

## *Infant Learning and Memory*

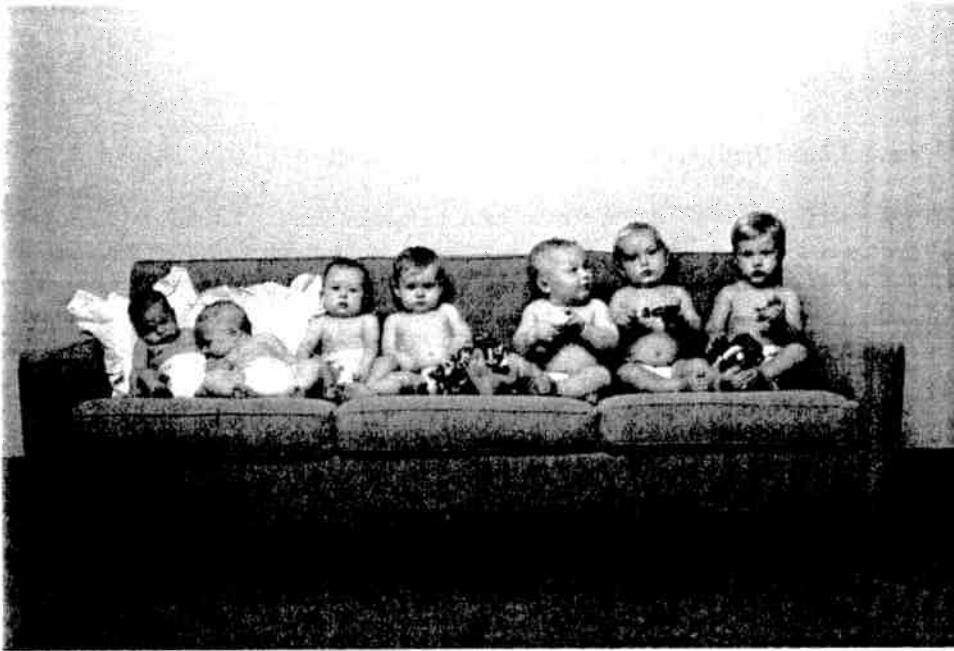
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### **Introduction**

Since Freud first proposed that adult behavior is rooted in the infancy period, the experiences of infants have been viewed as the cornerstone of behavioral and cognitive development. Most psychologists have assumed that the effects of early experiences gradually accrue and that later learning builds on what was learned before. Implicit in this assumption, however, is a capacity for long-term memory – some means by which a relatively enduring record of those early experiences is preserved. Paradoxically, this is a capacity that infants are thought to lack – a belief that also originated with Freud (1935), who thought that early memories are forced into an unconscious state where they motivate subsequent behavior but cannot be recalled. The phenomenon of infantile amnesia – that people usually cannot remember what occurred before the age of 2 or 3 – supports Freud's view.

During the infancy period (birth to 2 years), infants undergo rapid physical, social, and cognitive change (see Figure 8.1). What young infants remember about their prior experiences is difficult to study. Not only can they not verbalize what they remember, but also younger infants lack the motoric competence to perform most of the nonverbal tasks that have been used with older infants and children to study memory. In addition, factors such as the presence or absence of the caregiver, the familiarity or novelty of the training and/or test setting, and the infant's momentary state of arousal radically affect their learning and memory differently at different ages. In describing the major experimental procedures that have been applied to the study of learning and memory development, we will also describe how some of the problems associated with conducting research with human infants have been overcome.

The first part reviews what and how infants learn, how long they remember it, and the effect of reminder procedures on retention. The second part considers recent challenges to maturational models of memory development.



**Figure 8.1** From left to right, infants are 2, 3, 6, 9, 12, 15, and 18 months of age. Note the dramatic physical and behavioral differences between the youngest and oldest infant.

### Research on Infant Learning and Memory

For many years, the notion that ontogeny recapitulates phylogeny was thought to describe the progressive development of learning abilities during the infancy period. The evolutionary continuum of learning extends from habituation, the simplest form of learning that is exhibited by single-celled organisms, to deferred imitation, a form of observational learning that is exhibited by new world primates (Buss, 1973). Today, however, this notion has been refuted by evidence that infants have exhibited every form of learning along the entire continuum within the first 3 months of life. This chapter presents a “broad brush” picture of what is currently known about what young infants can learn and remember. As the bulk of systematic research on infant learning and memory has used habituation, conditioning, and imitation procedures, we have focused on them.

#### *Habituation*

Habituation is a stimulus-specific response decrement that results from repeated exposures to a stimulus that elicits orienting toward or away from it. This definition excludes response decrements resulting from constant exposure (e.g., swaddling), one-stimulus exposure, fatigue, sensory adaptation, circadian rhythms, and physiological processes.

These are the definitions (Spencer, 1966):

- 1 Repeated stimulation produces an exponential function of habituation. When the stimulus is repeatedly presented, the response declines exponentially. The next time the stimulus is presented, the response is smaller than the previous time. Over repeated presentations, the response progressively declines. The rate of decline is faster the more complex the stimulus. The weaker the stimulus, the faster the decline. The habituation curve is a hyperbolic function. When the habituation has ceased, even a small stimulus produces a response. Developmental changes in habituation are reflected in the rate of responding to a stimulus. The smaller the stimulus, the faster the habituation. The smaller the stimulus, the less after habituation.
- 2 When the stimulus is presented again, the response is smaller than the previous time. The next time the stimulus is presented, the response is smaller than the previous time. When the stimulus is presented again, the response is smaller than the previous time. When the stimulus is presented again, the response is smaller than the previous time.
- 3 Over repeated presentations, the response progressively declines. The rate of decline is faster the more complex the stimulus. The weaker the stimulus, the faster the decline. The habituation curve is a hyperbolic function. When the habituation has ceased, even a small stimulus produces a response. Developmental changes in habituation are reflected in the rate of responding to a stimulus. The smaller the stimulus, the faster the habituation. The smaller the stimulus, the less after habituation.
- 4 Other things being equal, the rate of habituation is faster the more complex the stimulus. The weaker the stimulus, the faster the decline. The habituation curve is a hyperbolic function. When the habituation has ceased, even a small stimulus produces a response. Developmental changes in habituation are reflected in the rate of responding to a stimulus. The smaller the stimulus, the faster the habituation. The smaller the stimulus, the less after habituation.
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- 6 The habituation curve is a hyperbolic function. When the habituation has ceased, even a small stimulus produces a response. Developmental changes in habituation are reflected in the rate of responding to a stimulus. The smaller the stimulus, the faster the habituation. The smaller the stimulus, the less after habituation.
- 7 Habituation to a stimulus produces a response. The smaller the stimulus, the faster the habituation. The smaller the stimulus, the less after habituation.
- 8 When an extra stimulus is presented, the response to the original stimulus is smaller than the previous time. When the distractor is removed, the response to the original stimulus is smaller than the previous time. Developmental changes in habituation are reflected in the rate of responding to a stimulus. The smaller the stimulus, the faster the habituation. The smaller the stimulus, the less after habituation.
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Sokolov's (1963) procedure was used to assess infants' perception of a stimulus representation and

These are the defining characteristics (examples italicized) of habituation (Thompson & Spencer, 1966):

- 1 Repeated stimulus presentations result in decreased responding (usually, a negative exponential function of presentation number) to an asymptote or zero. *A new object is repeatedly presented for 10 s. Initially, the infant fixates it continuously. Over successive presentations, she fixates it progressively less until she stops fixating it altogether.*
- 2 When the stimulus is withheld, responding recovers over time ("spontaneous recovery"). *The next day, the infant fixates the object again.*
- 3 Over repeated series of habituation and spontaneous recovery trials, habituation is progressively more rapid. *When the same object is presented on successive days, the infant's fixation declines to asymptote after fewer and fewer trials.*
- 4 Other things being equal, the more rapid the stimulation, the more rapid and/or pronounced is habituation. *The shorter the interval between successive presentations, the faster the infant ceases fixating the object.*
- 5 The weaker the stimulus, the more rapid and/or pronounced is habituation. *The simpler the object, the faster the infant ceases fixating it.*
- 6 The habituation process can continue below the observable baseline level ("sub-zero habituation") if the stimulus continues to be presented after overt responding to it has ceased. Evidence of sub-zero habituation is seen when the subsequent level of spontaneous recovery is lower than if presentation of the stimulus terminated when responding to it ceased. *Presenting the object after the infant had stopped fixating it reduces the magnitude of the infant's renewed fixation the next day.*
- 7 Habituation to one stimulus generalizes to another stimulus to the extent that they share common elements. How similar the infant perceives a novel stimulus to be to the habituating stimulus is inferred from the magnitude of generalized habituation: The smaller the response (i.e., the greater the generalized habituation) to the novel stimulus, the greater is the inferred subjective similarity. *Infants fixate a green square less after habituating to a green triangle than after habituating to a red triangle.*
- 8 When an extraneous (usually strong) stimulus occurs during habituation trials, responding to the original habituating stimulus increases ("dishabituation"). Responding to the distractor temporarily disrupts the active inhibitory process of habituation, so that the previously habituated response is stronger on the next habituation trial. Developmental psychologists frequently confuse "dishabituation" with increased responding to a novel stimulus (see 7, above). *If a fire alarm sounds after the sixth presentation of an object, then the infant will fixate that object longer on its seventh presentation.*
- 9 Over repeated presentations of the extraneous stimulus, responding to it habituates. *When the alarm sounds periodically, the infant habituates to it, and its excitatory effect on fixation diminishes correspondingly.*

Sokolov's (1963) model of habituation of the orienting reflex was exploited by researchers to assess infants' perceptual and cognitive abilities. In this model, an internal representation of a stimulus is formed during each encounter, and the discrepancy between the representation and the physical stimulus determines how long subjects fixate the stimulus

on the next encounter. As the representation becomes progressively fleshed out by new information that participants notice in the physical stimulus, they attend to it progressively less. When the discrepancy disappears, looking ceases. Because the internal representation decays over time (i.e., forgetting), looking will be renewed to the extent that the internal representation and the physical stimulus no longer match. When the delay is such that looking is as long as when the stimulus was novel, forgetting is complete.

Fantz (1964) obtained habituation to a repeated visual stimulus with infants between 2 and 6 months of age, and older infants habituated faster. Graham, Leavitt, Strock, and Brown's (1978) finding that an anencephalic infant habituated to an auditory stimulus that normal infants did not revealed that habituation is controlled at multiple levels of the central nervous system, with the functions of newly developing structures superimposed on more primitive ones.

Using a habituation procedure, Stinson (1971, cited in Werner & Perlmuter, 1979) obtained the first forgetting function with infants. Each high-amplitude suck of 4-month-olds on a nonnutritive nipple produced the brief illumination of a visual stimulus on a screen, and the faster infants sucked, the more continuously the stimulus remained visible. As infants habituated (satiated) to the visual stimulus, their rate of sucking decreased until it was only a fraction of its original rate. At this point, the nipple was removed for an interval of 0, 15, 30, or 75 s. When it was reinserted, infants' rate of sucking to produce the visual stimulus was increasingly faster when more time had elapsed since infants last saw it. After just 15 s, infants had begun to suck as fast as they had initially, when the visual stimulus was novel. These data were taken as evidence that infants forgot the visual stimulus within 15 s.

There are both individual and age-related differences in habituation. Infants who habituate faster exhibit better visual recognition memory (i.e., they look longer at a novel test stimulus) than slow habituators (for review, see Colombo & Mitchell, 1990). Also, infants typically remember the habituating stimulus for 5 to 15 s at 3 to 4 months, 1 min at 6 months, and 10 min at 9 to 12 months (for review, see Rose, Feldman, & Jankowski, 2007).

### *Classical (Pavlovian) conditioning*

Like habituation, classical conditioning occurs at all phyletic levels and involves repeated stimulus presentations, but the correlation between the repeated stimulus and a given subsequent environmental event is 1 instead of zero. Because events in nature often occur in an orderly fashion, classical conditioning permits organisms to exploit this orderliness by anticipating (preparing for) the succeeding event instead of simply reacting to it, as in habituation. The classical conditioning procedure initially requires two basic components – an unconditional stimulus (US) that reliably elicits a reflex (the unconditional response, UR) and a stimulus (the eventual conditional stimulus, CS) that does not initially elicit the same reflex as the US. After repeated and contiguous CS–US pairings, the CS elicits a response (the conditional response, CR) that is similar to the UR, either before the US is actually presented or on trials when it is omitted. In essence, in classical conditioning, subjects do not learn a new response but a new occasion for the old response.

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Pavlov thought that conditional reflexes were exclusively cortical. Early Soviet researchers, therefore, viewed the timing of the appearance of the first conditional reflex to stimuli from different modalities as a reflection of the functional maturation of the cortex. In 1913, Krasnogorski (Pavlov's student) failed to obtain conditioning with infants younger than 6 months and concluded that the cortex was too primitive for the formation of cortical connections before then. Much later, Soviet researchers obtained conditioned sucking in 3-week-olds (Koltsova, 1949) and conditioned eyeblinks in 6-week-olds who were 2.5 months premature (Irzhanskaia & Felberbaum, 1954).

Early western studies of classical conditioning traced the conditioning performance of single subjects over time, thereby providing evidence of long-term memory as well. In a famous study (Watson & Rayner, 1920), a loud gong (the US) that produced crying and hand withdrawal (the UR) was sounded each time 11-month-old Albert touched a white rat (the CS). One week later, Albert withdrew his hand (the CR) from the rat and, after several CS-US pairings, responded 5 days later to the rat and other stimuli that were somewhat similar (a rabbit, dog, fur coat, Santa Claus mask, cotton swatch, and Watson's beard). Ten days later, his weak CR was "freshened" by pairing the gong with the rat, rabbit, and dog. One month later – 2 months after his initial conditioning experience – Albert still exhibited CRs to the rat, dog, mask, and fur coat. This study demonstrated that CRs are established rapidly, maintained by occasional CS-US repetitions, and generalized to physically similar stimuli. In another single-subject study, Jones (1930) repeatedly presented a tapping sound (CS) followed by an electrocutaneous stimulus (US) to a 7-month-old over 5 days. Without more CS-US pairings, the CR was still exhibited 7 weeks later.

Many classical conditioning studies were successfully conducted with newborns between 1959 and 1970 (for review, see Siqueland, 1970), but skeptics continued to challenge the evidence (Sameroff, 1971). Blass, Ganchrow, and Steiner (1984) laid all challenges to rest by demonstrating classical conditioning in newborns as young as 2 hours. Between scheduled feedings, the experimental group received forehead stroking (CS) immediately followed by sucrose (US) delivered through a pipette; the explicitly paired control group received the same number of CS-US trials but received sucrose after longer and variable delays; and the sensitization control group received sucrose only. In acquisition, only the experimental group exhibited CRs (head-orienting, pucker-sucks) during the CS. In extinction, the experimental group exhibited a classic decrease in CRs during the CS, with the sharpest decline occurring between trials 1 and 2.

In heart-rate conditioning studies, immature and compromised infants often cannot respond during the CS-US interval, so whether the two stimuli have been associated is determined by interspersing US-omission trials among CS-US trials. Researchers infer that an association was formed if a heart-rate change occurs during the US-omission trial. Omitting an aversive US (e.g., a loud noise) produces *heart-rate acceleration*, and omitting an appetitive US (e.g., sucrose) produces *heart-rate deceleration*. These changes are interpreted as defensive (protective) and orienting (where-is-it?) responses, respectively. There is an important exception to this rule: Premature and decerebrate infants exhibit heart-rate acceleration on US-omission trials.

The optimal CS-US interval (ISI, interstimulus interval) is substantially longer for infants than for adults of all species. At 10 to 30 days of age, a 1500-ms ISI yields classical eyeblink conditioning, but a 500-ms ISI does not (Little, Lipsitt, & Rovee-Collier,



**Figure 8.2** A 4-month-old infant producing illumination of a visual target by means of high-amplitude sucks. *Source:* Photograph courtesy of E. R. Siqueland.

1984). Thereafter, the optimal ISI decreases to 650 ms for 5-month-olds (Herbert, Eckerman, & Stanton, 2003) and 500 ms for young adults. Numerous failures to obtain classical conditioning with infants younger than 6 months undoubtedly resulted from selecting an ISI that was optimal for adults.

### *Operant conditioning*

Classically conditioned responses are reflexive and elicited; operantly conditioned responses are voluntary and emitted. Infants must spontaneously perform the response at a low or moderate rate in order for the response to be followed by a reinforcer (reward) that increases its rate. There is no biological relation between the reinforcer and the response it influences. Sucking increases as readily whether it produces the mother's voice, a computer-generated speech sound, a colored slide (see Figure 8.2), or milk. Early operant conditioning studies had very brief baselines and did not demonstrate that increased responding was attributable to the response-reinforcement contingency (operant control) instead of behavioral arousal. Studies of "social reinforcers" (reinforcers administered by humans, such as smiling, eye contact, touching, vocalizing), for example, were criticized because the adult's auditory/visual reinforcement might have elicited the infant's reciprocal social or affective behavior, thereby mimicking conditioning (Bloom, 1984).

Brackbill (1958) asked whether 4-month-olds' smiling behavior was sensitive to the reinforcement schedule. Infants' baseline level of smiling was determined while the

experimenter stood after every smile, up, jostled, patted (PRF) group was reinforcer. Although the response rate of all species, PRI Although Brackbill group received the same results, a (1970).

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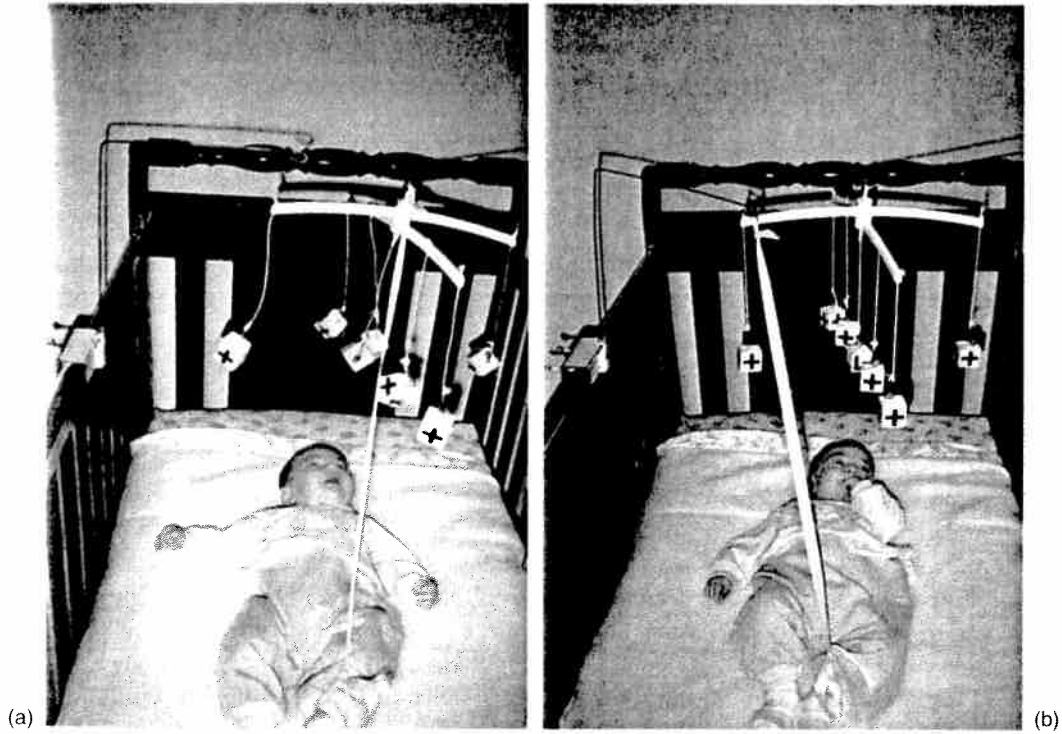
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experimenter stood motionless and expressionless above each infant. During acquisition, after every smile, the continuous-reinforcement (CRF) group was smiled at, picked up, jostled, patted, and talked to for 30 s by the experimenter; the partial-reinforcement (PRF) group was initially treated the same but eventually had to emit three smiles per reinforcer. Although their responding did not differ during baseline or the initial phase, the response rate after PRF increased with the reinforcement schedule. As with adults of all species, PRF led to a higher response rate and more total responses in extinction. Although Brackbill's study lacked noncontingent-reinforcement controls, and the CRF group received more total reinforcing stimulation, correction of these problems yielded the same results, and the same finding was obtained with other tasks and ages (Siqueland, 1970).

Other operant studies used constant-magnitude, simple, and discrete reinforcers that rapidly became ineffective. In most, therefore, training lasted only a few minutes. Because critics doubted that young infants could be operantly conditioned (Piaget, 1952), such short sessions obviously worked against obtaining positive results. These problems were overcome in conjugate reinforcement procedures, in which the intensity of reinforcing stimulation varies from 0 to 100%, depending on the intensity and rate of responding. In the mobile conjugate reinforcement task (Rovee & Rovee, 1969), 10-week-olds' kicks produced movement (the reinforcement) in a crib mobile via a ribbon strung from one ankle to an overhead suspension hook (Figure 8.3a). Small foot movements slightly jiggled the mobile, whereas vigorous and/or rapid kicks made it bounce and swing back and forth. During acquisition, infants' kicking doubled or tripled within a few minutes and remained under operant control throughout sessions lasting 15 to 46 min. Ironically, Piaget had recorded in his diary that Laurent, his 3-month-old, increased hand movements after his hand hit and moved an object hanging over the bassinet. Piaget had called this an "elicited joy reaction." He thought that infants could not initiate "interesting spectacles" until they were several months older.

The mobile procedure has been standardized to assess infants' capacity for long-term memory. Infants are trained at home for two 15-min sessions 24 hr apart. In session 1, the ankle ribbon and mobile are connected to different hooks, and operant level (*baseline*) is recorded for 3 min. Next, the ribbon is switched to the same hook as the mobile, and kicks conjugately moved the mobile for 9 min (*acquisition*). Finally, the baseline condition is reinstated for 3 min. Session 2 is identical, but in the final 3-min nonreinforcement period (*immediate retention test*), the infant's final level of learning and retention after zero delay is measured. After a delay of 1 or more days, infants receive a 3-min *long-term retention test* with the original mobile or one that differs in some way (Figure 8.3b). Infants kick robustly if they recognize the mobile and respond at baseline if they do not. Because the retention test occurs during a nonreinforcement period, responding reflects only prior learning and not savings. At 6 months, sessions are one-third shorter, infants are seated inside a playpen, and the mobile is suspended from a modified floor microphone stand.

Three-month-olds' memories are highly specific. For example, they do not recognize a pink block mobile displaying black +s that are 25% smaller or larger than the +s that were on the training mobile, which they had not seen for 1 day (Figure 8.3). With longer delays, as infants gradually forget the specific details of their training mobile, they



**Figure 8.3** The experimental arrangement in the mobile task, shown with a 3-month-old. (a) *Acquisition*. The ribbon and mobile are attached to the same hook so kicks move the mobile. (b) *Baseline and Long-term recognition test*. The ribbon and mobile are attached to different hooks so kicks cannot move the mobile.

increasingly respond to (“recognize”) a novel test mobile until they finally treat them equivalently (Rovee-Collier & Sullivan, 1980).

Because infants outgrow the mobile task after 6 months, an upward extension of the mobile task is used with older infants. Instead of kicking to move a mobile, infants press a lever to move a miniature train (Figure 8.4); during nonreinforcement periods, the lever is deactivated. Combining these two tasks reveals that the duration of retention increases linearly over the first 18 postnatal months (Figure 8.5; Hartshorn et al., 1998).

*Latent learning*

Latent learning epitomizes the learning–performance distinction: It is behaviorally “silent.” Unlike habituation and conditioning, its acquisition is not accompanied by a change in responding; in fact, there is no observable evidence of learning when it takes place. Moreover, latent learning is not available to scrutiny by the outside world until

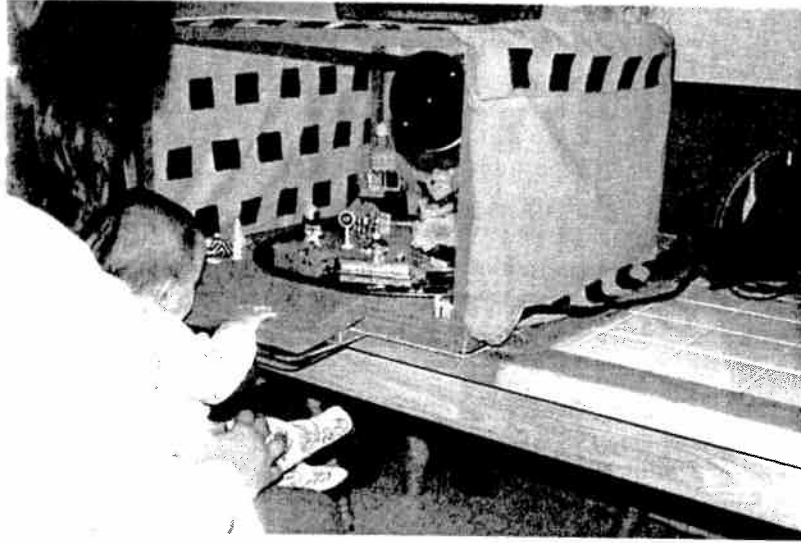


**Figure 8.4** The experimental arrangement in the upward extension of the mobile task, shown with a 3-month-old. The experimenter is shown in the background. The infant is shown in the foreground. The ribbon and mobile are attached to the same hook so kicks move the mobile.

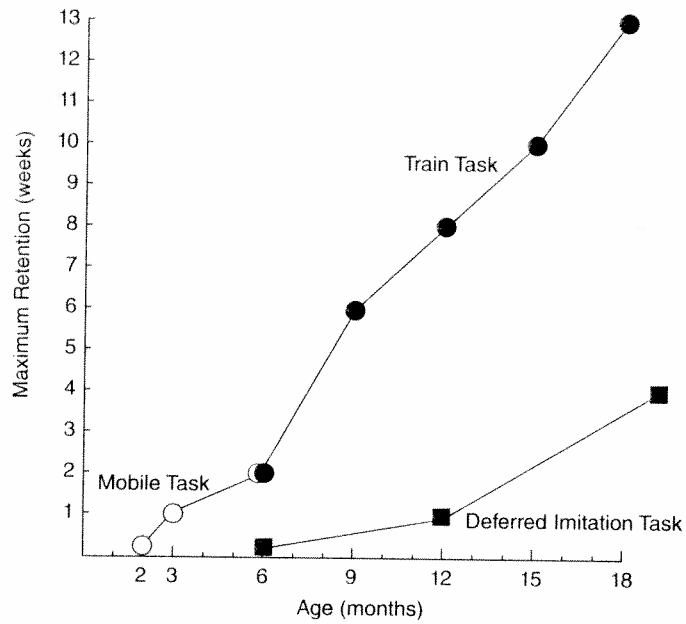
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Maximum Retention (weeks)

**Figure 8.5** Standard deviation of infants trained at different ages in the upward extension of the mobile task using a miniature train (puppet) task using different training durations. The graph shows a linear increase in maximum retention over time.





**Figure 8.4** The experimental arrangement in the train task, shown with a 6-month-old. During baseline and all retention tests, the lever is deactivated so presses cannot move the train. Note the complex array of toys in the train box.



**Figure 8.5** Standardized reference functions for the maximum duration of retention (in weeks) of infants trained and tested in the operant mobile and train tasks and the deferred imitation (puppet) task using standardized procedures with age-calibrated parameters. Slope differences reflect different training parameters.

such time that there is an occasion to express it (if one ever arises) and a means by which to do so. All learning, latent or not, is relatively permanent and is incorporated in an individual's knowledge base.

*Deferred imitation.* In deferred imitation tasks, infants observe a sequence of target actions and then receive an opportunity to reproduce them after a delay. In elicited imitation, a variant of deferred imitation, infants imitate the actions immediately (and also sometimes during the retention interval) as well as after a delay, and they receive verbal prompts during modeling and testing. These procedural differences significantly affect infants' deferred imitation. Immediate imitation, for example, facilitates generalization, whereas both interpolated imitation and verbal cues independently promote deferred imitation after long delays (for review, see Hayne, 2004; Jones & Herbert, 2006a, b).

Piaget (1962) believed that before 18 months of age, infants could not form mental representations and hence could not exhibit deferred imitation. Meltzoff's (1988a) report that 9-month-olds imitated a novel action after a 24-hr delay dramatically altered this conception and motivated the current surge of studies of deferred imitation with young infants (see chapter 11 this volume). Barr, Dowden, and Hayne (1996) developed a single task to document deferred imitation from 6 to 24 months of age. In their task, a sequence of three target actions is modeled on a hand-puppet wearing a same-colored mitten on one hand. Infants who observe a demonstration lasting 60 s at 6 months or 30 s at 9 to 24 months exhibit deferred imitation 24 hr later. An infant's imitation score is the number of target actions (remove the mitten, shake it, attempt to replace the mitten) performed within 90 to 120 s of touching the puppet (Figure 8.6). Although older infants have higher imitation scores, some 6-month-olds imitate all three actions. Age-matched con-



**Figure 8.6** The experimental arrangement used with 6- to 24-month-old infants in the deferred imitation (puppet) task. A 6-month-old is removing the puppet's mitten – an action that was modeled 24 hours earlier. *Source:* Barr, Dowden, & Hayne (1996).

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Retention of retention function in the training phase is significantly higher than when it has been retrieved. In a study, infants remember memory on memory. Campanella, 2004, the original demonstration. Further, all of the (also one retrieval exhibited deferred delay was doubt when the test d with a new experimental modeling. A control group but did. Because 6-month they imitate immediately & Rovee-Collier long infants remember.

*Sensory preconditioning* stimuli or events them generalizes formed between reinforcement, however, the subject expressing it. Trial (S1 + S2); (2) a (3) subjects are introduced to S2 (S2 stimulus to the formed when there no response transition phase 1.

Barr, Marrott study associative group was preexperimental days, and the control of day. In phases 2 (1 day later), phase 3 (1 day after

control groups who have not seen the modeling event rarely produce the target actions spontaneously.

Retention of deferred imitation also increases linearly with age (Figure 8.5), but the retention function is shallower than the operant retention function because of differences in the training parameters of the two tasks. At all ages, however, the duration of retention is significantly affected by the number of times the memory of the demonstration has been retrieved and the time between successive retrievals. At 6 months, for example, infants remembered the demonstration for at least 10 weeks when they retrieved its memory on multiple occasions that were widely spaced (Barr, Rovee-Collier, & Campanella, 2005). Six-month-olds who watched a second 30 s demonstration 24 hr after the original demonstration (one retrieval) exhibited deferred imitation 7 days later. Further, all of the 6-month-olds who actually imitated the modeled actions 24 hr later (also one retrieval) exhibited deferred imitation 10 days later, and all of these infants also exhibited deferred imitation both 30 days after modeling (two retrievals), when the test delay was doubled from 10 to 20 days, and 70 days after modeling (three retrievals), when the test delay was doubled again, from 20 to 40 days. This result was replicated with a new experimental group whose final deferred imitation test was 60 days after modeling. A control group that received the same regimen of tests as the experimental group but did not see the target actions modeled performed at baseline throughout. Because 6-month-olds otherwise remember the same target actions for only 1 day whether they imitate immediately after the demonstration or not (Barr et al., 1996; Barr, Vieira, & Rovee-Collier, 2001), this study documented the dramatic effect of retrieval on how long infants remember.

*Sensory preconditioning (SPC).* During SPC, an association is formed between two stimuli or events that occur together, such that what is eventually learned about one of them generalizes to the other. "Preconditioning" refers to the fact that the association is formed between two contiguous external ("sensory") stimuli or events in the absence of reinforcement, before formal conditioning occurs. Because associations are latent, however, the subsequent conditioning (training) procedure provides an overt means of expressing it. The SPC paradigm has three phases: (1) two neutral stimuli are paired ( $S1 + S2$ ); (2) a specific response ( $R1$ ) is trained to one of the stimuli ( $S1 \Rightarrow R1$ ); and (3) subjects are tested with the other stimulus ( $S2$ ). If the trained response ( $R1$ ) is produced to  $S2$  ( $S2 \Rightarrow R1$ ), then it can be concluded that transfer of responding from one stimulus to the other was mediated by an association between  $S1$  and  $S2$  that had been formed when they were paired in phase 1. This conclusion is dependent on a finding of no response transfer between two stimuli that were preexposed separately (unpaired) in phase 1.

Barr, Marrott, and Rovee-Collier (2003) used SPC and a deferred imitation task to study associative learning and memory with 6-month-olds. In phase 1, the experimental group was preexposed to two paired hand puppets ( $A + B$ ) for 1 hr/day on 7 consecutive days, and the control group saw the puppets equally long, but unpaired, at different times of day. In phases 2 and 3, paired and unpaired groups were treated identically. In phase 2 (1 day later), an adult modeled the target actions on one puppet ( $A \Rightarrow R_A$ ); in phase 3 (1 day after modeling), infants were tested with the other puppet (B). They found

that the paired group imitated the target actions on the other puppet ( $B \Rightarrow R_A$ ), but the unpaired group did not. The transfer of learning from A to B indicated that an  $A \Leftrightarrow B$  association had been formed in phase 1. Barr et al. (2003) also found that infants associated the paired puppets after a 1-hr preexposure on each of 2 consecutive days.

Giles (2008) found that infants could also associate puppets A and B if exposed to them for 1 hr on a single day. To determine how long infants could remember the association, she inserted a delay between the preexposure phase (phase 1) and the demonstration of the target actions on puppet A (phase 2), testing for deferred imitation (phase 3) on puppet B after increasing delays until infants failed to imitate on puppet B. The longest interval after which infants could successfully transfer responding from puppet A to B was 7 days after a 1-hr preexposure on 2 consecutive days or 3 days after a single, 1-hr preexposure session.

The basis of the retention benefit following two spaced sessions, however, was unclear. Two sessions entailed both twice as much exposure time and one memory retrieval at the outset of session 2. To deconfound the effects of exposure time and retrieval, Giles (2008) administered 1 hr of preexposure time in two 30-min sessions that were 5 hr apart. In this way, the total exposure duration was the same for one session as for two, but a retrieval was required at the outset of session 2. They found that the single retrieval produced a five-fold increase in infants' retention; 6-month-olds now remembered the association (i.e., imitated the actions on the second puppet) for 14 days instead of 3 days. Notably, 14 days is the same duration for which 6-month-olds remember the operant train and mobile tasks after two training sessions. This finding reveals that when and how often the memory was retrieved determines how long infants remember – not the type of task or the duration of preexposure beyond some minimum amount.

Using a variant of the puppet SPC procedure, Townsend (2007) preexposed 6-month-olds to a different pair of puppets (instead of repeating exposure to the same pair) on successive days. One member of each new pair overlapped with the pair that was preexposed the day before, while the other member was novel. His results suggested that infants had formed an associative chain in which the successive puppet–puppet associations were linked by the common member. When one member of the chain was activated, the activation spread along the chain to more remote members, allowing responding to transfer from the training stimulus to other stimuli that had not been directly paired with it.

In phase 1, Townsend preexposed 6-month-olds to a different pair of puppets each day (day 1: A + B; day 2: B + C). In phase 2, he modeled the target actions on either puppet C or puppet A. In phase 3, he administered a deferred imitation test with either puppet A or puppet C, respectively. When puppet A was the retrieval cue during testing, infants exploited a forward associative chain and imitated the actions that had been modeled on puppet C ( $A \Rightarrow B \Rightarrow C$ ). When puppet C was the retrieval cue, infants exploited a backward associative chain and imitated the actions that had been modeled on puppet A ( $A \Leftarrow B \Leftarrow C$ ). When another puppet pair (C + D) was added to the chain, and the actions were modeled on puppet D, infants imitated them on puppet A as well, but they did not imitate on a novel puppet (puppet E).

Finally, infants who saw either puppets A and B unpaired on the first day of phase 1 or on puppet B alone after the A + B association was formed (an extinction procedure), failed

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to imitate the modeled actions on puppet A, confirming that the integrity of the  $A \Rightarrow B$  link of the chain was critical. These data reveal that by 6 months of age, infants form relational representations of new associations that enter into a mnemonic network, where they are linked to existing memory representations and participate in the establishment of new associations. As the network expands and becomes increasingly interconnected and complex, memory performance becomes increasingly flexible.

*Potentiation.* When a response to one stimulus is learned better in the presence of another stimulus, the enhancement is called *potentiation*. A cognitive account of associative learning holds that one member of an association (S1) evokes a memory representation of the second member (S2), which then enables the participant to produce the response that was originally made to S1. This cognitive representational account has important implications for memory. Any operation that will strengthen the memory of S1 (e.g., retrieving it) will also potentiate, or strengthen, all learning that occurs in its presence. The potentiation effect will be expressed in the duration of retention: members of stronger associations are remembered longer.

In studies with laboratory animals, potentiation has been studied almost exclusively in conditioned taste or odor aversion paradigms. The development of an associative learning paradigm in which operant conditioning and deferred imitation tasks were linked, however, permitted the first opportunity to study potentiation with human infants. A potentiation effect was seen in the duration of deferred imitation, for example, when the demonstration of the target actions on the puppet was associated with the previously learned operant train task. At 6 months of age, infants can exhibit deferred imitation of actions modeled for 60 s on a hand puppet for 24 hr. In contrast, they can remember the operant train task for 2 weeks. When the target actions were modeled on the puppet in the presence of the train immediately after operant training ended, however, 6-month-olds exhibited deferred imitation on the puppet for 2 weeks – the same duration that they remembered the train task (Barr et al., 2001). How did this happen? The memory of the train and the demonstration were associated when they simultaneously occupied primary (active) memory. Theoretically, the strength of the memory of the train task transferred to the demonstration via the association, potentiating the encoding of the demonstration to the same degree as the train task and thus enabling infants to remember the two tasks for an equal length of time.

We have found that retrieving the memory of an event increasingly later along its forgetting function actually strengthens that memory increasingly more and protracts its future retention increasingly longer (Galluccio & Rovee-Collier, 2006; Hsu & Rovee-Collier, 2009). When the target actions were demonstrated on the puppet in the presence of the train 7 days after operant training, for example, the mere sight of the train cued retrieval of the train memory, which was strengthened and associated with the demonstration because the two representations were simultaneously active in primary (short-term) memory. The stronger memory of the train task potentiated the strength of the associated demonstration and enabled infants to exhibit deferred imitation after 4 weeks instead of only 24 hr. Finally, when the demonstration occurred in the presence of the train 14 days after operant training, the train memory was strengthened even more, and the potentiation effect was even stronger. Now, 6-month-olds remembered the train task for 8 weeks

after its memory was retrieved, and they exhibited deferred imitation after 6 weeks instead of only 24 hr (Rovee-Collier & Barr, 2007). These data reveal that the length of time young infants remember what they see depends on the meaningfulness of the context in which they see it. These findings have major implications for the important role of varied experience and enriched environments in early learning and memory.

*Video deficit effect.* Although additional stimulation benefits learning and memory, the source of that stimulation affects the benefit. Researchers using a number of different experimental paradigms have demonstrated that infants, toddlers, and preschool children learn less from television and still 2D images than from face-to-face interactions (for review, see Anderson & Pempek, 2005). The *video deficit effect* refers to the fact that infants' ability to transfer learning from television to real-life situations is poor relative to their ability to transfer learning from a live demonstration. The video deficit effect is nonapparent at 6 months of age, peaks around 15 months of age, and persists until at least 36 months of age (Barr & Hayne, 1999; Barr, Muentener, & Garcia, 2007; Hayne, Herbert, & Simcock, 2003; Meltzoff, 1988b). Recently, research using event-related potentials has found that 18-month-olds recognize familiar 3D objects significantly earlier in the attentional process than familiar objects depicted in 2D digital photos (Carver, Meltzoff, & Dawson, 2006). The slower processing of 2D information that then must be transferred to 3D test conditions might contribute to the video deficit effect. Because the video deficit effect can be partially offset by additional repetitions of the target actions (Barr, Muentener, & Garcia, 2007; Barr, Muentener, Garcia, Fujimoto, & Chavez, 2007), it is possible that more repetitions strengthen the representation of the event in much the same way that additional repetitions enabled 6-month-olds to exhibit deferred imitation of a live demonstration after 24 hr (Barr et al., 1996). Given the prevalence of 2D materials – including books, television, touch screens, and computers – in homes and daycare centers, understanding the basis of the video deficit effect and its amelioration has obvious practical consequences for early education.

### Reminders

Most psychologists assume that early experiences have a critical influence on later behavior. Yet, arguments that the infant brain is too immature to encode and maintain early memories over the long term has cast doubt on this assumption. Recent evidence that *reinstatement* and *reactivation* reminders can maintain early memories over significant periods of development, however, has removed this doubt. Reminders have now been successfully used with infants in all paradigms (for review, see Rovee-Collier & Cuevas, 2008).

*Reinstatement.* Reinstatement is a small amount of periodic, partial practice throughout the retention interval (Campbell & Jaynes, 1966). The experimental group, both trained and given periodic reminders, exhibits significant retention at the end of the interval. A *reinstatement control group* receives the same reminders but is not trained and a *forgetting control group* is trained but not reminded and exhibits no retention during

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the long-term test. The control groups are necessary to demonstrate that the reminders themselves did not produce new learning and that forgetting would have been complete without reminders.

Even very young infants can remember after long delays if periodically reminded. For example, 2-month-olds learned the mobile task, were reminded every 3 weeks (six reminders total), and received a final retention test at 7.25 months of age, when the study ended. Although 2-month-olds typically forget the task after 1 to 2 days, all remembered it for 4.5 months after periodic reminding, and four of six infants remembered it for more than 5.25 months. Control groups exhibited no retention after any delay (Rovee-Collier, Hartshorn, & DiRubbo, 1999). As most infants still remembered the mobile task when the study was terminated, Hartshorn (2003) repeated the study using the train task beginning at 6 months of age. After only five reminders, infants trained at 6 months still exhibited significant retention when they were 2 years old – 1.5 years after they were originally trained. Furthermore, infants had received only one reminder in the preceding year – at 18 months. Control groups exhibited no retention after any delay.

*Reactivation.* Reactivation is a priming procedure in which an isolated component of the original event is presented once at the end of the retention interval – after forgetting has occurred but before the long-term test. Concluding that the original memory was reactivated requires that subjects who were both trained and primed exhibit renewed retention and that control groups that were only primed or only trained exhibit none.

In the first reactivation study with human infants, 3-month-olds learned the mobile task, forgot it, and were primed 13 or 27 days after training. During priming, the experimenter moved the mobile. After both delays, conditioned responding was restored to its original level, and infants forgot the reactivated memory at the same rate as the original one. Although reactivating the memory within 1 week of forgetting doubles the duration of retention throughout the infancy period, reactivating it after the longest delay possible quadruples it through 12 months of age (Hildreth & Hill, 2003). Fifteen- and 18-month-olds remember for so long, however, that they outgrow the task before the upper limit of reactivation is reached. When the forgotten training memory is primed after infants reach 2 years of age, most children simply quit lever pressing when the train does not move during the test and tell the experimenter that the train is “broken” or “needs batteries” (Hsu & Rovee-Collier, 2006). Although their verbal behavior confirms that the forgotten memory had been reactivated, their rate of lever pressing (the “official” retention measure) does not. Obviously, the operant measure underestimates the upper limit of reactivation when infants are tested at older ages. Although a single reactivation can dramatically increase the duration of retention, repeated reactivations can have an even greater effect (Hayne, 1990; Hitchcock & Rovee-Collier, 1996).

The memory-preserving effect of reactivation is not unique to studies of infant conditioning but has also been reported in studies of deferred imitation (e.g., Barr et al, 2003; Hayne, Barr, & Herbert, 2003; Campanella & Rovee-Collier, 2005). Campanella and Rovee-Collier, for example, used SPC and repeated reactivations to document deferred imitation with 3-month-olds, who are motorically incapable of performing the target actions. Infants were exposed to puppets A + B paired for 1 hr/day for 7 days, and on day 8 the experimenter modeled the three target actions on puppet B for 60 s. On day 9

and five more times over the next 3 months, the infants were shown puppet B for 30s on the experimenter's stationary hand (a reactivation treatment). At 6 months of age, when infants had become sufficiently coordinated to perform the target actions, they were tested with puppet A. Despite not seeing the target actions or puppet A for 3 months, infants exhibited significant deferred imitation. In contrast, both the unpaired A-B control group and the reactivation control group responded at baseline during the deferred imitation test. This result confirms that repeated reactivations maintain early memories over long periods of behavioral development and that doing so is not task-specific.

## Maturational Models of Infant Memory

Most developmental and cognitive psychologists assume that young infants suffer a maturational deficiency in the ability to encode, store, and retrieve memories over the long term. It is commonly thought that infant memory capacity undergoes a transition beginning late in the first year of life that is made possible by the progressive maturation of the hippocampal region and adjacent cortex (for review, see Bauer, 2008; Bauer, DeBoer, & Lukowski, 2007). Currently, maturational models of infant memory face serious challenges. In this part we review these challenges and their implications.

### *Multiple memory systems*

Maturational models of memory development are rooted in the assumption that the memories of adults are supported by two neuroanatomical memory systems (implicit and explicit memory), and the memories of young infants are supported by only one (implicit memory). Implicit memory is characterized as a primitive system that processes perceptual information automatically and mediates memories of skills and procedures, whereas explicit memory is characterized as a higher-level system that supports the conscious recollection of specific prior episodes. Since adult amnesics performed normally on priming (implicit memory) tests but failed recall and recognition (explicit memory) tests, their brain damage was thought to impair explicit memory but not implicit memory. Schacter and Moscovitch (1984) likened the memory capacity of young infants to that of amnesics and concluded that the higher-level (explicit) memory system matured late in the first year of life.

Graf, Squire, and Mandler (1984) found that the same memory dissociations that amnesics exhibited on recall/recognition and priming tests were also exhibited by healthy adults who were instructed to "say the first word that comes to mind" (a priming test) or to "circle the words that were on the list you studied a few minutes ago" (a recognition test). Since then, researchers have identified more than a dozen independent variables (e.g., the retention interval, trial spacing, interference, amount of training) that produce functional memory dissociations on recognition and priming tests. In all instances, different levels of these variables had a major effect on recognition but none on priming.

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The first challenge to a maturational account of infant memory development came from evidence that 2- to 6-month-old infants, who presumably possess only one memory system, exhibit the same functional memory dissociations in response to all of the same independent variables on priming (implicit memory) and recognition (explicit memory) tests as adults, who presumably possess two memory systems (Rovee-Collier, 1997; Rovee-Collier, Hayne, & Colombo, 2001). For example, infants' magnitude of retention on a recognition test declines as a function of the length of the retention interval, but their retention on a priming test is high and stable over retention intervals ranging from 1 day to 1 month. These findings suggested that if memory dissociations are diagnostic of two memory systems, then two memory systems must be present in early infancy.

Other challenges to maturational models of infant memory development have come from studies of deferred imitation, which is widely regarded as an explicit memory task (McDonough, Mandler, McKee, & Squire, 1995). The report that infants exhibited reliable 24-hr deferred imitation at 9 months but not before (Carver & Bauer, 2001) was taken as evidence that the explicit memory system becomes functionally mature late in the first year of life (Bauer, 2008; Carver & Bauer, 2001). However, more recent reports that 6-month-olds with no practice exhibited significant deferred imitation 7 days after the demonstration (Barr et al., 2005) and that 3-month-olds, also with no practice, exhibited significant deferred imitation 3 months after the demonstration (Campanella & Rovee-Collier, 2005) significantly advances the age at which infants can first exhibit reliable deferred imitation. Second, evidence that 3- and 6-month-olds form artificial categories (Greco, Hayne, & Rovee-Collier, 1990; Hayne, Rovee-Collier, & Perris, 1987) and acquire relationships between arbitrary pairs of objects (Barr et al., 2001, 2003; Cuevas, Rovee-Collier, & Learmonth, 2006; Giles, 2008; Rovee-Collier & Barr, 2007; Townsend, 2007) also pose a significant challenge to neuromaturational models of infant memory development. If there are two independent memory systems, then they do not mature hierarchically but instead develop simultaneously from early infancy.

*Maturation or experience.* Prior neuroanatomical studies of adult memory fostered speculation that infants undergo a developmental transition in memory capacity that corresponds to the progressive maturation of the hippocampal region and adjacent cortex, which are critically implicated in adult declarative memory (e.g., Bauer, 2008; Nelson, 1995). Currently, however, a growing number of age-related changes in infant memory that were previously attributed to maturation of the neural structures that support explicit memory in adults have been found to be experientially determined in young infants. Although on the precipice, developmental researchers currently lack the technology necessary to study the maturation of different brain regions in infants directly, and therefore they must infer it from infants' behavior. Even so, positive behavioral evidence of a given memory capacity in very young infants is totally silent about the neural mechanisms that underlie it.

A major impact of experience on infant memory capacity pertains to the formation of long-term memories. Amnesics, for example, can form short-term but not long-term memories. Additionally, the duration of retention in operantly trained infants increases linearly between 2 and 18 months of age (Figure 8.5), as predicted by a neuromaturational

account. At all ages, however, infants can remember twice as long if they are given two sessions instead of only one, and their retention is prolonged exponentially – by weeks or months – if the interval between the two sessions is increased (Hsu & Rovee-Collier, 2009). As a result, even the youngest infants can remember for as long as infants 2 to 3 times older. Thus, the maturational status of the infant brain does not limit their ability to form long-term memories.

Parallel effects have been found in studies of deferred imitation (Figure 8.5). As discussed above (see Potentiation), if 6-month-olds associated the target actions with the train task, then they subsequently remembered both actions for an equal length of time. For example, they exhibited deferred imitation and retention of the train task for 2 weeks when the association was formed immediately after operant training, 4 weeks when the association was formed 1 week after operant training, and 6 weeks when the association was formed 2 weeks after operant training (Rovee-Collier & Barr, 2007). Otherwise, 6-month-olds can exhibit deferred imitation for only 24 hr after the demonstration (Barr et al., 1996, 2001).

Prior priming experience also increases the duration of long-term memories when infants are primed again. At 3 months, for example, a second prime increases retention from 1 week to 2 weeks (Hayne, 1990) – the same duration of retention exhibited by once-primed 6-month-olds. Similarly, the speed of responding to a memory prime increases logarithmically over the first year of life (Hildreth & Rovee-Collier, 1999), but after prior priming, 3-month-olds respond to the second prime as rapidly as 6-month-olds had responded to the first (Hayne, Gross, Hildreth, & Rovee-Collier, 2000). Also, the minimum duration for which an effective prime can be exposed 1 week after forgetting and still be effective decreases from 2 min at 3 months to 1.8 s at 18 months (Hsu, Rovee-Collier, Hill, Grodkiewicz & Joh, 2005). Priming the forgotten memory before, however, cuts the minimum duration of 3-month-olds' second prime in half, regardless of when the first prime was presented or for how long it was exposed (Bearing & Rovee-Collier, 2006).

Finally, Hitchcock and Rovee-Collier (1996) primed the forgotten memory of 3-month-olds twice, using a novel cue or novel context during the second prime. The second prime reactivated the memory when the context was novel – just as the first prime reactivates the memory of 12-month-olds when the context is novel (DeFrancisco, 2008). During priming a third time, either a novel cue or a novel context reactivated the memory. The fact that prior priming eliminates the hyperspecificity that is a hallmark of implicit memory is a stark example of the pervasive contribution of experience to memory performance.

Clearly, models of infant memory development that cast neuroanatomical maturation as the *determinant* of infant memory capacity are fundamentally flawed. Currently, mounting evidence indicates that the basic memory capacities of adults and young infants are the same and that a higher-level memory system does not simply come online at a given age as previously conceived. If the late-maturing development of neuroanatomical mechanisms does not initially *permit* particular memory capacities, then what does it do? We propose that it *facilitates the efficiency of memory processing* by providing multiple and more direct routes of access to critical memory structures.

### Infantile amnesia

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*Infantile amnesia.* Most adults cannot remember what occurred before the age of 2 or 3. This phenomenon, *infantile amnesia*, is popularly attributed to the functional immaturity of the neurological mechanisms responsible for maintaining memories over the long term (Nelson, 1995).

Recently, however, even very young infants remembered a prior event after very long delays when they were periodically exposed to multiple reminders in the interim (Hartshorn, 2003; Rovee-Collier et al., 1999). Taken together, these studies provide unequivocal support for the hypothesis that periodic reminding can maintain early memories over a significant period of development. Moreover, because periodic nonverbal reminders maintained the memories of two comparable events (the mobile task and the train task) over an overlapping period between 2 months and 2 years of age, it is highly likely that appropriate periodic nonverbal reminders could also maintain the memory of a single event from 2 months through to 2 years of age, if not longer. This period encompasses the entire time span thought to be characterized by infantile amnesia.

How might these experiential factors contribute to infantile amnesia? First, the memory attributes that represent contextual information (i.e., when and where an event happened) are fragile and lost with repeated reactivation (Hitchcock & Rovee-Collier, 1996); as a result, older children and adults may actually remember early-life events but be unable to pinpoint their origins. Second, because memories encoded early in life have probably been modified or updated many times, their original source would be impossible to identify.

### Conclusions

In most current models, memory is viewed as being composed of two independent and functionally distinct systems that mature at different rates. These models are based on data that were originally obtained from amnesic adults and are at odds with data obtained directly from infants themselves. The infant data, gathered with a variety of tasks, reveal that young infants and adults possess the same basic memory capacities. Most of the age-related changes in infant memory that have been attributed to maturation can be reproduced in very young infants by merely giving them additional experience with the manipulation. Very young infants also encode the relations between events (a late-maturing capacity), which can remain latent for a relatively long periods. These new associations can be linked to what was learned before in a rapidly expanding memory network, also called the *knowledge base* – because only the tiniest fraction of this knowledge will ever be expressed, it is impossible to guess its extent.

Evidence of the sophistication of young infants' learning and memory capacities marks a sharp departure from prior views and raises the question of their adaptive significance. In fact, from their earliest moments, all organisms must learn the structure of the niche into which they are born. Meeting this evolutionary imperative requires building stable representations of the physical and functional relations in their environment by either passively inspecting or actively interacting with it. Recurring associations are strengthened, becoming increasingly accessible, while one-time relations are eventually culled or

forgotten and cannot be reactivated (Hsu & Rovee-Collier, 2009; Richardson, Wang, & Campbell, 1993).

### Future Directions

Current insights into infant learning and memory have come from asking new questions and using new paradigms and technologies to answer them. In the future, two lines of research hold great promise. First, it is critical to understand the mechanisms that increase the accessibility of target information as well as the mechanisms that reduce the accessibility of potentially useless or interfering information. Additionally, it is important to examine the organization of the developing associative network and how changes in the strengths of existing links affect it. Second, the application of noninvasive technologies (e.g., eye tracking, electroencephalography, event-related potentials, magnetoencephalography, near infrared spectroscopy) are poised to shed new light on the relationship between infant behavior and neurobiological functioning during tests administered both after different delays and after priming. It would also be important to know what neurobiological changes are produced by the provision of additional experience that produces behavioral changes that mimic maturational changes (cf. Casey & de Haan, 2002; Jones & Herbert, 2006a, b; Spelke, 2002). Until advances in neuroimaging techniques permit the direct study of infants' brain structures, however, we have to make do with what we have – behavioral evidence and inferences from indirect measures. Meanwhile, there is plenty of exciting work to keep us busy!

### Further Reading

The following list expands upon the topics reviewed in the present chapter. The list includes seminal papers on habituation, conditioning, deferred imitation, latent learning, and reminder procedures.

- Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior and Development, 19*, 159–170. This is the first report of deferred imitation in infants as young as 6 months and also of developmental changes in deferred imitation across a wide age range using the same task.
- DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*, 1174–1176. This paper reports that infants within a day or so of birth will learn an operant response that gives them selective access to the voice that they had heard in the womb.
- Fantz, R. L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science, 46*, 668–670. This classic study showed that infant attention habituates during repeated exposures to the same pattern but is maintained at a high level during repeated exposures to changing patterns.
- Melzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science, 198*, 75–78. This important report of imitation by infants only hours old initiated a storm of controversy over the imitative capacity of young infants.

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- Rovee-Collier, C. (1997). Dissociations in infant memory: Rethinking the development of implicit and explicit memory. *Psychological Review*, 104, 467–498. This article reviews numerous parallels between memory data from infant and adults. It concludes that infants and adults possess the same memory systems.

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