The Development of Infant Memory

Carolyn Rovee-Collier[1]

Department of Psychology, Rutgers—The State University of New Jersey, Piscataway, New Jersey

Abstract

Over the first year and a half of life, the duration of memory becomes progressively longer, the specificity of the cues required for recognition progressively decreases after short test delays, and the latency of priming progressively decreases to the adult level. The memory dissociations of very young infants on recognition and priming tasks, which presumably tap different memory systems, are also identical to those of adults. These parallels suggest that both memory systems are present very early in development instead of emerging hierarchically over the 1st year, as previously thought. Finally, even young infants can remember an event over the entire "infantile amnesia" period if they are periodically exposed to appropriate nonverbal reminders. In short, the same fundamental mechanisms appear to underlie memory processing in infants and adults.

Keywords

recognition; priming; infantile amnesia; reminders

All people have a natural curiosity about their own memory. This curiosity was tweaked several years ago by reports in the popular press of recovered memories from early childhood. These reports also renewed a long-standing debate about whether infants can actually remember for any length of time. Some researchers argue that infants possess only a primitive memory system that cannot encode specific events (Mandler, 1998), that early development is characterized by "infantile amnesia" (the absence of enduring memories; Pillemer & White, 1989), that children cannot remember events until they can rehearse them by talking about them (Nelson, 1990), and that children younger than 18 months are incapable of representation (Piaget, 1952); others argue that the behavior of older infants and children is shaped by their earlier experiences (Watson, 1930) and that adult personality is shaped by memories of events that occurred in infancy (Freud, 1935). Surprisingly, this debate has been waged in the absence of data from infants themselves.

This article reviews new evidence that infants' memory processing does not fundamentally differ from that of older children and adults. Not only can older children remember an event that occurred before they could talk, but even very young infants can remember an event over the entire infantile-amnesia period if they are periodically reminded.

DEVELOPMENTAL CHANGES IN RECOGNITION

Before now, the major impediment to research on infants' memory development was methodological: Tasks commonly used with older infants were inappropriate for younger ones. This problem is not surprising when one considers the considerable physical and behavioral changes that infants undergo over the first 18 months of life (see Fig. 1). Unfortunately, even when the same task was used, researchers often changed stimuli and task parameters nonsystematically; failed to equate age differences in motivation, stimulus salience, task demands, or original learning; or used identical instructions or prompts with infants who differed in verbal competence. Such practices made cross-age comparisons precarious at best.

To sidestep these problems, my colleagues and I have used two nonverbal tasks to study infants' memory development—a mobile task with 2- to 6-month-olds and a train task with 6- to 18-month-olds. All task parameters are standardized and age-calibrated. Because the memory performance of 6-month-olds is identical on these two tasks, comparisons between the memory performance of older and younger infants is not confounded by the shift in task.

In the mobile task, infants learn to move a crib mobile by kicking via a ribbon strung between the mobile hook and one ankle (see Fig. 2a). The rate at which they initially kick before the ankle ribbon is connected to the mobile serves as a baseline for comparison with their kick rate during the subsequent recognition test, when infants are again placed under the mobile while the ankle ribbon is disconnected. If they recognize the mobile (see Fig. 2b), they kick above their baseline rate; otherwise, they do not. In the train task, infants learn to move a miniature train around a circular track by depressing a lever (see Fig. 3). Again, baseline is measured, and retention is tested when the lever is deactivated; infants who recognize the train respond above their baseline rate.

Infants ages 2 to 18 months have been identically trained for 2 successive days in the mobile or train task and tested after a series of different delays. They exhibit equiva-

Published by Blackwell Publishers, Inc.

Fig. 1. Infants 2, 3, 6, 9, 12, 15, and 18 months of age (from left to right). Note the dramatic differences between the younger and older infants.

lent retention after short delays, but their duration of retention increases linearly with age (see Fig. 4)—a result not attributable to age differences in activity or speed of learning. At any given age, however, memory performance can be altered simply by changing the parameters of training. If given three 6-min training sessions instead of two 9-min sessions, for example, 8-week-olds remember for 2 weeks (as long as 6-month-olds given two 6-min sessions), instead of 1 or 2 days only.

Age differences in retention that have been obtained with other paradigms similarly reflect differences in task parameters and not in the underlying memory processes. In the deferred-imitation paradigm, for example, infants watch an adult manipulate

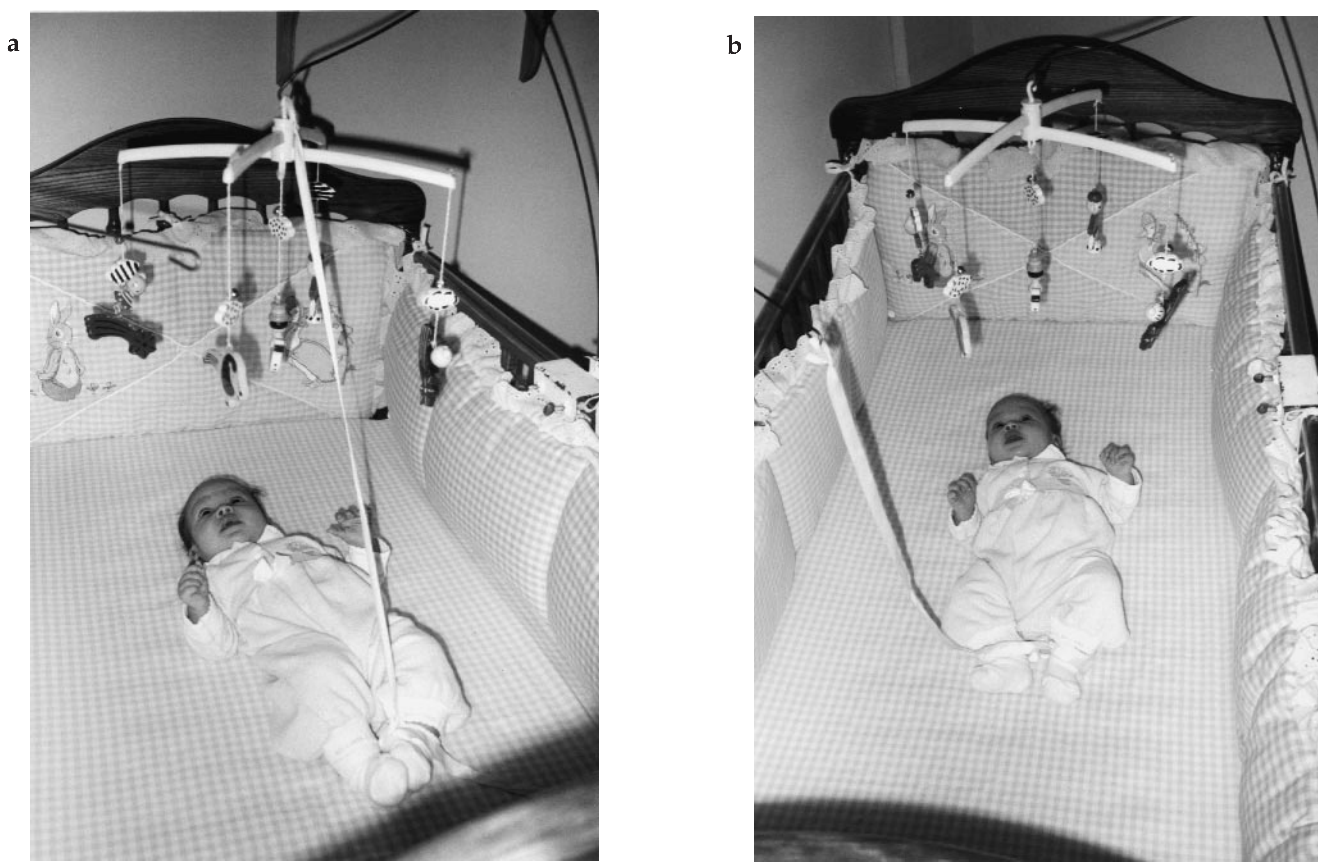

Fig. 2. A 3-month-old during training in the mobile task and during a retention test. During training (a), the infant's kicks move the mobile by means of the ankle ribbon that is connected to the mobile hook. During baseline and all retention tests (b), the ankle ribbon and the mobile are connected to different hooks so that kicks cannot move the mobile.

Fig. 3. A 6-month-old infant during training in the train task. Pressing the lever moves the toy train.

an object and are asked to imitate those actions later. At 6 months (the youngest age at which this paradigm can be used), infants who watch for 30 s in a single session successfully imitate if tested immediately afterward, but not if tested 24 hr later; if they watch for 60 s, however, they can imitate successfully 24 hr later (Barr, Dowden, & Hayne, 1996). Similarly, 18-month-olds exhibit deferred imitation for 4 weeks after one session but for 10 weeks after two sessions.

DEVELOPMENTAL CHANGES IN MEMORY SPECIFICITY

Because only cues that are highly similar to what is in a memory can retrieve it, the informational content of infants' memories can be determined by probing the memories with different retrieval cues and seeing which ones are effective. We followed this strategy with infants from 2 to 12 months of age by testing them after a series of delays either with a new mobile or train or in a context different from where they were trained. Because infants remember increasingly longer as they get older (see Fig. 4), we compared their memory performance after equivalent delays—the shortest, middle, and longest points on the forgetting function of each age.

For infants between 2 and 6 months of age, only the original mobile (or train) is an effective retrieval cue when testing occurs 1 day after training; a novel one is not. For infants between 9 and 12 months of age, however, a novel train can cue retrieval when testing occurs within 2 weeks of training, but not after longer delays (from 3 to 8 weeks), when only the original train can cue retrieval. A similar pattern is seen in deferred-imitation tests, although the duration of retention in this paradigm is shorter overall. Six-month-olds will not imitate if the test object is novel. Twelve-month-olds will—but only after delays on the order of minutes; after longer delays, they will imitate only if the test object is the one they saw originally (Hayne, MacDonald, & Barr, 1997). The fact that novel objects can cue retrieval only after delays when they can be clearly differentiated from the original training objects indicates that older infants actively disregard the difference. This emerging strategy enables older infants to "test the waters" and determine whether or not new objects that they encounter in the same context are functionally equivalent to the old ones.

When the training and testing contexts differ, infants exhibit a different pattern. At 3, 9, and 12 months of age, infants recognize the training object in a different context after all but the very longest test delays. Apparently, when the memory is weak, information about the context facilitates its retrieval. Between 12 and 24 months of age, infants will also imitate an action that they saw in one context (e.g., the day-care center) when tested with the same object in a different context (e.g., the laboratory) a few days later. Taken together, these findings reveal that infants can remember what they learn in one place if tested in another except after relatively long delays. Parents, educators, and public policy experts will be comforted to know that infants can transfer what they learn at the day-care center or in nursery school to home if given an opportunity to do so before too much time has passed.

DEVELOPMENTAL CHANGES IN PRIMING LATENCY

Even if infants cannot recognize a stimulus, like adults, they can still respond to it if they are exposed to a memory prime (or prompt) before the retention test. The prime, an isolated component of the original training situation, such as the original mobile or context, initiates a perceptual identification process

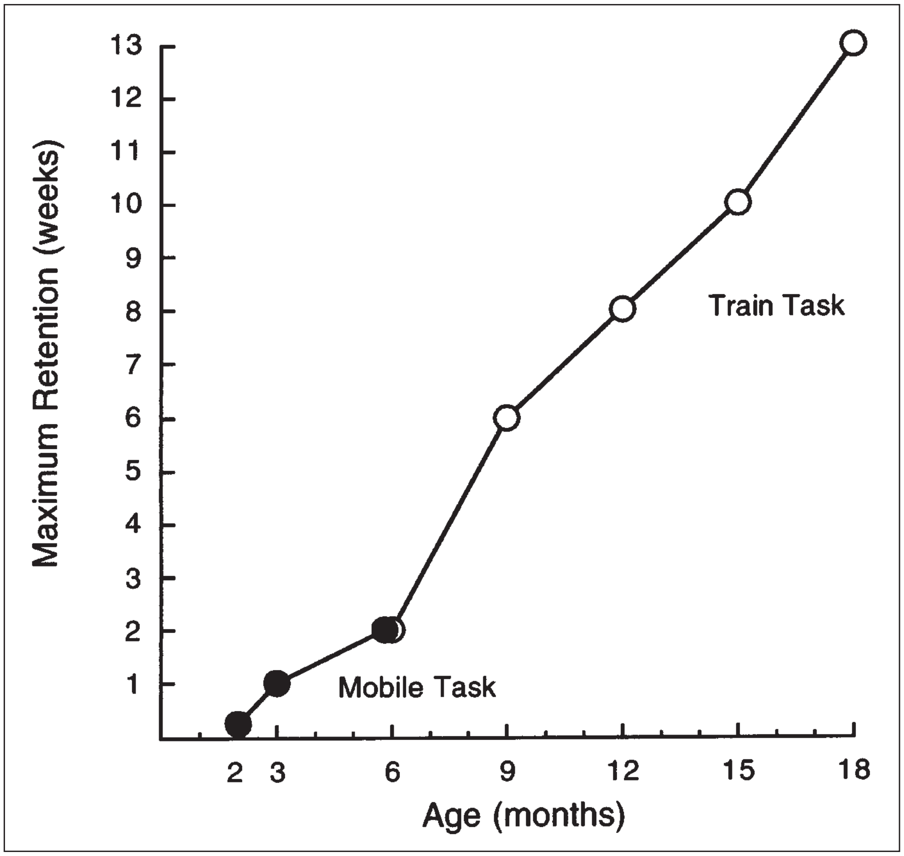

Fig. 4. Maximum duration of retention over the first 18 months of life. Filled circles show retention on the mobile task, and open circles show retention on the train task; 6-month-olds were trained and tested in both tasks.

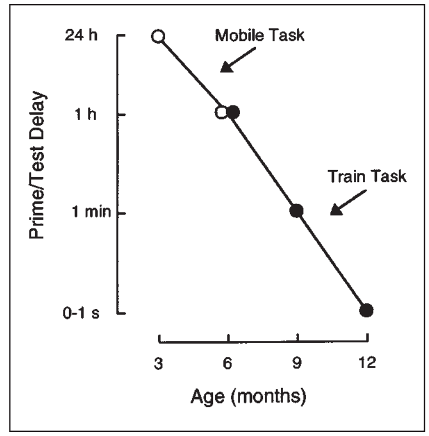

Fig. 5. Decrease in priming latency (graphed in log seconds) over the 1st year of life. Open circles show results on the mobile task, and filled circles show results on the train task; 6-month-olds were trained, primed, and tested in both tasks. Each data point indicates how long it took infants of a given age to exhibit retention after being exposed to a 2-min prime.

that facilitates retrieval of the latent memory by increasing its accessibility. In a recent series of studies, Hildreth and I primed memories that infants had forgotten (i.e., their performance on the long-term retention test was at baseline) and then assessed how long it took for the memories to be recovered (i.e., for infants to exhibit significant retention on the ensuing test; Hildreth & Rovee-Collier, 1999). Infants from 3 to 12 months of age were trained in the mobile or train task and were primed—only briefly and only once—with the original mobile or train 1 week after they no longer recognized it. Even though the time it took infants to forget the training event increased linearly with age (see Fig. 4), the latency of priming decreased over this same period until, at 12 months of age, infants responded instantaneously to the prime (see Fig. 5).

This result reveals that the speed of memory processing increases over the 1st year of life. Even at 3 months of age, however, infants respond instantaneously if a prime is presented if the memory was recently acquired. Infants who were trained with a three-mobile serial list, for example, recognized only the first mobile on the list 24 hr later—a classic primacy effect. If primed with the first mobile immediately before the 24-hr test, however, they also recognized the second mobile; and if successively primed with the first two mobiles on the study list, they recognized the third mobile (Gulya, Rovee-Collier, Galluccio, & Wilk, 1998).

DEVELOPMENT OF MULTIPLE MEMORY SYSTEMS

The notion that memory processing is mediated by two functionally different and independent memory systems originated more than a quarter-century ago with clinical observations that amnesics are impaired relative to normal adults on recognition but not on priming tests. Amnesics, for example, performed poorly when asked to recognize which of four words was on a list they had studied just minutes earlier, but they performed as well as normal adults when given a word fragment (the prime) and asked to complete it with the first word that came to mind. Typically, they completed the word fragments with words from the previous study list, even though they could not recognize them. This dissociation suggested that recognition and priming tests tap different underlying memory systems—one that is impaired in amnesia (explicit or declarative memory) and one that is not (implicit or nondeclarative memory). Since then, more than a dozen independent variables have been found to differentially affect adults' memory performance on recognition and priming tests, and memory dissociations have become a diagnostic for the existence of two memory systems.

For years, these memory systems were thought to develop hierarchically, with infants possessing only the primitive, perceptual-priming system until late in their 1st year. This assumption was based on the Jacksonian "first in, last out" principle of the development and dissolution of function (i.e., the function that appears earliest in development disappears last when the organism is undergoing demise), but empirical support for it in the domain of memory came only from studies of aging amnesics (McKee & Squire, 1993)—not infants. Now, new evidence has shown that all of the same independent variables that produce dissociations on recognition and priming tests with adults produce dissociations on recognition and priming tests with infants as well (Rovee-Collier, 1997). For example, priming produces the same degree of retention after all training-test delays, but the degree of retention on recognition tests decreases as the training-test delay becomes longer for both adults (Tulving, Schacter, & Stark, 1982) and infants. This evidence demonstrates that the Jacksonian principle does not apply to the development of memory systems; rather, both systems are present and functional from early infancy.

MAINTAINING MEMORIES WITH REMINDERS

Two recent studies from our laboratory have demonstrated that periodic nonverbal reminders can maintain the memory of an event from early infancy (2 and 6 months of age) through 1 1/2 to 2 years of age—-the entire span of the developmental period thought to be characterized by infantile amnesia. In the first study (Rovee-Collier, Hartshorn, & DiRubbo, in press), 8-week-olds learned the mobile task. Every 3 weeks thereafter until infants were 26 weeks of age, they received a preliminary retention test followed by a 3-min visual reminder—either a reactivation (priming) treatment in which they merely observed a mobile moving (a nonmoving mobile is not an effective reminder) or a reinstatement treatment in which they moved it themselves by kicking. Their final retention test occurred at 29 weeks of age, when the experiment had to be terminated because the infants outgrew the task. Although 8-week-olds forget after 1 to 2 days (see Fig. 4), after exposure to periodic reminders, they still exhibited significant retention 4 1/2 months later, and most still remembered 5 1/4 months later. Control infants who were not trained originally but saw the same reminders as their experimental counterparts exhibited no retention after any delay.

The impact of periodic reminders is illustrated in Figure 6, which shows the retention data of individual 8-week-olds superimposed on the retention function from Figure 4. When the experiment ended, four 8-week-olds had remembered as long as expected of 2 1/4-year-olds, one had remembered as long as expected of 2-year-olds, and the infant with the "poorest" memory had remembered for as long as children almost 1 1/2 years old. Had we been able to continue the study, some infants undoubtedly would have remembered even longer.

In the second study (Hartshorn, 1998), 6-month-olds learned the train task, were briefly reminded at 7, 8, 9, and 12 months of age, and were tested at 18 months of age. Although 6-month-olds typically forget after 2 weeks, after being periodically reminded, they still exhibited significant retention 1 year later, at 18 months of age. In addition, 5 of 6 infants who were reminded immediately after the 18-month test still remembered when retested at 24 months of age, 1 1/2 years after the original event. These infants had encountered only one reminder (at 18 months) in the preceding year!

Unfortunately, the mobile task is inappropriate for infants older than 6 months, and the train task is inappropriate for infants younger than 6 months. However, because periodic nonverbal reminders maintained memories of these two comparable events over an overlapping period between 2 months and 2 years of age, it seems highly likely that periodic nonverbal reminders could also maintain the memory of a single event from 2 months through 2 years of age, if not longer.

WHENCEFORTH INFANTILE AMNESIA?

The preceding evidence raises serious doubts about the generality of infantile amnesia, as well as the accounts that have been put forth to explain it. Clearly, neither the immaturity of their brain nor their inability to talk limits how long young infants can remember an event. As long as they periodically encounter appropriate nonverbal reminders, their memory of an event can be maintained—perhaps forever. Because a match between the encoding and retrieval contexts is critical for retrieval after very long delays, however, a shift from

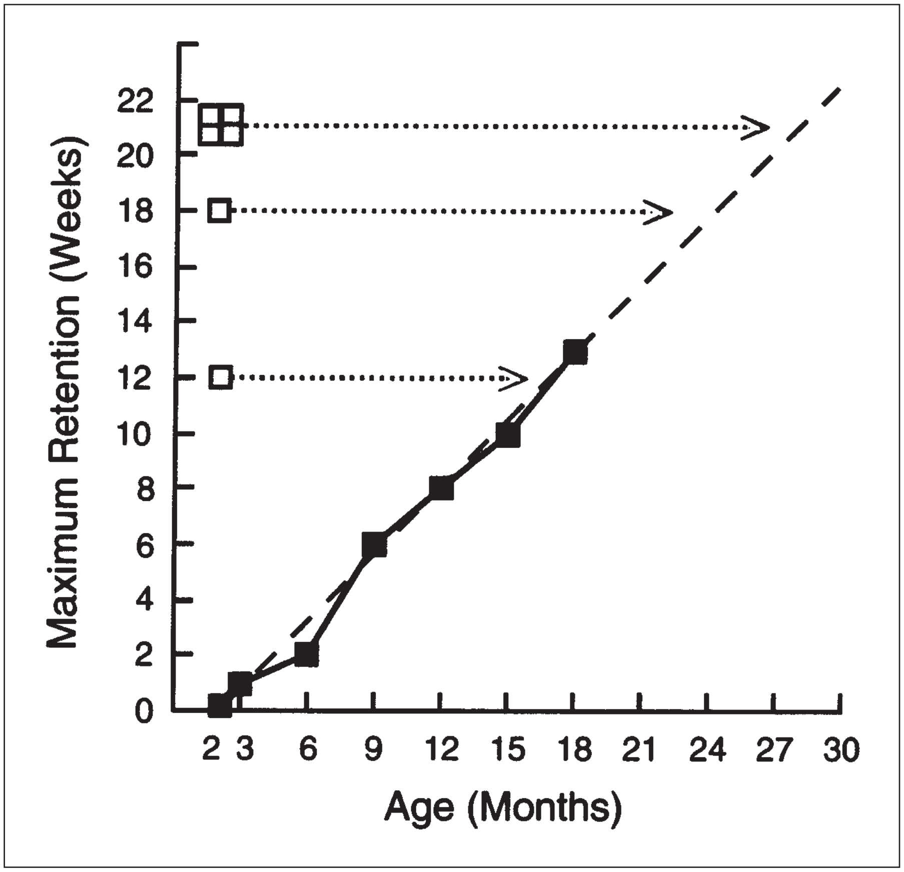

Fig. 6. Maximum duration of retention of individual 2-month-olds who were reminded every 3 weeks through 26 weeks of age (open squares) relative to the maximum duration of retention of unreminded infants (solid line, from Fig. 4). The dashed line, fitted by eye, extrapolates the original retention function through 30 months of age. By following each arrow to a point on the function and reading down to the x-axis, one can determine the age equivalent for the duration of retention of each reminded 2-month-old.

nonverbal to verbal retrieval cues or any other contextual change—either natural or perceived—would lessen the probability that a memory encoded in infancy would be retrieved later in life. In addition, because contextual information disappears from memories that have been reactivated once or twice, older children and adults may actually remember a number of early-life events but not know where or when they occurred. In short, even if an appropriate retrieval cue were to recover an early memory later in life, a person would probably be unable to identify it as such.

Recommended Reading

Campbell, B.A., & Jaynes, J. (1966). Reinstatement. *Psychological Review*, *73*, 478–480.

Gulya, M., Rovee-Collier, C., Galluccio, L., & Wilk, A. (1998). (See References)

Hartshorn, K., Rovee-Collier, C., Gerhardstein, P., Bhatt, R.S., Wondoloski, T.L., Klein, P., Gilch, J., Wurtzel, N., & Campos-de-Carvalho, M. (1998). The ontogeny of long-term memory over the first year-and-a-half of life. *Developmental Psychobiology*, *32*, 1–31.

Hayne, H., MacDonald, S., & Barr, R. (1997). (See References)

Rovee-Collier, C. (1997). (See References)

Acknowledgments—This research was supported by Grants R37-MH32307 and K05-MH00902 from the National Institute of Mental Health.

Note

1. Address correspondence to Carolyn Rovee-Collier, Department of Psychology, Rutgers University, 152 Frelinghuysen Rd., Piscataway, NJ 08854-8020; e-mail: rovee@rci.rutgers.edu.

References

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.

Freud, S. (1935). *A general introduction to psychoanalysis.* New York: Clarion Books.

Gulya, M., Rovee-Collier, C., Galluccio, L., & Wilk, A. (1998). Memory processing of a serial list by very young infants. *Psychological Science*, *9*, 303–307.

Hartshorn, K. (1998). *The effect of reinstatement on infant long-term retention.* Unpublished doctoral dissertation, Rutgers University, New Brunswick, NJ.

Hayne, H., MacDonald, S., & Barr, R. (1997). Developmental changes in the specificity of memory over the second year of life. *Infant Behavior and Development*, *20*, 233–245.

Hildreth, K., & Rovee-Collier, C. (1999). *Decreases in the latency of priming over the first year of life.* Manuscript submitted for publication.

Mandler, J.M. (1998). Representation. In W. Damon (Ed.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (pp. 255–308). New York: Wiley.

McKee, R.D., & Squire, L.R. (1993). On the development of declarative memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 397–404.

Nelson, K. (1990). Remembering, forgetting, and childhood amnesia. In R. Fivush & J.A. Hudson (Eds.), *Knowing and remembering in young children* (pp. 301–316). Cambridge, England: Cambridge University Press.

Piaget, J. (1952). *Origins of intelligence in children* (M. Cook, Trans.). New York: International Universities Press.

Pillemer, D.B., & White, S.H. (1989). Childhood events recalled by children and adults. In H.W. Reese (Ed.), *Advances in child development and behavior* (Vol. 21, pp. 297–340). New York: Academic Press.

Rovee-Collier, C. (1997). Dissociations in infant memory: Rethinking the development of implicit and explicit memory. *Psychological Review*, *104*, 467–498.

Rovee-Collier, C., Hartshorn, K., & DiRubbo, M. (in press). Long-term maintenance of infant memory. *Developmental Psychobiology*.

Tulving, E., Schacter, D.L., & Stark, H.A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *8*, 336–342.

Watson, J.B. (1930). *Behaviorism.* Chicago: University of Chicago Press.