation for these findings. It is possible, for example, that in spite of their ability to reach for objects, the motor demands of the task were too great for the youngest subjects. One way to assess this possibility is to determine whether or not 6-month-olds could perform the task in the absence of a delay. The purpose of Experiment 2, therefore, was to examine immediate imitation in 6- and 12-month-old infants.

EXPERIMENT 2

Method

Subjects

The final sample consisted of 24 (12 males, 12 females) 6-month old (M age = 185 days, $SE = 7$) and 24 (12 males, 12 females) 12-month-old (M age = 349.90 days, $SE = 4.64$) infants recruited through public birth records and by word

of mouth. Six additional 12-month-old infants were tested but were not included in the final sample due to interruptions during the test session ($n = 4$) or maternal interference ($n = 2$). Seven additional 6-month-old infants were not included in the final sample due to crying ($n = 2$), interruptions during the test ($n = 3$), or failure to pass the reaching test ($n = 2$).

Apparatus

The apparatus was identical to that described in Experiment 1.

Reaching Test. As before, parents reported that the infants in our sample had been reaching for objects for approximately 6 weeks ($M = 46$ days, $SE = 4$). Each infant's reaching ability was assessed, however, prior to the puppet demonstration in the manner described for Experiment 1. Two infants did not pass this test and were replaced.

Demonstration and Test. The demonstration and test procedures were also identical to those used in Experiment 1 except that there was no delay between the demonstration and the test. All infants were tested immediately following the demonstration. As before, infants were given 90 s from the time they first touched the puppet in which to respond.

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 noted the presence or absence of three target behaviors during the test: (1) remove the mitten, (2) shake the mitten, (3) put the mitten back on the puppet (or attempt to put the mitten back on). Interrater reliability was

expressed as the number of agreements divided by the total number of behaviors recorded. This calculation yielded an interobserver reliability score of 100% ($\kappa = 1.00$). Both observers also recorded the latency, in seconds, for the infant to touch the puppet and to remove the mitten. Pearson's product moment correlations were calculated for the latency to touch the puppet and the latency to remove the mitten. These calculations yielded interobserver reliabilities of .95 and .99, respectively.

The average imitation score of the infants in each condition (demonstration and control) is shown in Figure 3 as a function of age. To determine whether or not either age group exhibited deferred imitation, separate t tests were calculated comparing each demonstration group with the age-matched control group. These analyses indicated that there was a significant difference between the two groups for both the 6-month-olds, $t(22) = 2.16, p < .05$, and the 12-month-olds, $t(22) = 3.53, p < .002$. The data presented in Figure 3 were also subjected to a 2 (condition) \times 2 (age) analysis of variance. This analysis yielded a significant main effect of condition, $F(1, 44) = 13.76, p < .001$; infants in the demonstration condition exhibited significantly higher imitation scores than infants in the control condition. There was no significant main effect of age and no interaction. That is, within the demonstration condition, 6-month-olds were just as likely to

remove the mitten ($n = 8$) as 12-month-olds ($n = 8$). In addition, an analysis of the latency data indicated that the 6-month-olds (M latency = 35.32 s, $SE = 8.32$) removed the mitten as quickly as the 12-month-olds (M latency = 39.38 s, $SE = 12.43$) during the test. Consistent with Experiment 1, however, these young infants were less likely to imitate the other two target behaviors, and there was no difference between the two age groups (*shake*: 6-month-olds = 2, 12-month-olds = 1; *replace*: 6-month-olds = 0, 12-month-olds = 3).

The results of Experiment 2 demonstrate that 6-month-old infants imitated the target behaviors at a level equivalent to that of 12-month-olds when they were tested immediately after the demonstration. In spite of this, however, the younger infants were apparently unable to use the information gleaned from the modeling session when tested for the first time after a 24-hour delay (Experiment 1). Given that the 6-month-olds could perform the task as well as 12-month-olds in the absence of a delay, their failure to exhibit deferred imitation in Experiment 1 must be related to their inability to remember the event following the retention interval. On the surface, these findings support Piaget's stage theory that immediate imitation developmentally precedes deferred imitation. Before concluding that 6-month-olds are incapable of deferred imitation using this task, however, we attempted to facilitate their performance by increasing their exposure to the target behaviors in Experiment 3.

EXPERIMENT 3

There are at least two ways to increase infants' exposure to the target actions. First, the duration of the demonstration session could be held constant, but the number of sessions could be increased. Second, the number of demonstration sessions could be held constant, but the duration of the session could be increased. Previous research has shown that these two manipulations may have different effects on retention depending upon the age of the infant (Enright, Rovee-Collier, Fagen, & Caniglia, 1983; Ohr, Fagen, Rovee-Collier, Hayne, & Vander Linde, 1989; Vander Linde, Morrongiello, & Rovee-Collier, 1985). In Experiment 3, infants' exposure to the target actions was doubled by adding additional demonstration

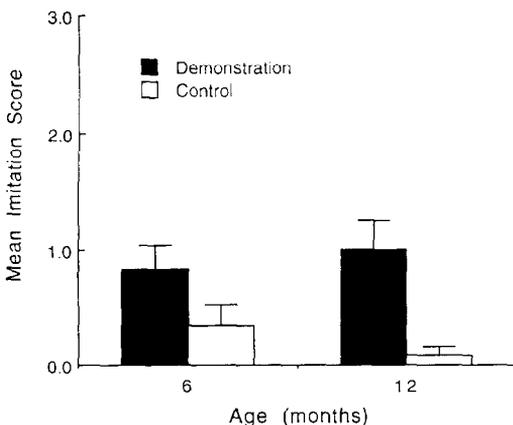


Figure 3. The mean imitation score (+ 1 SE) of 6- and 12-month-old infants tested immediately after the demonstration session as function of experimental condition (Experiment 2).

sessions or by increasing the duration of a single session.

Method

Subjects

The final sample consisted of 48 (24 males, 24 females) 6-month-old (M age = 188.5 days, $SE = 5.0$) infants who were recruited as before and were randomly assigned to either the demonstration condition or the control condition as they became available for testing. Five additional infants were tested but were not included in the final sample due to scheduling difficulties ($n = 2$), procedural error ($n = 1$), or interruptions during the test ($n = 2$).

Reaching Test. As in Experiments 1 and 2, parents reported that the infants in Experiment 3 had been reaching for objects for approximately 6 weeks ($M = 46$ days, $SE = 4.5$ days). Each infant's reaching ability was assessed prior to the demonstration in the manner described for Experiment 1. All infants passed this test.

Demonstration. The demonstration procedure was similar to that used in Experiments 1 and 2, except that the exposure to the puppet was doubled. For infants in the demonstration condition, the experimenter removed the mitten from the puppet's right hand, shook it three times ringing the bell inside, and replaced it on the puppet's right hand. This sequence was repeated a total of six times. For half of the infants in the demonstration condition, the sequence was repeated six times within a single session (1 demonstration session), and for the other half, the sequence was repeated three times during each of two sessions that were separated by 24 (± 2) hours (2 demonstration sessions). As before, infants in the control condition were exposed to the puppet, the mitten, and the ringing bell for the same amount of time as infants in the demonstration condition, however, the target actions were never modelled. For infants in the control condition, the experimenter moved the puppet back and forth ringing the bell attached to the puppet's back. This procedure was repeated a total of six times. For half of the infants in the control condition, the control procedure was repeated six times within a single session (one demonstration session), and for the other half, the sequence was repeated three times during each of two sessions that were separated by 24 (± 2) hours (2 demonstration sessions).

Test. The test procedure was identical to that used in the previous experiments. All infants were tested 24 hours after their final (or only) demonstration session. As in Experiments 1 and 2, infants were given 90 s from the time they first touched the puppet in which to respond during the test.

Results and Discussion

As in Experiments 1 and 2, each videotaped test session was scored by two independent observers, one of whom was blind to the infant's group assignment. Both observers noted the presence or absence of three target behaviors during the test: (1) remove the mitten, (2) shake the mitten, (3) put the mitten back on the puppet (or attempt to put the mitten back on). Interrater reliability was expressed as the

number of agreements divided by the total number of behaviors recorded. This calculation yielded an interobserver reliability score of 100% ($\kappa = 1.00$). Both observers also recorded the latency, in seconds, for the infant to touch the puppet and to remove the mitten. Pearson's product moment correlations were calculated for the latency to touch the puppet and the latency to remove the mitten. These calculations yielded interobserver reliabilities of .99 and .99, respectively.

The mean imitation scores of infants in Experiment 3 are displayed in Figure 4 as a function of experimental condition. To determine whether or not infants exhibited deferred imitation following 1 or 2 demonstration sessions, separate t tests were calculated comparing each demonstration group with their matched control group. These analyses indicated that there was a significant difference between the two groups following a single session, $t(22) = 3.53$, $p < .002$, but not when the same total demonstration time was spaced over two consecutive sessions. The data presented in Figure 4 were also subjected to a 2 (condition) \times 2 (session number) analysis of variance. This analysis yielded a significant main effect of condition, $F(1, 44) = 6.62$, $p < .01$, and a significant condition \times session number interaction, $F(1, 44) = 5.47$, $p < .05$. Post hoc Tukey tests, $p = .05$, indicated that infants in the demonstration condition who were tested following a sin-

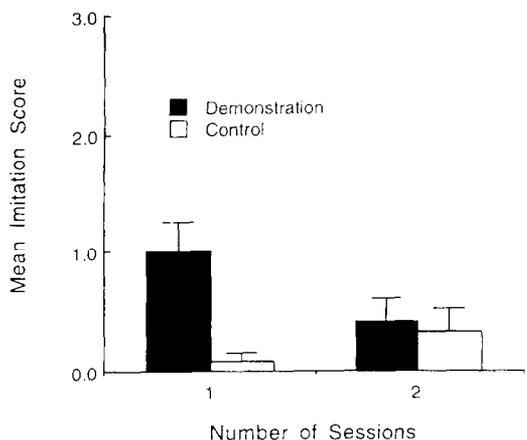


Figure 4. The mean imitation score ($+1 SE$) of 6-month-old infants tested 24 hours after the demonstration session as a function of session number and experimental condition (Experiment 3).

gle demonstration session exhibited the highest imitation scores when tested 24 hours later; the scores of the remaining three groups were not different from one another. The imitation performance of the former group was virtually identical to that of the 6-month-old infants in Experiment 2 who were tested immediately after the demonstration (*remove* = 8; *shake* = 3; *replace* = 0).

In summary, the results of Experiment 3 demonstrate that, given sufficient exposure to the target actions, even 6-month-old infants exhibit deferred imitation following a 24-hour delay. Furthermore, the results of Experiment 3 also indicate that, while holding total exposure time constant, increasing the duration of a single session is more effective in facilitating performance than increasing the total number of sessions.

GENERAL DISCUSSION

Based on the observations of his own three children, Piaget proposed that infants were not capable of deferred imitation until they were approximately 18 to 24 months old. Although initial laboratory research provided some support for this conclusion (McCall et al., 1977), an increasing number of recent studies have shown that infants much earlier in development can imitate a wide range of actions following a delay (e.g., Hanna & Meltzoff, 1993; Meltzoff, 1985, 1988a, 1988b, 1988c). The results of these experiments add to this growing body of research and provide support for the view that infants well before 18 months of age are able to reproduce modelled actions following a 24-hour delay.

Although these findings provide evidence for deferred imitation by infants as young as 6 months, they also suggest that important developmental changes in imitative ability occur during the first 2 years of life. First, younger infants required more exposure to the target actions in order to exhibit deferred imitation following a 24-hour delay. In these experiments, for example, 12-, 18-, and 24-month-old infants exhibited deferred imitation after observing the modelled actions only three times

over a single 20- to 30-s period; 6-month-olds, on the other hand, required twice as much exposure to the target actions in order to exhibit imitation following the same delay. Second, older infants were more accurate in their imitation of the target sequence following a 24-hour delay. In Experiment 1, for example, 12-month-olds successfully imitated one of the modelled actions, however, their ability to imitate the second and third actions was inferior to that of their 18- to 24-month-old counterparts. In Experiment 2, 6- and 12-month-olds imitated the first behavior almost exclusively, even though the other behaviors were within their repertoire.³ Finally, in Experiment 3, 6-month-olds primarily imitated only the first behavior, even though their exposure time to the entire sequence was doubled. Although it has been argued that infants can accurately imitate two-step sequences by their first birthday (Bauer & Mandler, 1992; Mandler & McDonough, 1995), they have only been shown to do so with a considerable degree of procedural support including prior practice, sequence narration, and verbal praise. The results of these experiments, however, suggest that there may be important age-related changes in infants' ability to imitate multistep sequences on the basis of observation alone (i.e., deferred imitation). Furthermore, there may also be age-related differences in infants' perception of the sequence goal and in competing responses that interfere with imitation of the target sequence. We are currently exploring these possibilities.

These findings raise a number of important questions. First, how can we account for the large discrepancy in age between our findings of deferred imitation (i.e., 6 months) and those proposed by Piaget (i.e., 18 to 24 months)? In our experiments, we attempted to maximize the opportunity for imitation to occur—infants were tested in the familiar setting of their own home, with stimuli that were identical to those encountered during the original demonstration, the infant was the primary focus of attention, and all other distracting activities were held to a minimum. Whether or not parents structure their young infants' learning environment in a similar way is not known, but it is likely that individual differences in parents and home environments (e.g., the presence of siblings, other adults, television) will have a dramatic effect on the age at which children are first

³ Extensive pilot work showed that younger infants reliably shake (90%) and replace (40%) the mitten when these target behaviors are demonstrated and tested separately but not when they are imbedded within the sequence.

likely to acquire novel behavior via deferred imitation (e.g., Tomasello et al., 1993). The extent and limits of deferred imitation by infants under more natural conditions, similar to those originally studied by Piaget, clearly warrant further research.

Second, what are the implications of the findings for the development of declarative memory? Over the last decade, the study of deferred imitation has emerged as the dominant paradigm for examining memory development in preverbal children. Renewed interest in this paradigm has been due, in large part, to the relation between deferred imitation tasks and other measures of declarative memory (Bauer & Mandler, 1990; Mandler, 1990; Meltzoff, 1990). This research is the first attempt to examine age-related changes in deferred imitation across the first 2 years of life within a single paradigm. Although their behavior was not as sophisticated as that of older infants, the results of the experiments indicate that subjects as young as 6 months of age exhibited evidence of deferred imitation. Our data demonstrate that, under some conditions, 6-month-olds can encode information on the basis of observation alone and can retrieve and use this information following a significant delay. Based on these findings, we would argue that memory does not develop in a discontinuous, stage-like manner as has been suggested in the past (e.g., Nadel & Zola-Morgan, 1984; Piaget, 1962; Schacter & Moscovitch, 1984). Instead, we propose that declarative memory, like all other forms of memory, changes gradually over the course of development; initial evidence of declarative memory can be observed as early as 6 months of age (and probably even earlier), but significant changes in the scope of this cognitive ability continue to occur over a protracted period of development extending well into the 2nd year of life. What changes, if any, occur beyond the age of 2 are yet to be determined. It is quite likely, for example, that developmental changes in language comprehension and production may extend the range of situations in which deferred imitation will be observed under both highly controlled and more naturalistic conditions. We are currently exploring this possibility.

Finally, what do the findings add to our current understanding of infant memory development more generally? In the past, the mobile

conjugate reinforcement paradigm has dominated research on memory development during the first 6 months of life. In this operant conditioning task, 2- to 6-month-old infants learn to kick their feet to produce movement in an overhead mobile. Delayed recognition is assessed by returning the infant to the experimental situation and observing his or her behavior prior to the reintroduction of the contingency; during the test, the mobile is visible but remains stationary and is unaffected by kicking (for reviews, see Hayne, 1996; Rovee-Collier, 1990; Rovee-Collier & Hayne, 1987; Rovee-Collier & Shyi, 1992). The demonstration of deferred imitation by infants as young as 6 months provides the opportunity to integrate findings from studies obtained using this paradigm with the large body of data available for infants of the same age tested in the mobile conjugate reinforcement paradigm. Due to the dichotomy between procedural and declarative memory that has dominated memory research, this integration is easier said than done. It has been suggested that as an operant conditioning paradigm, mobile conjugate reinforcement falls into the procedural realm. On the basis of objective criteria, however, infants as young as 3 months of age can acquire information in the mobile conjugate reinforcement paradigm on the basis of observation alone, in the absence of prior practice, and can exhibit retention of that information over very long periods of time (Greco, Hayne, & Rovee-Collier, 1990; Hayne, Greco-Vigorito, & Rovee-Collier, 1993; Rovee-Collier, Greco-Vigorito, & Hayne, 1993). Given that these same criteria that have been used to argue that deferred imitation is a valid measure of declarative memory (Meltzoff, 1990), we would argue that, under some circumstances, mobile conjugate reinforcement can provide a measure of declarative memory as well. This offers the opportunity for the synthesis of findings obtained within these two paradigms.

Historically, there has been considerable debate about the development of human memory. Some theorists have proposed that memory development occurs in a discontinuous, stage-like manner (Mandler, 1990; Nadel & Zola-Morgan, 1984; Piaget, 1952; Schacter & Moscovitch, 1984), whereas others have argued that memory development is a gradual and con-

tinuous process (Rovee-Collier, 1990). The data from Experiments 1 through 3 are most consistent with the latter hypothesis and indicate that age-related changes in deferred imitation occur gradually throughout the infancy period. In fact, we would argue that discrete, stage-like development in any cognitive domain is exceedingly rare (for a similar argument, see Baillargeon, 1987; Baillargeon, Spelke, & Wasserman, 1985; Diamond et al., 1994) and that a more productive approach to the study of infant memory development would include a synthesis of findings across paradigms in an attempt to uncover the large number of continuities that undoubtedly exist.

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