Deferred Imitation by 6- and 9-Month-Old Infants: More Evidence for Declarative Memory

ABSTRACT: Deferred imitation has recently surfaced as a hallmark measure of nonverbal declarative memory. In two experiments, we examined the developmental origins of deferred imitation during early infancy. Six- and 9-month-old human infants observed an experimenter perform specific actions with multiple objects. The infants' ability to reproduce those actions was assessed following a 24-hr delay. With a single demonstration session, infants of both ages reproduced significantly more actions that had been demonstrated than control actions that had not. These findings challenge the view that memory development is characterized by the emergence of a fundamentally different, declarative memory system later in development. We conclude that the rudiments of declarative memory are present by at least 6 months of age.

Keywords: imitation; infants; declarative memory

Over the past 20 years, an increasing number of researchers have argued that memory is not a unitary process, but rather is comprised of two or more neural systems that serve different functions and operate according to different principles (for recent reviews, see Eichenbaum, 1997; Schacter & Tulving, 1994; Squire, 1992a, 1992b). Although a large number of dichotomous terms have been generated to describe these multiple memory systems (for review, see Nadel, 1992; Schacter & Tulving, 1994), the most commonly cited dichotomies are procedural versus declarative memory (Cohen & Squire, 1980; Squire, 1994) and implicit versus explicit memory (Graf & Schacter, 1985; Schacter, 1994).

Although the procedural/declarative and implicit/explicit distinctions are not identical, they share the claim that one memory system supports the retention of habits, learned skills, priming, and gradual or incremental learning (procedural, nondeclarative, or implicit memory), while a second memory system supports conscious recollection of episodic facts and events and allows for rapid, one-trial learning (declarative or explicit memory). In addition, they share the common claim that different underlying neural mechanisms subserve each memory system. For ease of exposition, the terms procedural and declarative memory will be adopted throughout the present article.

The notion of independent, multiple-memory systems has had a major impact on theories of memory development. According to the multiple-system view,
memory development occurs in a discrete, stage-like manner with one memory system emerging significantly earlier than the other (Bachevalier, 1990, 1992; Bachevalier & Mishkin, 1984; Moscovitch, 1985; Nadel & Zola-Morgan, 1984; Nelson, 1995; Schacter & Moscovitch, 1984). It has been argued that the memory skills of human infants are initially restricted to procedural memory but that by approximately 8 to 9 months of age the declarative memory system matures (Nadel & Zola-Morgan, 1984; Nelson, 1995; Schacter & Moscovitch, 1984). Within this framework, an analogy is frequently drawn between the memory skills of young human infants and those skills that are spared in human adults with temporal-lobe amnesia. Amnesics, for example, perform normally on a variety of nondeclarative tasks (Brooks & Baddeley, 1976; Cohen, 1984; Cohen & Squire, 1980; Corkin, 1968; Kinsbourne & Wood, 1975; Milner, Corkin, & Teuber, 1968; Wood, Ebert, & Kinsbourne, 1982), but they cannot perform tasks thought to require declarative memory (Squire, 1987, 1992a, 1992b). The presumed immaturity of the medial temporal lobe and related structures in the human infant brain is thought to preclude the formation of declarative memories in the same way that damage to the medial temporal lobe disrupts declarative memory performance by human adult amnesics (Moscovitch, 1985; Nadel & Zola-Morgan, 1984; Nelson, 1995; Schacter & Moscovitch, 1984).

Despite the prevalence of the infant/amnesic analogy, the verbal nature and/or motoric sophistication of most declarative memory tasks have precluded direct comparison between the memory performance of preverbal infants and the memory performance of adult amnesics on common tasks. Over the last decade, however, deferred imitation has reemerged as a potentially useful paradigm for examining memory in both infants and adults. In the standard deferred imitation paradigm, the experimenter demonstrates a series of actions with novel objects, and the participant’s ability to reproduce those actions is assessed after a delay. Although there has been considerable debate about the definition of true imitation in studies with animals (Byrne & Russon, 1998), in studies with human infants and adults imitation is defined as an increase in the target behavior relative to baseline following the demonstration of that behavior (McDonough, Mandel, McKee, & Squire, 1995; Meltzoff, 1985, 1988; Poulson, Nunes, & Warren, 1989). Because deferred imitation is based on a brief observation of the target actions and involves no practice, this paradigm is thought to provide a measure of declarative memory (Meltzoff, 1990, 1995). This notion has been supported by recent evidence that adults with temporal-lobe amnesia fail traditional tests of deferred imitation (McDonough et al., 1995).

Previous research has shown that 9-month-olds exhibit deferred imitation after a delay of 24 hr (Meltzoff, 1988). This finding is often cited in support of the view that declarative memory emerges at approximately 8–9 months of age (Nelson, 1995). Recent research from our laboratory, however, has yielded evidence of deferred imitation by 6-month-olds after the same delay (Barr, Dowden, & Hayne, 1996). In the Barr et al. (1996) study, infants in the demonstration condition watched as an experimenter modeled three target actions with a puppet. Infants in the control condition were exposed to the puppet and to the experimenter but the target actions were never modeled. Infants in both conditions were tested for the first time after a 24-hr delay. Infants in the demonstration condition exhibited clear evidence of deferred imitation. Their performance was significantly better than that of the age-matched control group and was not different from that of the 12-month-old infants tested after the same delay. These findings challenge the view that a dramatic shift in memory processing occurs at 8–9 months of age. Rather, it appears that the capacity for declarative memory emerges by at least 6 months, if not earlier.

The purpose of the present study was threefold. First, we sought to replicate the finding of deferred imitation by infants as young as 6 months of age. Second, we sought to extend our previous findings with 6-month-olds by examining their ability to imitate multiple actions with multiple objects following a delay. Finally, we sought to document potential changes in deferred imitation between 6 and 9 months of age. This age range was chosen to straddle the period over which declarative memory is thought to emerge in human infants (Nelson, 1995; Schacter & Moscovitch, 1984).

EXPERIMENT 1

In the Barr et al. (1996) study, the experimenter modeled three target actions with a single stimulus. In Experiment 1, we compared 6- and 9-month-olds’ ability to imitate multiple actions performed with multiple objects after a 24-hr delay.

Participants

Twelve infants (6 males, 6 females) with a mean age of 6.59 months (SD = 2.5) and 12 infants (6 males, 6 females) with a mean age of 9.39 months (SD = 1.7) were recruited through public birth records and by

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SD means Standard Deviation

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Table 1. The Objects and Target Actions Used in Experiment 1*

<table>
<thead>
<tr>
<th>Pair</th>
<th>Object 1</th>
<th>Target Action(s) 1</th>
<th>Object 2</th>
<th>Target Action(s) 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Woman</td>
<td>Pull cord (legs jump)</td>
<td>Man</td>
<td>Spin (turns upside down)</td>
</tr>
<tr>
<td>2</td>
<td>Rabbit</td>
<td>Remove from pocket</td>
<td>Worm</td>
<td>Shake (sattles)</td>
</tr>
<tr>
<td>3</td>
<td>Owl</td>
<td>Remove from tree</td>
<td>Sun</td>
<td>Lift leaf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Press belly (eyes flash)</td>
<td></td>
<td>Press (makes noise)</td>
</tr>
</tbody>
</table>

*For each infant, 1 member from each pair served as a demonstration object and the other served as a control object. The outcome of the target action(s) is shown in parentheses.

word of mouth. Infants were predominantly Pakeha (New Zealanders of European descent) and from a wide range of socioeconomic backgrounds. Two additional 6-month-olds (1 male, 1 female) were excluded from the final sample due to maternal interference or for failing to touch the apparatus during the test.

Apparatus

The apparatus consisted of a 65 × 31-cm “activity” board covered in brightly colored felt. Six objects were secured to the board at all times. The objects and their associated target actions are shown in Table 1. During all sessions, the activity board was secured to a portable floor stand in an upright position. This apparatus was conceptually similar to commercially available infant activity boards, but both the board and the individual objects were constructed specifically for the present experiments and were not commercially available. As such, infants had no experience with any of the objects prior to the experiment.

Procedure

All infants were tested in their own homes at a time of day when they were likely to be playful. The two sessions, a demonstration session and a test session, were separated by 24 hr (±4 hr). During all phases of the experiment, the infant’s caregiver sat with the infant on the floor in front of the experimental apparatus and supported the infant, when required, by the hips. The caregiver was requested not to prompt the infant in any way during the demonstration or the test. All caregivers complied with this request. At the outset of each session, the experimenter interacted with the infant until the infant appeared comfortable.

Demonstration Session

Reaching Test. In order to imitate the target actions, infants were required to engage in visually guided reaching—a motor milestone typically achieved by 4 to 5 months of age (Bushnell, 1985). To ensure that all infants in the sample could perform the task, their reaching ability was assessed at the outset of the demonstration session (cf. Barr et al., 1996). For this test, the experimenter held a brightly colored object within reach, approximately 15–25 cm in front of the infant, and verbally encouraged the infant to reach out and grasp it. All infants did so successfully.

Demonstration. After the reaching test, the apparatus was positioned approximately 50 cm in front of the infant but out of reach. During the demonstration session, the experimenter modeled the target action(s) for three of the six objects on the apparatus (see Table 1). As shown in Table 1, the objects were divided into pairs. The experimenter modeled the target action(s) for one object from each pair six times in succession. The remaining member of each object pair was not touched by the experimenter during the initial demonstration and served as a control object. The order in which a given object was used during the demonstration session was counterbalanced across participants, and each object served equally often as a control and a demonstration object. The entire demonstration procedure lasted 2–3 min.

Test Session

All infants were tested 24 hr (±4 hr) after the demonstration session. The apparatus was placed on the floor as before. Once the infant and the caregiver appeared settled, the apparatus was moved within reach, approximately 20 cm in front of the infant. The test session was videorecorded.

Behavior was scored for 3 min from the time the infant first touched the apparatus. Each videotape was scored by two independent observers, one of whom was blind to the infant’s prior experience. Both made a yes/no decision as to the presence or absence of each target action during the test. Infants were given credit only for the first time they produced a given action; repetitions of that action did not contribute to an infant’s score. In addition to the target behaviors, infants also engaged in nontarget behaviors, including mouth- ing the objects or throwing them on the floor. These behaviors did not contribute to an infant’s score. In-
Collie and Hayne

FIGURE 1 The mean number of demonstration and control actions (+1 SE) for 6- and 9-month-old infants tested after a 24-hr delay (Experiment 1).

terobserver reliability was expressed as the number of agreements divided by the total number of target actions coded. Interobserver reliability for the 6-month-old infants was 96% (kappa = 0.95) and for the 9-month-old infants, 100% (kappa = 1.00).

Results and Discussion

A preliminary three-way (Gender × Action Condition × Age) analysis of variance (ANOVA) revealed no significant main effect of infant gender, and gender did not enter into any significant interactions. The data were, therefore, collapsed across gender for subsequent analysis. The mean number of target actions produced by infants is shown in Figure 1 as a function of action condition (demonstration or control) and age. A 2 × 2 (Action Condition × Age) ANOVA yielded a significant main effect of action condition, F(1, 22) = 7.67, p < .01. Both 6- and 9-month-olds produced more actions that had been modeled by the experimenter the day before (demonstration actions) than control actions that had not (see Figure 1). The significant main effect of age, F(1, 22) = 10.75, p < .005, revealed that 9-month-olds produced more target actions overall than 6-month-olds. This difference was due to an age-related increase in overall activity, however, rather than an increase in deferred imitation, per se. That is, the 9-month-olds produced significantly more demonstration and control actions than their 6-month-old counterparts. The Action Condition × Age interaction was not significant.

The present results replicate and extend previous demonstrations of deferred imitation by 6- and 9-month-old infants following a 24-hr delay (Barr et al., 1996; Meltzoff, 1988). Consistent with those previous reports, imitation occurred on the basis of a brief observation of the target actions with no motor practice prior to the retention interval. Furthermore, the present results yielded evidence of deferred imitation under conditions that were more challenging than those used in prior studies. For example, relative to past imitation procedures used with 6- to 9-month-olds, the present procedure involved a greater number of to-be-remembered actions that were performed with multiple objects. In past imitation procedures, the experimenter modeled either a single target action for each of three different objects (Meltzoff, 1988) or three target actions for a single object (Barr et al., 1996). In the present study, the experimenter modeled a total of five target actions using three different objects. Furthermore, unlike past imitation procedures, the present procedure involved a backdrop of potential distractors. That is, during both the demonstration and the test sessions, an equal number of demonstration and control objects was present on the apparatus. Infants had to first locate the target object and then recall what to do with it.

EXPERIMENT 2

In Experiment 2, we further increased the difficulty of the deferred imitation task by increasing the number of demonstration and control objects and their associated actions.

Method

Participants. Twelve infants (6 males, 6 females) with a mean age of 6.86 months (SD = .26) and 12 infants (6 males, 6 females) with a mean age of 9.40 months (SD = .22) were recruited as before. One additional 6-month-old female was tested but excluded from the final sample due to sibling interference during the test.

Apparatus and Procedure. The activity board was similar to the one used in Experiment 1, but 12 objects were mounted on the board instead of six. The objects and their associated target actions are shown in Table 2. The reaching test, demonstration, and test procedures were the same as before. All infants passed the reaching test on the first trial. The entire demonstration procedure lasted 3–4 min. The interobserver reliability for each age group was 99% (kappa = .98).
Table 2. The Objects and Target Actions Used in Experiment 2*

<table>
<thead>
<tr>
<th>Pair</th>
<th>Object</th>
<th>Target Action(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frog</td>
<td>Pull cord (legs jump)</td>
</tr>
<tr>
<td>2</td>
<td>Man</td>
<td>Spin (turns upside down)</td>
</tr>
<tr>
<td>3</td>
<td>Sun</td>
<td>Press (squeaks)</td>
</tr>
<tr>
<td>4</td>
<td>Rabbit</td>
<td>Pull (comes off board)</td>
</tr>
<tr>
<td>5</td>
<td>Owl</td>
<td>Remove</td>
</tr>
<tr>
<td>6</td>
<td>Bird</td>
<td>Open door</td>
</tr>
<tr>
<td></td>
<td>Cat</td>
<td>Pull (comes off board)</td>
</tr>
</tbody>
</table>

*For each infant, 1 member from each pair served as a demonstration object and the other served as a control object. The outcome of the target action(s) is shown in parentheses.

Results and Discussion

A preliminary three-way ANOVA again revealed no significant main effect or interactions associated with gender; therefore, the data were collapsed across gender for subsequent analysis. A 2 × 2 × 2 (Action Condition × Age) ANOVA yielded a significant main effect of action condition, \(F(1, 22) = 6.89, p < .01\) (see Figure 2). Both 6- and 9-month-old infants produced more demonstration target actions than control target actions during the test. There was no significant main effect of age and no Action Condition × Age interaction.

Taken together, these results replicate and extend the finding of 24-hr deferred imitation by 6- and 9-month-old infants. Deferred imitation occurred in both age groups even though a total of eight unique actions were modeled during the demonstration session, and infants again did not practice the actions prior to the long-term test.

GENERAL DISCUSSION

The present results indicate that, under a number of challenging conditions, infants as young as 6 months of age exhibit deferred imitation after a 24-hr delay. Deferred imitation by these young infants was observed in spite of the fact that the present task was more difficult than the tasks previously used by Barr et al. (1996) and Meltzoff (1988) to study deferred imitation by 6- and 9-month-old infants, respectively.

The present findings have important implications for current theories of memory development. Historically, there has been considerable debate about the nature of memory development. Some theorists have argued that memory development occurs in a discrete, stage-like manner. According to this view, a procedural memory system emerges significantly earlier than a declarative memory system. Traditionally, the emergence of declarative memory was thought to depend upon the maturation of the hippocampus and related structures in the medial temporal lobe (Nadel & Zola-Morgan, 1984; Nelson, 1995; Schacter & Moscovitch, 1984). Recently, it has been argued that the maturation of the cortical association areas might contribute to the emergence of declarative memory during development (Bachevalier, 1990, 1992; Nelson, 1995). The underlying assumption of both neural views, however, remains the same. That is, the maturation of some component of the central nervous system results in a dramatic shift in memory processing which allows infants to progress from the constraints of an exclusively procedural memory system to a more-mature declarative memory system.

Alternatively, other theorists have argued that memory development is a smoother, more continuous process with changes in two (or more) memory systems occurring gradually and in concert (Barr et al.,...
Traditionally, performance on the DNMS task was assumed to emerge late in development. Bachvalier and Mishkin (1984) found that DNMS performance in nonhuman primates emerged well after performance on tests of object discrimination and did not reach adult levels of performance until approximately 1 year. Their results led to the argument that the habit memory system supporting object discrimination develops early in infancy while the “true” memory system that supports DNMS emerges much later and develops more slowly.

Recent studies by Diamond (1990, 1995), however, have yielded evidence of declarative memory by human infants as young as 6 months of age tested on the DNMS task. In one study (Diamond, 1995), the reaching component of the task was reinstated, but infants’ reward was the object, per se, not an item located beneath it. Under these conditions, infants as young as 6 months of age could also perform the task.

Taken together, our studies of deferred imitation and Diamond’s studies of DNMS clearly demonstrate that infants can perform at least two tasks that are thought to tap declarative memory as early as 6 months of age. The finding that declarative memory emerges so early in life challenges the utility of the notion that these two systems emerge independently during development. In fact, Meltzoff has argued, “There may never be a time that the human infant is confined to a purely habit/procedural mode” (Meltzoff, 1990, p. 20). Consistent with this view, Rovee-Collier (1997) has argued, “If there indeed are two memory systems, then they develop simultaneously and not sequentially from early in life” (p. 491).

In conclusion, research from a number of different laboratories, using a number of different experimental procedures, provides convergent evidence that declarative memory emerges very early in life. These findings force us to reexamine the explanatory value of memory dichotomies for current theories of memory development.

REFERENCES


NOTES

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1996; Hartshorn et al., 1999; Hayne, MacDonald, & Barr, 1997; Rovee-Collier, 1997). Resolution of this issue has been hindered in the past because participants of different ages have been tested using different procedures. In the present experiments, however, 6- and 9-month-old infants successfully performed a declarative memory task that has been used with older infants and young children (Hayne et al., 1997; Meltzoff, 1990, 1995) and amnesic adults (McDonough et al., 1995). Findings from deferred imitation studies with infants younger than 9 months raise fundamental questions about the discrete stage-like nature of memory development. Both the present study and Barr et al. (1996), for example, clearly demonstrate that the capacity for declarative memory is present several months earlier than predicted by most multiple-memory system accounts (i.e., 8–9 months of age).

In the past, the delayed-nonmatching-to-sample (DNMS) task has provided considerable support for the notion of multiple, independent memory systems. During the familiarization phase of this task, the subject is presented with an object. During the test phase, the subject is re-presented with the original object and a novel one. Subjects are rewarded for selecting the novel (i.e., nonmatching) object during the test. This procedure, initially developed for use with nonhuman primates, is thought to provide a valid index of the kind of declarative memory that is lost in human amnesia (Squire, Zola-Morgan, & Chen, 1988). A large body of literature has shown that nonhuman primates with lesions to the medial temporal lobe exhibit severe impairments on the DNMS task, while they continue to perform at near-normal levels on other tasks of pattern discrimination and motor skill learning (e.g., Zola-Morgan & Squire, 1990).

As early as 6 months of age, infants can perform at near-normal levels on other tasks of pattern discrimination and motor skill learning (e.g., Zola-Morgan & Squire, 1990).
