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On Resolving the Enigma of Infantile Amnesia

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Historical and current theories of infantile amnesia are examined. To evaluate the viability of these theories, as well as the phenomenon of infantile amnesia itself, a review of memory development from birth through the preschool years is provided, including an overview of relevant perceptual and neurological maturation. In the context of this review, extant theories of infantile amnesia are shown to falter, and it is concluded that infantile amnesia is a chimera of a previously unexplored relationship between the development of a cognitive sense of self and the personalization of event memory. This hypothesis is examined in detail and discussed in the context of related developments in language and social cognition.

The fate of very early childhood memories has remained an enigma for over a century. Most people, when queried about the events of childhood, normally fail to recall the very earliest of occurrences. In fact, according to a review by Dudycha and Dudycha (1941) published over half a century ago in this journal, this infantile amnesia spans the first 3.5 years of life. More recent investigators have generally confirmed this average age (e.g., Kihlstrom & Harackiewicz, 1982), although there are others who claim that the actual age of our first recoverable memory is much earlier and who cite individuals able to recall at least one memory from around the age of 2 years (e.g., Usher & Neisser, in press; Winograd & Killinger, 1983). Alternatively, there are those who would have us believe that autobiographical events recovered from this era are not true memories at all but rather remembrances of things told to us by others.

The study of infantile amnesia has a hoary tradition, and many of the original reports of adults' failure to provide verbal recall of early (primarily nonverbal) experiences were anecdotal. However, discovering the fate of early memories has considerable theoretical importance because of its relevance to issues concerning the relative permanence of long-term memory storage. For example, historically, a variety of hypotheses have been entertained concerning the locus of forgetting, ranging from theories in which permanently stored information simply fluctuated in its retrievability (e.g., Freud, 1914/1938; Hoffding, 1891) to speculation that changes in the information in storage were at the root of memory failure (e.g., Kohler, 1929, 1941). Modern-day theories echo a similar range of conjecture about whether memory is a permanent or labile storage system (e.g., Howe & Brainerd, 1989; Loftus & Loftus, 1980). On the one hand, if storage is permanent, then the inability to recall early experiences may simply be a matter of retrieval failure and can be alleviated by reinstating the appropriate testing conditions (a particularly poignant discussion can be found in Nash's, 1987, review of the hypnotic age regression literature). In essence, this is a model of contextually dependent memory in extremis in which, although early memories survive intact in storage, the context (both internal and external) in which these memories were laid down (infancy) is so discrepant from the one in which they are trying to be retrieved (later childhood or adulthood) that it is impossible to make contact with the relevant traces. On the other hand, if storage is not permanent, particularly in an immature organism, then no matter what retrieval remedies are implemented, recall of early experiences may be impossible.

If, as has been commonly assumed (see Loftus & Loftus, 1980), storage is permanent, then early childhood memories, although gone from consciousness, are not forgotten. Perhaps the best known proponent of this view was Freud (1905/1953, 1916–1917/1963), who argued that early autobiographical memories persist, unknown to us (repressed in the unconscious), and serve to influence everyday behavior (albeit in a disguised fashion). In fact, according to Freud, favorable therapeutic outcomes in adulthood hinge on the successful retrieval of these early childhood events. Clearly, then, in Freud's implicit theory of memory, autobiographical events from childhood remain intact, but locked safely away, in long-term memory.

More recently, the notion that memories affect behavior in the absence of conscious awareness has appeared in theories of implicit and explicit memory (e.g., Reber, 1989) and procedural and declarative memory (e.g., Mandler, 1984; Willingham, Nissen, & Bullemer, 1989). In both cases, behavior is affected by previous experience, but only one form of memory is subject to conscious inspection (explicit and declarative) and the other is not (implicit and procedural). Perhaps early experiences are stored as implicit or procedural records and are not subject to conscious inspection.

Unlike proponents of the retrieval failure hypotheses, other theorists suggest that these very early autobiographical events

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either were never registered properly initially or were rapidly lost from long-term memory. More specifically, either the events of early childhood were improperly or poorly encoded in storage to begin with, and hence "decayed" rapidly, or the memory system was too immature to support long-term retention of information (for an overview, see Kail, 1984). According to this line of reasoning, we owe our common experience of failing to recall early events to the fact that these events simply do not exist in long-term memory.

As in other areas of the literature on memory development in childhood, it is clear that an understanding of the phenomenon of infantile amnesia requires an answer to the question of whether failures to recollect early autobiographical events are due to problems of retrieval, problems of storage, or some combination of the two. From this perspective, then, the problem of infantile amnesia can be framed in the following manner. First, if durable memories of early autobiographical events are not formed in the first place and infantile amnesia is the result of storage failure, then what are the nature and cause of this storage problem (e.g., neurological immaturity, perceptual immaturity, both)? Second, if durable memories are formed for these events, and infantile amnesia is the result of retrieval failure, then what is the cause of this inaccessibility (e.g., inappropriate retrieval cues)?

The resolution of this issue is complicated by an apparent paradox—namely, that although there is considerable evidence that adults fail to recall events that occurred prior to an average age of 3 years (with an estimated range between 2 and 4 years; e.g., Pillemer & White, 1989; Wetzler & Sweeney, 1986), a growing body of research indicates that preschool children's memory for events is quite remarkable (e.g., Fivush, Gray, & Fromhoff, 1987; Fivush & Hamond, 1989; Nelson, 1986, 1988). If 2- to 4-year-old (and older) children can recall events from the past with a reasonable degree of accuracy, the following question arises: What exactly is infantile amnesia and when exactly does it occur?

Given the importance of the theoretical issues involved in the phenomenon of infantile amnesia, it is essential that we reconcile the seemingly universal finding that adults fail to recall early life experiences with the apparent ability to remember such experiences during childhood. As Spear (1979) pointed out over a decade ago, perhaps the enigma of infantile amnesia can best be unlocked by first examining the properties of the immature memory system. Given the rapid growth of this field in recent years, we now have a considerable database from which to draw. In the present article, we reconsider the phenomenon and paradox of infantile amnesia in light of these (and other) recent findings. We begin by reviewing the empirical and theoretical literature on very early neurological, perceptual, and memory development and then critically examine the conditions surrounding attempts to retrieve information about early autobiographical events in later childhood and adulthood. To anticipate the outcome of this review process, the results of our analysis indicate, somewhat ironically, that basic memory mechanisms per se are probably not directly involved in infantile amnesia, and therefore the term *amnesia* may be somewhat of a misnomer. Indeed, our review establishes that the fundamental processes that comprise memory are relatively sophisticated even in infancy and that, although clear ontogenetic shifts in memory occur throughout the early years, they are probably not the primary source of later failures to recall early childhood events. We argue, on both theoretical and empirical grounds, that the solution to the problem of infantile amnesia lies not in searching for changes in memory mechanisms themselves but rather in considering changes that occur in related areas of cognitive functioning. We propose that the most important of these is the maturation of the sense of self, an achievement that is not evident until about 2 years of age and is coincident with the offset of infantile amnesia.

Autobiographical memory, by definition, is memory for information and events pertaining to the self. Therefore, knowledge of the self as an independent entity with characteristics, thoughts, and actions that are separate and distinct from those of others is perhaps the minimum criterion for the existence of autobiographical memory. Without a clear recognition of an independent self, there can be no referent around which personally experienced events can be organized. Prior to the articulation of the self, the infant will learn and remember, but these experiences cannot be recognized as specific events, coded with respect to time and place, that happened to a "me." We argue here that the phenomenon called *infantile amnesia* devolves as knowledge of the self evolves and that the emergence of the infant's sense of self is the fundamental cornerstone in the development of autobiographical memory. This line of reasoning is developed in a subsequent section in which we trace the development of the young child's self-concept, including the acquisition of self-relevant language. We conclude by arguing that this theory can account for the extant literature on infantile amnesia, including commonly witnessed individual differences in the age of the offset of infantile amnesia, and by outlining some of the unique predictions that emerge from this new perspective.

On the Precocity of Early Memory Skills

Unlike previous reviews of infantile amnesia in which discussion of early memory development has been restricted to the study of children's event memory (Pillemer & White, 1989), the purpose of this section is to provide a more extensive overview of the memory capacities of infants and very young children. Obviously, given the size of this literature, we cannot review all of it within the confines of this article. In selecting areas for our review, we decided to focus on topics that have been at the center of recent research on early memory development and have not been reviewed extensively in the past. Therefore, our review focuses on studies of infants' and preschool children's memory as reflected in a number of paradigms, including conjugate reinforcement, deferred imitation, search, memory for location, and memory for traumatic and nontraumatic events. We begin with a survey of the literature on memory skills in infancy and then turn to the development of memory in preschoolers.

Memory Skills in the Early Months of Life

Because a number of excellent reviews of the research on habituation, discrimination, and operant- and classical conditioning paradigms already exist (e.g., Rovee-Collier, 1987), and because the implications of this work for infant memory development are unclear (e.g., Rovee-Collier, 1987; Rovee-Collier & Hayne, 1987), it is not reviewed here. Instead, we provide an overview of (a) the work of Rovee-Collier and her colleagues on infant memory during the first 6 months of life and (b) the neurological and perceptual changes that may mediate early memory development.

Memory development in the first 6 months. Research during the past decade has shown that long-term memory is functional prior to birth. For example, DeCasper and his colleagues (DeCasper & Prescott, 1984; DeCasper & Spence, 1986; Spence & DeCasper, 1987) showed that newborns (approximately 33 hr old) recognized auditory stimuli that were presented prenatally (during the last trimester of pregnancy). Because postnatal auditory experience could not have contributed to these results, it seems clear that long-term memory is functioning prenatally.

The most comprehensive program of research on early postnatal memory development was conducted by Rovee-Collier and her colleagues (for recent reviews, see Rovee-Collier & Hayne, 1987; Rovee-Collier & Shyi, 1992). The methodological centerpiece of this research is the mobile conjugate reinforcement paradigm. Here, the basic procedure involves connecting a ribbon to both an overhead mobile and the infant's ankle. The goal is to have the infant learn the contingency between his or her own kicking and movement in the mobile (the reinforcement). Following acquisition of the response, the infant is tested for immediate and delayed retention.

In some experiments, an additional reactivation treatment is administered prior to tests of retention. Here, following a retention interval over which some forgetting has occurred, infants are administered a simple reminder (some cue or feature that is presumably represented in the trace) and tested at some later point (generally, at least 24 hr after the administration of the reminder). If the reminder is a functional component of the memory trace at the time it is presented, it presumably acts to prime the memory and may even redintegrate the trace. This procedure allows one to evaluate which features were encoded in the memory trace and which are still functional after varying delays.

Using this paradigm, Rovee-Collier and her associates traced the course of memory development from 2 to 6 months and isolated a number of factors critical to the maturation of long-term memory and retention. One of the most important results to emerge from the simple forgetting paradigm (no reactivation treatment) was that despite similar levels of performance at the end of training, infant age and length of retention interval were positively correlated, and differences in retention were larger in the earlier than the later months (e.g., W. L. Hill, Borovsky, & Rovee-Collier, 1988; Rovee-Collier & Hayne, 1987; Rovee-Collier & Shyi, 1992). Specifically, 2-month-olds exhibited considerable forgetting following a 1-day interval and no retention after 3 days (Greco, Rovee-Collier, Hayne, Griesler, & Early, 1986), 3-month-olds showed little or no forgetting after a 4-day delay and complete forgetting around 13 days (Sullivan, Rovee-Collier, & Tynes, 1979), and 6-month-olds exhibited a relatively shallow forgetting slope with an asymptote at around 21 days (W. L. Hill et al., 1988). Interestingly, the finding that age variability in forgetting is not simply an artifact of failing to control initial levels of learning is not restricted to the period of infancy. Indeed, that there exist true age–forgetting relationships that do not depend on initial learning levels has been established from birth to adulthood (e.g., Brainerd, Reyna, Howe, & Kingma, 1990; Howe, 1991; Howe, Courage, & Bryant-Brown, 1992; Howe, Kelland, Bryant-Brown, & Clark, 1992).

The poor retention of 2-month-olds can be alleviated with additional training (Hayne, Greco, Early, Griesler, & Rovee-Collier, 1986), and more generally, increasing either the duration or the number of sessions significantly improves retention in most infants (e.g., Ohr, Fagen, Rovee-Collier, Hayne, & Vander Linde, 1989; Vander Linde, Morrongiello, & Rovee-Collier, 1985). It is interesting that the essential component of additional training that leads to enhanced retention is not the total time spent in training but rather whether the additional training is distributed across more sessions (Vander Linde et al., 1985). The finding that retention is improved with distributed as opposed to massed training is ubiquitous, having been observed in infant animals (e.g., Richardson, Riccio, & McKenney, 1988; Solheim, Hensler, & Spear, 1980), children (e.g., Dempster, 1988), and adults (e.g., Postman & Knecht, 1983).

The positive effects of distributed training are usually attributed to increased variation in feature sampling and encoding, which, in turn, leads to more viable and less labile traces in long-term memory (e.g., Rovee-Collier, Early, & Stafford, 1989). Increased feature sampling also leads to a higher probability of retrieval because there is a corresponding increase in the number of potential cues that could lead to trace reactivation and recovery at the time retention is tested (Rovee-Collier et al., 1989). Although it has been difficult to obtain unambiguous evidence that younger infants benefit more than older infants from distributed training than from massed training (e.g., compare Enright, Rovee-Collier, Fagen, & Caniglia, 1983, and Ohr et al., 1989), it does seem clear that (a) regardless of age or species, retention improves as the number of encoded features increases (Estes, 1988; Howe & Brainerd, 1989; Richardson et al., 1988; Solheim et al., 1980) and (b) across species, early age changes in retention are controlled, at least in part, by developments in feature sampling (Richardson et al., 1988; Rovee-Collier et al., 1989).

Unlike the rather pessimistic picture of infant retention painted by studies of simple forgetting, research with the reactivation paradigm indicates that a considerable amount of information remains in memory even after lengthy retention intervals. Reactivation occurs when attributes of the original trace, either from the display itself (e.g., the mobile) or the surrounding context (e.g., the crib bumper), are reencountered naturally or experimentally (for a complete review, see Rovee-Collier & Shyi, 1992). Studies using the reactivation procedure have shown that older infants (6-month-olds) require more specific cues for retrieval than younger infants (3-month-olds) and that although all infants process context, long-term retention (at least over a 1-week interval; see Boller, Rovee-Collier, Borovsky, O'Connor, & Shyi, 1990) is more strongly determined by contextual features at 6 months than at 3 months (Rovee-Collier & Shyi, 1992).

The effectiveness of reactivation is contingent on when additional encounters with trace attributes occur. Indeed, amount of reactivation is correlated with the current trace contents (i.e., what remains in memory of the originally encoded event), which, in turn, are correlated with the time interval since original encoding (or since the last reactivation). However, once reactivated, a trace can again be retained for at least as long as it could when it was originally encoded. In fact, "the reactivation phenomenon raises the possibility that infants might be able to remember for weeks, months, or perhaps even years" (Rovee-Collier & Hayne, 1987, p. 203). More important for the present purposes, if attributes of encoded traces are frequently reencountered in the infant's environment, leading to numerous opportunities for trace reactivation, then theoretically "an individual's early experiences could be remembered over a lifetime" (Rovee-Collier & Hayne, 1987, p. 231).

Although this is an intriguing possibility, reactivation has an important side effect. Specifically, it serves to modify the contents of the original trace by integrating the features of the current retrieval context with the remnants of the reactivated trace. What this implies is that over the course of a number of reactivations the original trace may become so modified that its contents are no longer representative of the original event. If so, then rather than preventing infantile amnesia, reactivation may actually promote early infantile amnesia by modifying the contents of memory rather than preserving them. Contrary to traditional views of forgetting in which traces are either present but inaccessible (retrieval failure) or simply absent from memory (storage failure in extremis), the memory modifications brought about through reactivation emphasize the dynamic properties of memory and represent a change, not erasure, of what is in storage.

Consistent with this supposition is the finding that although 6-month-olds process (i.e., encode and retrieve) memory traces more rapidly than 3-month-olds, access to either the original or reactivated trace is more difficult for the older infants after longer intervals (Boller et al., 1990). Because older infants process memories so rapidly, such traces are most likely subject to more rapid modification. If so, "then infantile amnesia may be a consequence of the rapidity with which early memories are retrieved and modified rather than the ability of young infants to store memories over the long term" (Boller et al., 1990, p. 778).

As viable a proposition as this may seem, there are serious problems with this explanation. Specifically, even if this were a reasonable explanation of infantile amnesia for events occurring in the first few months of life, it does not account for infantile amnesia for events up to the target age of 2 to 3 years (Pillemer & White, 1989; Usher & Neisser, in press). Moreover, reactivation and memory modification occur in preschoolers (Howe, Courage, & Bryant-Brown, 1992), elementary-school children (Hoving & Choi, 1972; Hoving, Coates, Bertucci, & Riccio, 1972), and adults (e.g., Loftus, Hoffman, & Wagenaar, 1992), with no apparent differences in the degree of trace modification (although this remains an empirical question). Thus, if the memory-modification-through-reactivation hypothesis is to be used to explain infantile amnesia, it must (a) be extended to encompass traces encoded up to approximately 2 to 3 years of age and (b) provide a developmental mechanism, one that kicks in at around age 2 to 3 years, that modulates the amount of modification that occurs after the critical infantile amnesia years.

Even if reactivation and memory modification do not provide a complete explanation of infantile amnesia at the present time, this line of research has clearly shown that long-term memory and retention are dynamic processes that are relatively sophisticated even in very young infants. In fact, many of the properties of this memory system that are thought to be important in both childhood (e.g., Howe & Brainerd, 1989) and adulthood (e.g., Howe & Hunter, 1986) are clearly present in infancy. Although memory appears to function in much the same way in infancy as it does in childhood and adulthood, one would certainly not wish to claim that there are not major developmental advances that occur throughout childhood. Although there exist numerous cognitive changes that significantly shape memory development (e.g., changes in knowledge, strategies, and the like; for recent reviews, see Bjorklund, 1987; Howe & O'Sullivan, 1990), the question arises as to whether there are not other, neurological and perceptual, changes that influence memory early in development, ones that may contribute to (or be responsible for) infantile amnesia. Thus, before we proceed to our review of memory development from 7 months onward, we pause to examine the contribution of perceptual and neurological factors to early memory development.

Neurological and perceptual changes and early memory development. Rovee-Collier and Shyi (1992), after reviewing numerous studies recounting the memory skills of infants, concluded that whatever the neurological structures are that mediate the basic mechanisms of encoding, storage, and retrieval over extended retention intervals, they must certainly be functional very early in life. In this section, unlike in previous authors' treatments of infantile amnesia, we seek (a) independent, neurological data concerning this conclusion and (b) data regarding any subsequent elaboration of neuroanatomical systems subserving memory that may provide an explanation of infantile amnesia. Because much of the research on memory development has involved visually encoded memories, our discussion is limited to relevant literature on the development of visual perception, visual recognition memory, and recall of visual experiences.

The visual system of the human neonate is immature in both its structure and function. Although the major optical and anatomical components of the eye are in place at birth, there are marked neurological immaturities in the structures along the retino-geniculo-cortical pathway (for reviews, see Aslin, 1987; Banks & Salapatek, 1983; Hickey & Peduzzi, 1987). Specifically, the foveal region of the retina is poorly defined and cone cells are sparsely distributed. Although the lateral geniculate nucleus has many characteristics of the mature structure, cell bodies are relatively small, sluggish, and easily fatigued. Whereas the neurogenesis of cells in the primary visual (striate) cortex is complete at birth and its laminar structure is visible, only a skeletal organization of mature cortical receptive fields (retinotopicity, direction and orientation selectivity, binocularity) is evident, and ocular dominance columns are unformed. Axons and dendrites are recognizable in the cortex, but the latter are short and poorly arborized. Mylenation is incomplete. Further projections from the primary visual cortex to the visual association areas in the inferior temporal cortex and the parietal cortex, although known to be important in the recognition of visual stimuli (Hickey & Peduzzi, 1987), have not been investigated developmentally. These early immaturities in the visual system do not last long. Although the component structures and pathways have their own maturational timetables, it is generally true that the first 3 postnatal months mark a period of rapid development such that by the end of this time much of the basic neural "hardware" is in place. However, considerable fine-tuning of the visual system continues throughout the remainder of the first postnatal year.

The limitations in the neonatal visual system place significant constraints on visual function and perception in the early months. Predictably, newborn infants have poor visual acuity, contrast sensitivity, and color vision. Although visual reflexes (e.g., saccadic and pursuit movements, optokinetic nystagmus) are present, more general visuomotor immaturity restricts infants' ability to scan extensively or to detect stimuli beyond about 30° in the peripheral visual field. However, the rapid neurological development that occurs in the early postnatal months coincides with significant improvement in all of these visual functions, an expansion of the effective visual field, and the onset of more mature perceptual abilities whereby infants come to recognize objects and determine their spatial layout. Thus, beginning at about 3 months infants demonstrate the following abilities, which continue to mature over the next several months: They perceive forms as such, rather than in terms of their component parts; their recognition of faces is excellent; and their perception of pattern shows sensitivity to the Gestalt principles of proximity, symmetry, good continuation, and common fate. They perceive objects as constant in size and shape in spite of variable information projected to the eye as objects move in relation to themselves, and they can use binocular and monocular cues to determine the location of objects in the environment (Aslin, 1987; Banks & Salapatek, 1983). In summary, although neurophysiological immaturities constrain young infants' perceptual abilities in the early postnatal months, babies are fully capable of encoding, storing, and retrieving information in the visual world. Although these perceptual abilities become more adultlike over the remainder of the first year and coincide with improvements in information-processing efficiency, it is clear that the basic neural "hardware" needed for the early memory skills discussed previously is functional very early in life.

Despite this fact, however, it has been suggested that neurophysiological immaturity may underlie the apparent memory deficits attributed to infantile amnesia. Evidence for this comes from three different sources. First, it has been proposed that the hippocampal region of the forebrain, integrally important to learning and memory, is immature in young organisms (Mishkin, Malamut, & Bachevalier, 1984; Nadel & Zola-Morgan, 1984; Schacter & Moscovitch, 1984; Squire, 1987). Second, there is evidence that the prefrontal cortex is immature at birth and undergoes a period of rapid synaptogenesis toward the end of the first postnatal year, coinciding with improved performance on a variety of cognitive tasks (Diamond & Doar, 1989; Fischer, 1987; Goldman-Rakic, 1987a; Greenough, Black, & Wallace, 1987). The third, relatively unexplored possibility is that changes in synaptic efficiency (Harris & Teyler, 1984; Teyler & Fountain, 1987) or hormonal modulation (Gold, 1987) that follow certain types of stimulation may only become functional beyond infancy. Although much of this research has been based on work with either brain-injured humans or animals, which severely complicates its application to human memory development, we examine each of these different possibilities next.

The idea that immaturity of the hippocampal region is the basis of infantile amnesia has its roots in the study of human memory pathology. Patients with bilateral damage to the medial aspect of the temporal lobe (especially the hippocampus and amygdala) or the diencephalic structures (especially the mammillary bodies and the dorsomedial nucleus of the thalamus) experience marked anterograde amnesia whereby they are unable to access (or perhaps store) recently experienced events and factual information. However, their immediate memory and memory for remote events are intact, as are their general intellectual capacity, language, and social skills. They can also learn and retain perceptual, motor, and certain cognitive skills, although without awareness of the time and place of having acquired these skills (for reviews, see Squire, 1986; Squire & Cohen, 1984; Squire & Frambach, 1990; Squire & Zola-Morgan, 1988). These circumscribed memory deficits suggest that memory may not be a unified phenomenon and that the brain has organized its memory functions around fundamentally different storage systems. Although the same experiences normally engage both systems, the two can become dissociated in amnesia (Cohen & Squire, 1980; Jacoby, 1982; Kinsbourne & Wood, 1982; Mishkin et al., 1984; Moscovitch, 1982; Schacter & Moscovitch, 1984; Schacter & Tulving, 1982; Warrington & Weiskrantz, 1982; Wickelgren, 1979). The kinds of information (or types of memory) that are lost or spared in amnesia have been variously described, with the terms *declarative* and *procedural,* respectively, being perhaps the most familiar (Cohen & Squire, 1980).

Although the study of human memory pathology has been instructive, the lack of neuropathological data on the extent or exact locus of damage provided by these early case studies made it difficult to specify the relationship between memory structure and function. Consequently, animal models have been developed in which rhesus monkeys with medial temporal or diencephalic lesions or both are required to perform a variety of tasks that are said to be sensitive to the skills that have been lost or spared in human amnesia (for reviews, see Mishkin et al., 1984; Squire & Cohen, 1984; Squire & Zola-Morgan, 1983; Zola-Morgan & Squire, 1985). On the basis of these animal models, Mishkin and his associates (Aggleton & Mishkin, 1983; Malamut, Saunders, & Mishkin, 1984; Mishkin et al., 1984; Mishkin, Spiegler, Saunders, & Malamut, 1982; Zola-Morgan, Squire, & Mishkin, 1982) proposed that there are indeed two separate retention systems in the brain that store the effects of experience in fundamentally different ways—a cortico-limbic ("memory") system and a cortico-striatal ("habit") system. The "memory" system is dependent on the integrity of the medial temporal and diencephalic regions and is lost in amnesia. The "habit" system is independent of these regions and mediates the learning ability that is spared in amnesia. Mishkin proposed that the probable neural substrate of the habit system is the striatum or basal ganglia, a group of structures in the forebrain that, because of the structures' connections with both sensory and motor areas of the brain, is a likely link between stimuli and responses. The memory and habit systems in rhesus monkeys are believed to be roughly comparable to declarative and procedural systems, respectively, in humans.

Bachevalier and Mishkin (1984) examined the functional development of the memory and habit systems ontogenetically. They found that whereas 3-, 6-, and 12-month-old monkeys were equally proficient on tasks involving the habit system (concurrent discrimination), only the older groups were proficient on tasks involving the memory system (delayed nonmatching to sample). They argued that the failure of the youngest monkeys on the memory task was likely due to immaturity of the cortico-limbic system, which is slower to develop than the corticostriatal system. It is interesting that this conclusion is consistent with the findings of Rakic and his associates, who reported that neurons continue to proliferate in the hippocampal region of the rhesus monkey for 4 to 6 months after birth and that synaptogenesis reaches its peak and begins to decline toward the adult level during the first postnatal year (Eckenhoff & Rakic, 1981, 1988; Nowakowski & Rakic, 1981; Rakic, Bourgeois, Eckenhoff, Zecevic, & Goldman-Rakic, 1986). Similarly, the emergence of mature spatial exploration skills in rats (known to depend on the hippocampus in adult animals) coincides with the period of rapid neurogenesis and synaptogenesis in the dentate gyrus of that species (Crain, Cotman, Taylor, & Lynch, 1973; Nadel & Zola-Morgan, 1984). Thus, it has been suggested that the infantile amnesia observed in these species, as well as the pervasive human inability to recall experiences during infancy, may well be a natural consequence of the immaturity of the cortico-limbic system early in ontogeny.

There are a number of problems with this suggestion. For example, the database on which it rests is composed of a bewildering array of tasks, ones that purport to provide separate measures of memory (declarative) and habit (procedural) processes (for descriptions, see Squire & Shimamura, 1986; Squire & Zola-Morgan, 1983). The critical distinction between these two types of tasks is supposedly that the latter are simply skill learning tasks based on conditioning and the strengthening of stimulus–response bonds across trials, whereas the former depend on the subject's having some stored knowledge of what happened on the previous trial and, in the absence of external cues, using this representation to guide behavior. However, in the absence of appropriate task analyses that provide information about the component skills and difficulty level of these tasks, this distinction cannot always be clearly made. Worse, there are inconsistencies (a) in performance among the various tasks said to assess recognition memory or visual discrimination, (b) between studies using the same tasks, and (c) even in decisions as to whether a particular task is a measure of discrimination or of recognition (Malamut et al., 1984; Squire & Zola-Morgan, 1983).

This confusing state of affairs is compounded by the fact that most tasks are probably tapping both declarative (memory) and procedural (habit) systems to a greater or lesser degree (Squire, 1987). This, in turn, leads to another problem—namely, the legitimacy of considering visual discrimination tasks to be nothing more than habit or procedure. The case is made on the basis of an incremental improvement in performance over trials as the animal gradually identifies the correct stimulus dimension to be rewarded. However, it appears that not all pattern discriminations are made in this incremental way, especially in human subjects (see Morris, 1984). Is it the case that this task is an example of habit or procedural learning in the monkey but something else in the human? If so, then why is it being used to model skills spared in human amnesia? Although recent progress has been made in addressing this complex issue (Squire & Shimamura, 1986; Zola-Morgan & Squire, 1985), the problem of task standardization is an important one that has yet to be fully resolved. What this means is that there is not yet a sound empirical basis for making cross-species and cross-age generalizations about the neural structures that mediate performance on the tasks used to assess memory.

Schacter and Moscovitch (1984) also developed a dual systems approach to memory development in humans and attempted to relate the types of memory spared and lost in amnesia to human infants' performance on a variety of tasks. They argued that an "early" system (habit, procedural) is available to infants (perhaps from birth) and accounts for their performance on habituation, novelty preference, and simple conditioning tasks. A "late" (memory, declarative) system gradually becomes available after about 8 months and accounts for infants' performance on more complex habituation, novelty preference, and conditioning paradigms that require the subject to use spatiotemporal contexts (Millar & Schaffer, 1972), tolerate long intertrial intervals or delays between response and reinforcement (Millar, 1972; Ramey & Ourth, 1971), or demonstrate cross-modal recognition (Rose, Gottfried, & Bridger, 1979).

The Schacter and Moscovitch (1984) analysis is an interesting one and is consistent with Bachevalier and Mishkin's (1984) interpretation of infantile amnesia. However, as Schacter and Moscovitch acknowledged, their proposed dichotomy of memory into two systems likely underestimates the enormous complexity of both neurological and cognitive development in humans. For example, in addition to the problems concerning the earlier than expected appearance of spatiotemporal skills,[1] there is a more fundamental problem—namely, comparing the performance of a developing organism with that of an adult of its species (especially one whose functioning is limited by a neurological impairment). The obstacle here is that for many tasks, we simply do not know at what age to expect adultlike performance, nor do we know the full spectrum of functional immaturities that may limit infants' performance on a particular cognitive task. Again, the fundamental problem is that we do not have the database that is necessary to unequivocally

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[1] Recall that Rovee-Collier and Shyi (1992) clearly showed that even very young infants (e.g., 3-month-olds) encode and retain contextual information. This finding is important because it illustrates, contrary to the 8-month-old figure discussed by some authors (e.g., Nadel & Zola-Morgan, 1984; Schacter & Moscovitch, 1984), that the brains of 3-month-olds are functionally mature enough to encode and retain location or contextual information. Indeed, using a radically different training procedure, Smith, Arehart, Haaf, and deSaintVictor (1989) showed that 4- to 6-month-old infants retain memory for spatiotemporal events for at least a week. In addition, these findings open up the possibility that even very early infantile amnesia could arise from a discrepancy between the initial encoding conditions (infancy) and the context at retrieval (adulthood). This "contextual-shift" hypothesis of infantile amnesia is discussed in a subsequent section.

identify relationships between neurological development (or functioning) and performance.

Although not directly concerned with memory development per se, Goldman-Rakic (1987a, 1987b) addressed this issue of the relationship between structure and function in the ontogeny of cognitive skill. Specifically, she explored the relationship between the development of the prefrontal cortex (an area of the forebrain that has been well described anatomically, biochemically, and functionally in adult monkeys) and the emergence of the ability to perform the delayed response task. It has long been established through a variety of measures that performance on the delayed response task is mediated by the prefrontal cortex in monkeys (see Goldman-Rakic, 1987a, for a review). In this task, the monkey observes food being hidden in one of two identical wells, a delay is imposed during which a screen blocks the view of the wells, and finally the monkey selects one of the locations. Because the correct response cannot be cued by any obvious stimulus present at the time of the response, but must be guided by stored knowledge of what the subject saw previously, it is said to indicate the presence of representational memory. This ability to access stored information and hold it "on line" to guide behavior is arguably different (and requires different brain areas) from learning and memory in situations in which all necessary information is present at the time the response is made.

Goldman-Rakic (1987b) further noted that the delayed response task is fundamentally the same as Piaget's AB Stage IV object permanence task, which also requires representational memory (as defined earlier). Extensive comparison between the performances of lesioned and unlesioned adult monkeys, normal infant monkeys, human infants, and human adults with prefrontal brain damage on the delayed response task and the AB task strongly indicates that performance on both of these tasks follows the same developmental course, requires the integrity of the prefrontal cortex, and is selectively impaired by lesioning of this area (Diamond, 1985; Diamond & Doar, 1989; Diamond & Goldman-Rakic, 1983, 1989; Freedman & Oscar-Berman, 1986; Goldman-Rakic, 1987a, 1987b).

Using autoradiographic techniques and prenatal surgery, Goldman-Rakic and her associates found that synaptic density in the monkey's prefrontal cortex proceeds rapidly in the last third of gestation and continues to increase, and in fact overproduce in comparison to adult levels, into the early postnatal months. After this period there is a decrease in synaptic density that continues slowly until adult levels are attained, sometime after the first postnatal year. The period of greatest synaptic excess occurs between 2 and 4 months and coincides with the emergence of the ability to perform the delayed response and AB tasks in infant monkeys. It is interesting that the corresponding period of synaptic excess in the frontal cortex of humans begins at around 8 months and reaches a maximum at about 2 years (Huttenlocher, 1979), which is the time frame wherein human infants master both the AB object permanence task and the delayed response task. The implication of this research for early memory development is that the period of neurological maturation that occurs in the prefrontal cortex between 8 and 24 months in the human infant may facilitate the child's ability to perform cognitive tasks that require him or her to access stored information represented in memory and to use it to guide problem-solving behavior. Moreover, Chugan and Phelps (1986), who used positron emission tomography to measure glucose utilization, reported the onset of a period of increased neurological functioning in the frontal cortex of infants between 8 and 18 months of age. However, the capacity to guide behavior by stored information is not fully mature by 4 months in monkeys or by 2 years in humans but continues to grow throughout childhood. Although speculative, it is possible that further maturation and fine-tuning of this function may be related to synapse elimination or "pruning" (see Greenough et al., 1987) or to other factors such as continued myelination, development of neurotransmitters, or improved synaptic efficiency.

The idea that improved synaptic efficiency during infancy may underlie changes in learning and memory was originally suggested by Hebb in 1949. It is enjoying a resurgence due in large part to recent research on the process of long-term potentiation (LTP), which is an enduring change in synaptic efficiency that occurs following the application of a stimulus (usually brief, high-frequency electrical currents) to the postsynaptic fibers. Recently, it has been demonstrated that LTP also occurs in conjunction with mastery of certain maze learning and conditioning tasks in rodents (Hargreaves, Cain, & Vanderwolf, 1990; Harris & Teyler, 1984; Komatsu, Toyama, Maeda, & Sakaguchi, 1981; Teyler & Discenna, 1984). Although LTP occurs in many areas of the brain, it occurs most readily in the hippocampal formation (Racine, Milgram, & Hafner, 1983) and, thus, may serve as a biological substrate of memory. Furthermore, there is evidence that the LTP capability of the hippocampal region increases as a function of age in rats and kittens (Harris & Teyler, 1984; Komatsu et al., 1981; Represa, Tremblay, & Ben-Ari, 1989).

More important, there is a sense in which LTP may represent the unifying process that underlies the formation of memories of all types (including procedural and declarative forms of memory; also see Squire, Shimamura, & Amaral, 1989). That is, "behavioral learning and memory systems throughout the brain may rely on LTP as the mechanism for changing the neuronal substrate to encode information. In this sense, memory quite possibly could be a unitary process at the neuronal level" (Teyler & Fountain, 1987, p. 707). However, research on LTP is recent and ongoing, and questions about its molecular basis, its time course, and its role in the development of memory are only beginning to be answered (for reviews, see Madison, Malenka, & Nicoll, 1991; McNaughton & Morris, 1987).

Summary. Overall, the evidence reviewed here indicates that neonates (and fetuses) can process and retain information in long-term memory for considerable periods of time. The picture painted in this review of recent research is quite impressive and indicates that the young memory system is operating at a level more optimal than previously believed. Obviously, then, the basic "hardware" for perception, learning, and memory must be in place and functioning at (or before) birth, although it continues to mature considerably over the first 2 postnatal years.

Given such an exceptional memory system so early in life, the question remains, what is the locus of infantile amnesia? Although the neurological data are difficult to interpret, at least with respect to human functioning, it is clear, on the one hand, that the evidence does not as yet support the contention that infantile amnesia is the result of an abrupt neurobiological change that either renders information more memorable or that obliterates previously laid down memory traces. On the other hand, it does seem apparent that there are some very real neurological constraints that probably set limits on how well infants perceive, learn, and remember, particularly in the first year of life. Although the setting of such limits is neither informative about the disappearance of infantile amnesia nor directly relevant to its time frame, it is interesting that it is in these early months that infants can process most of the features in a visual display (at least those used to date), albeit the specificity of the cues necessary to retrieve memory traces increases with age, as does the use of contextual information.

Although it is true that more and better encoded features lead to more robust and longer lasting memory traces (e.g., Howe & Brainerd, 1989), the quantity and quality of featural encoding that even young infants engage in appear to be sufficient for the establishment and retention of long-term memory traces over days, weeks, and even months. Because this occurs despite the (rather broad) limits set during neurological and perceptual maturation, we believe the source of any infantile amnesia will most likely be located in the cognitive advances that are made early in infancy and childhood. Because infantile amnesia is associated not only with events in early infancy but also with events that transpire after 7 months and into the early preschool years, we turn now to an examination of the maturation of memory after the first 6 months.

Memory Development From 7 Months Through the Preschool Years

The sophistication and variety of memory-related behaviors increase dramatically in the succeeding months (from 7 or 8 months to 48 months and upward). In what follows, we review evidence from a number of sources that documents the rapid advances in both the development and expression of memory in the early years. We begin by providing a brief overview of memory as exhibited in deferred imitation and search and spatial location tasks. We then turn to recent findings concerning children's memory for events.

Deferred imitation. Meltzoff (1990) recently argued that if there is more than one memory system involved in memory development (e.g., Mishkin et al., 1984; Pillemer & White, 1989; Schacter & Moscovitch, 1984), then the higher order (nonhabit, nonprocedural) system must be present in the first year of life. Although important changes take place in this system (e.g., there may be a shift from empirical to hypothetical representations, the use of words to encode events, etc.; see Meltzoff & Gopnik, 1989), the basic system is operative probably within the first 9 months of life.

This claim is based on Meltzoff's work with infants' deferred imitation. Here, infants are shown an adult moving an object in a specific, unique manner for a brief (20-s) period of time. The infants are not allowed to handle or manipulate the object themselves. Following a 24-hr delay, the infants are re-presented the toy, and the question is whether they will repeat the unique action they saw the adult perform the previous day. The answer is yes; the existence of deferred imitation for novel action sequences, witnessed but not performed by subjects 24 hr earlier, has been demonstrated in 9-, 14-, and 24-month-old infants (Meltzoff, 1985, 1988a, 1988b, 1990). In fact, some infants exhibit deferred imitation up to a week later.

There are several important features of Meltzoff's task that lead to his conclusion that performance is mediated by a higher order memory system. For example, demonstrations of habit–procedural memory typically involve lengthy acquisition phases in which the to-be-learned pattern is well practiced by the subject. In the case of deferred imitation with infants, not only is the acquisition period brief (20 s) but also it does not involve any physical practice (infants merely watch another person perform a novel behavior). As Meltzoff (1990) pointed out, it strains credulity to suggest that infants' success on this task could be mediated exclusively by a habit–procedural memory system. Thus, although few studies have been conducted in this area to date, Meltzoff's work clearly shows that even young infants are capable of storing abstract representations of action sequences in long-term memory, not simply learned motor responses.

It is interesting to note that this interpretation of Meltzoff's work in terms of a higher order memory system is consistent with the work of Goldman-Rakic and her associates (discussed earlier) on the relationship between development of the prefrontal cortex in infants and their ability to perform delayed response and Piagetian AB tasks. Meltzoff's delayed imitation task bears at least a superficial resemblance to these tasks in that the subject is also required to recall previously stored information and to use it to guide responding when re-presented with the toy. Furthermore, the age at which infants first engage in deferred imitation parallels the time frame in which they become proficient at delayed response and AB tasks.

Search and spatial location. It is now clear that even 8- and 9-month-old infants have sufficient memory and problem-solving skills to successfully search for and retrieve hidden objects (e.g., Baillargeon & Graber, 1988; for a review, see Willatts, 1990). Studies with children ranging in age from 1 to 5 years have revealed that performance increments may not be due to any increase in memory per se but rather to a growing sophistication in search skills. For example, DeLoache and her colleagues found that older children (24 to 30 months) are better than younger children (18 to 22 months) at using cues (landmarks such as a piece of furniture; DeLoache & Brown, 1983, 1984) as well as strategies such as rehearsal (talking about the objects), monitoring (pointing to the locations and watching), and spatial categorization to aid in the retrieval of hidden toys (DeLoache, Cassidy, & Brown, 1985; DeLoache & Todd, 1988).

Studies of 3- and 4-year-old preschoolers' ability to use location information in the retrieval of objects in large-scale environments have also indicated that young children can use spatial context to facilitate recall (Hazen & Volk-Hudson, 1984). Cornell and Heth (1983) demonstrated that spatial information is effectively used by 1-, 3-, and 5-year-olds to search a familiar area (their living rooms at home) for hidden objects. It is interesting that 1-year-olds' search strategies were affected by the sequential nature of where objects were hidden (with search starting at the most recent hiding place), whereas for 3- and 5-year-olds, serial order was supplanted by spatial proximity (to self) strategies. Like the work of DeLoache and her colleagues, this research indicates that it is not memory for context and objects that increases with age but rather the type of search strategy that is used.

Memory for nontraumatic events. In their 1989 review of childhood amnesia, Pillemer and White stated that "attempts by preschool children to recall past events on demand—even events of the previous day—frequently are unsuccessful by adult standards" (p. 298). However, we contend on the basis of our review of studies of preschoolers' event memory that the results strongly suggest quite the opposite. For example, Hudson and Nelson (1986) found that differences in 3-, 5-, and 7-year-olds' autobiographical recall were restricted to the length and elaborateness of the narratives, which indicates more of a language than a memory limitation. Indeed, these authors suggested that "children organize and retrieve autobiographic memories in much the same way as do adults" (p. 253). In this section, we review the literature on children's memory for nontraumatic events that occurred naturalistically or were experimentally contrived. In all cases, the evidence clearly indicates that even very young preschoolers' (e.g., 2-year-olds') memory for events is successful, even by adult standards. As we will show later, the evidence is so overwhelming that the question concerning the onset of infantile amnesia looks more and more like a nonsequitur.

Studies of children's autobiographic recall of naturally occurring events have clearly established that (a) children as young as 2 years can recall episodes for at least 6 months (e.g., Fivush et al., 1987; Hurlock & Schwartz, 1932; Nelson & Ross, 1980) and (b) 3-year-olds can produce spontaneous (e.g., Umiker-Sebeok, 1979) or elicited (e.g., Todd & Perlmutter, 1980) well-structured narratives of previous events (Mandler, 1983). In fact, 3-year-olds provide well-organized, coherent, and accurate recollections not only of routine events such as going to McDonald's or grocery shopping (for a review, see Nelson, 1986) but also of unique, one-time events (Fivush, Hudson, & Nelson, 1984; Hudson & Nelson, 1986; Todd & Perlmutter, 1980). More recently, Fivush et al. (1987) demonstrated that 2-year-olds also provide coherent narrative accounts of past events regardless of whether those events occurred in the recent (e.g., 3 months ago) or distant (e.g., 6 months ago) past.

Although memory for events appears to be quite accurate even in 2-year-olds, there is an interesting suggestion that objects in the event sequence, but not the event itself, may be subject to more forgetting, especially in younger children (Jones, Swift, & Johnson, 1988). In a study of memory for preschool events (where the retention interval ranged over a 5-year period, cross-sectionally), Myles-Worsley, Cromer, and Dodd (1986) found that whereas recall for the sequence of events was relatively accurate, recall for some specific details tended to be reconstructed from general knowledge of schools rather than recalled directly. Thus, although autobiographical memory for events appears to be quite robust, some specific components of the events or objects themselves may fade from memory and be recalled through the process of reconstruction, a tendency that is not unique to the preschool years (for a review, see Howe & Brainerd, 1989).

Similar conclusions concerning the reliability of event memory in very young children have emerged from studies examining the recall of experimentally contrived episodes (e.g., Myers & Mervis, 1989). Remarkably, there is clear evidence that young infants can retain experiences for months or even years. For example, Cutts and Ceci (1989) found that infants between 8 and 18 months could remember to remove a puppet's glove to retrieve a hidden treat 4 months following training. Bauer and Shore (1987), using a deferred imitation procedure, demonstrated that 16-month-olds could reenact event sequences that were familiar (e.g., washing a bear in a bathtub) or novel (e.g., placing a ball in a cup and forming a shaker using another cup and "rattling" it) following a 6-week delay. As well, Fivush and Hamond (1989) found that 2-year-olds could recall play sequences following a 3-month delay. Moreover, as in previous naturalistic studies, children in Fivush and Hamond's experiment tended to be better at remembering the action than the object components of the event (see also recent studies by Bauer & Mandler, 1989, and Bauer & Thal, 1990).

A number of investigators have examined young children's memories of specific events that occurred during infancy. For example, Myers, Clifton, and Clarkson (1987) found that children who were almost 3 years old remembered laboratory procedures that had occurred when they were 6–40 weeks old! McDonough and Mandler (1990) found significantly better recall of action sequences in groups of subjects who participated in an experiment when they were 11 months old and returned to the lab 1 year later than in an age-matched control group. Perris, Myers, and Clifton (1990) tested memory of 1.5- and 2.5-year-olds for a single laboratory experience that occurred when they were 6.5 months old. Using both nonverbal and verbal measures of recall, Perris et al. found that memories laid down at 6.5 months were retained for 2 years. It is interesting that the nonverbal measures were superior to the verbal ones, a finding similar to that reported by Terr (1988; see following discussion). These results are particularly important because they provide a particularly clear demonstration that "2 years of physical, neurological, and cognitive changes do not prohibit retrieval based on the infant memory processes" (Perris et al., 1990, p. 1805). Indeed, when even more sensitive indexes of memory are used (e.g., the savings–relearning paradigm), the residue of early experience is more robust against forgetting than initially thought (Perris & Myers, 1990).

Although the results of these studies indicate that toddlers and preschoolers remember something of the events that occurred in their infancy, exactly what it is that they remember remains an empirical question. When children are old enough to narrate about these events in relation to themselves, at about 2 to 3 years of age, it is clear that the events have been organized autobiographically in memory. If, however, their recognition (recall) of prior events is nonverbally expressed or limited to single words (as was the case in the studies just described), we cannot be sure that their behavior reflects anything more than simple conditioned responding to discriminative stimuli cued by the current situation. This is certainly not unimportant, and it attests to the pervasive and lasting effects of early experience. However, we argue that events that occur before the child develops an independent sense of self at about 18 months of age cannot be organized autobiographically but will probably be coded in memory as a more generalized learning experience. The very striking finding revealed by these studies that very young children indeed remember certain aspects of their infant experiences should not overshadow the fact that what they actually remembered was incomplete and oftentimes quite fragmentary.

Memory for traumatic events. Reasonably accurate memory has been found in children's recollections of traumatic or stressful events (for an intriguing case study of recall of an event that occurred at 3 months of age, see Bernstein & Blacher, 1967). Goodman, Aman, and Hirschman (1987) reported two studies of preschool children's remembrances of traumatic or stressful events, one involving venipuncture (blood drawing) and the other involving experiences at an immunization clinic. After varying delay intervals, children were asked to free recall the event, answer questions, and identify the nurse or technician involved from a six-person photo lineup. In general, there were few age differences in recall of the events and recall was quite accurate, tending not to deteriorate over time. It is interesting that in a similar series of studies, Goodman, Hirschman, Hepps, and Rudy (1991) found that high levels of stress actually benefited recall. They argued, following Gold (1987), that recall is enhanced under stressful circumstances because of the release of adrenaline, a process that is believed to facilitate memory consolidation.

In a comprehensive examination of children's memory for traumatic events, Terr (1988) interviewed 20 children who experienced trauma (e.g., sexual abuse, accidents involving severe injury, death of a parent, and so on) prior to age 5 years. She examined both verbal and behavioral (reenactment of the event) indexes of memory for these events and found that (a) verbal memories tended to be poor if the event occurred prior to age 28 months, although girls were better than boys at verbalizing memories prior to 28 months; (b) short, single traumas were most likely to be recalled verbally; and (c) regardless of age at the time of the event, behavioral indexes of memory were accurate. Although these events had been previously reported (e.g., to the police) and some may view behavioral indexes of memory with some trepidation, it seems clear that, in keeping with Goodman et al.'s (1991) findings, traumatic events remain in memory even after a number of years have passed.

Summary. What this overview has shown is that memory from 7 or 8 months of age to the preschool years is remarkably stable and accurate. Contextual and spatial information is encoded and used to facilitate retrieval and memory for events, even in 2-year-olds, and is robust for at least a 6-month period. Although reconstructive tendencies exist in recall narratives (as they do in most children's and adults' recall), the gist and sequencing of information in events remain preserved in long-term memory.

With such a robust memory system in these early years, it is curious that memories from this era should suddenly become inaccessible (or unavailable). More specifically, at exactly which age do children (or adults) fail to recall events that, according to the evidence reviewed here, could be remembered at the time they occurred and up to several months or years after they occurred? With this review of very early memory development as background, we turn now to a reanalysis of this question.

A Reevaluation of the Nature of Infantile Amnesia

In contrast to the explanations of infantile amnesia that emphasize storage or retrieval difficulties or both, Pillemer and White (1989) proposed that infantile amnesia could best be understood in terms of two functionally independent memory systems. The first, a primitive system present from birth, contains fragmentary information, emotional associations, learned routines, and generalized past experiences that are not linked to specific events. The contents of this system are evoked by situational and affective cues and can be expressed behaviorally but not verbally. The second system emerges slowly throughout the preschool years and contains information that is specific to time and place, which the child experiences as autobiographical. These personal memories can be accessed on demand and communicated verbally. Pillemer and White argued that it is the immaturity or absence of this second, socially accessible, system that accounts for adults' inability to recall events of their early childhood years.

Although the development of this second memory system is at the root of the offset of infantile amnesia, Pillemer and White (1989) claimed that this memory system develops with the acquisition of language. Specifically, when children begin to talk they can communicate about their personal experiences. Although these initial accounts are usually replies to direct requests for information from adults or emerge from conversations in which the adult provides "scaffolding" or structure for the exchange, repeated experience with such conversational exchanges enables the child to gradually direct his or her recall of events from self-generated cues. Thus, verbal exchange in the context of social interaction is important to the emergence of autobiographical memory. Coincident with these conversational interactions, the child is developing elaborated scripts and schemata, an understanding of the causal sequencing of events, and the metamemorial knowledge that one of the social functions of memory is to communicate about the events of one's past.

Although we agree that social, emotional, and linguistic factors play an important role in the maturation of memory in general and autobiographical memory in particular, it is not clear that we need to posit more than a single memory system to account for the developmental gains that accrue across childhood. Indeed, as pointed out earlier (see the section *Neurological and perceptual changes and early memory development*), we contend that little compelling evidence attests to the existence of multiple memory systems of the sort envisaged by Pillemer and White (1989). In our view, they prematurely rejected what we consider to be the more parsimonious notion that memory develops as a unitary and continuous system across childhood, with the acquisition of language and, more particularly, as we argue later, the acquisition of a well-articulated self concept providing an additional mnemonic device capable of organizing personal experiences and providing an outlet for the expression of event memory.[2]

[2] It should be noted that although our comments are directed specifically at issues concerning the development of memory, as well as the dual-process system proposed by Pillemer and White (1989), we recognize that they may be interpreted by some as addressing the more general question of whether memory per se is best conceived of as a single, unitary system or as a series of multiple, interdependent systems. It is important in this latter context to underscore that we concur with Polster, Nadel, and Schacter's (1991) observation that "although

In addition, as we have reviewed, there is considerable evidence that the changes necessary to support an autobiographical memory system (including coding of sequential and temporal information) emerge considerably earlier than Pillemer and White's (1989) theory would have us believe. For example, it is well known that sensitivity to temporal order is present by at least 3.5 to 5 months of age (Haith, Hazan, & Goodman, 1988). Although it is unclear whether this sensitivity to temporal order is the same as the mature ability to sequence events temporally, it certainly seems to be a prerequisite. Furthermore, children as young as 16 months can organize representations of events sufficiently well to enable delayed recall (Bauer & Mandler, 1990). Indeed, a number of skills thought to be mnemonic prerequisites for the disappearance of infantile amnesia in most memory-based theories of this phenomenon are in fact present in children, at least in some form or another, significantly prior to the actual offset of infantile amnesia.

Clearly, in both a historical and present-day context, theories about the fate of early experiences rely heavily on the notion that memory somehow changes with age, becoming more durable (storage explanation) or sociolinguistically accessible (retrieval explanation). Although we neither disagree that ontogenetic changes in memory occur nor dispute the fact that language plays an important role in the expression, organization, and maintenance of autobiographical memory, we argue that a more fundamental change—namely, the development of the self-concept—has cognitive preeminence in foreshadowing the offset of infantile amnesia. However, before turning to an outline of the nature of the development of this critical self-concept and its relationship to the waning of infantile amnesia, we need to consider a number of methodological issues.

Consider the prototypical infantile amnesia study. Here, adults are asked to verbally free recall events from their past (e.g., Kihlstrom & Harackiewicz, 1982), or specific events with a known date in the subject's past (e.g., birth of a sibling) are probed (e.g., Sheingold & Tenney, 1982). Regardless of which procedure is used, the average age of the earliest memory is typically said to be around 3 years. Consistent with this formulation, Wetzler and Sweeney (1986) showed that the slope of the forgetting function for adult remembrances of early childhood events tends to be steeper for the preschool years than for later childhood. There are a number of reasons why conclusions such as these are fraught with considerable peril. First, a careful examination of the literature reveals that there are marked differences in the reported age of the earliest memory. For example, there are several studies in which probed or targeted recall of early events has been used to show that the offset of infantile amnesia occurs consistently earlier than previously thought (i.e., 2 years instead of 3) and tends to be much more gradual than previously reported (e.g., Usher & Neisser, in press; Winograd & Killinger, 1983). Although these differences may be due to variations in the way different investigators operationalize what constitutes an early memory, there does appear to be solid evidence from most studies that memories are available for many individuals from the age of 2 years.

Second, the variability in the reported offset of infantile amnesia may arise in part because the task from which these data emerge is very curious. For example, perhaps failures of recall, especially when specific events are probed, are failures to encode the original event in question. That is, we may be asking subjects to recall events that were never recallable in the first place. Of course, just as there is no evidence that the probed event was ever recallable, there is no assurance that it was salient to the child to begin with. Whereas the birth of a sibling (see Sheingold & Tenney, 1982) clearly seems to be a momentous occurrence by adult standards, the real question is whether it is similarly important to children. In fact, when asked, children often do not find this event particularly interesting or noteworthy (Fivush et al., 1987; also see Usher & Neisser, in press).

A third problem is that we are asking subjects to provide a verbal account of memories that were, in all likelihood, laid down prior to the use of language in memory. Perhaps it is more than coincidental that the presumed onset of infantile amnesia is also the point at which language terms are just beginning to be relatively automatically encoded simultaneously with experience. Perhaps language confers nothing more significant than simply adding a verbal code that can be used as an access code at retrieval. However, if these early memories are encoded in a primarily nonverbal fashion, then by many current encoding-specificity accounts of memory (e.g., Ackerman, 1985), such memories are most likely to be retrieved and expressed nonverbally. We have already seen that such experiences are perhaps best recalled using nonverbal expressions of memory (Perris et al., 1990; Terr, 1988). In fact, contrary to Pillemer and White's (1989) claim that children should be able to translate initially nonverbal experiences into verbal ones, there is no reason to suppose that nonverbal experiences should be recoded verbally, because their utility and meaning may lie in the experience, not in a narrative of the experience (see also Nisbett & Wilson, 1977; Reber, 1989). Because we know more than verbal reports reveal, not only in childhood but also in adulthood (e.g., Nisbett & Wilson, 1977), it behooves us to examine other, nonverbal indexes of memory expression (also see Spear, 1984).

Curiously, Pillemer and White (1989) restricted their definition of childhood amnesia to failures in narrative recall.

> As defined in this paper, childhood amnesia refers to the paucity of narrative accounts of early autobiographical events. This definition excludes all memories that are not accompanied by conscious and verbally communicable knowledge of having experienced the event before, in one time and one place. (p. 321)

Unfortunately, this definition excludes most memories of early childhood, at least to the extent that they were encoded nonverbally. In fact, the requirement that the memory be both verbal

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the evidence for some form of multiple memory systems hypothesis is compelling to many, a number of cognitive psychologists have claimed that it is not necessary to postulate different memory systems, preferring instead the idea of a single but flexible memory system" (p. 110). Although we believe that a unitary memory system approach provides a more parsimonious account of memory and its development (also see Howe & Brainerd, 1989; Jacoby & Kelley, 1987; Roediger, 1990), we acknowledge that extant data fail to provide unequivocal support for either the unitary or multiple systems views of memory. However, we contend that until definitive data are available, the time-honored principle of parsimony (in this case, a single rather than multiple memory system) should prevail.

and conscious is too restrictive because it is not clear that consciousness is necessary for the encoding of memories or their (automatic) retrieval.

The issue of how to measure the expression of memory, other than by verbal recall, has been a thorny issue for some time (see, especially, Spear & Isaacson, 1982). Currently, many researchers are of the opinion that the requirements that expressions of memory be "verbal and conscious" are unnecessary. In addition to the obvious areas in which such a definition does not hold (e.g., animal[3] and human infant research), investigators examining children's memory (e.g., Howe & O'Sullivan, 1990), human amnesic syndromes (e.g., Shimamura, 1990), and the aging of implicit and explicit memory (e.g., Howard, 1988) and activity memory (e.g., Kausler & Lichty, 1988) have also rejected "verbal and conscious" as necessary components in the expression of memory.

The exclusionary nature of this definition is particularly bothersome in the current context. If we accept the idea that early nonverbal event memory (primitive and fragmentary though it may be) provides the foundation on which autobiographical memories are built, then to say that autobiographical memory itself must be primarily verbal is to neglect a fundamental aspect of these memories. Furthermore, if we constrain our definition of these memories by requiring verbal, conscious recollection, then preverbal infants cannot, by definition, have event (or autobiographical) memory. Because it is this group (human infants) to which the problem of infantile amnesia applies, it is more than worrisome that although they cannot recall the experiences in a verbal and conscious manner at the time they experienced them they are then expected to do so in the future.

Because no one would argue that memory operates in an exclusively conscious or verbal mode, especially early in life, infantile amnesia may be a chimera, an epiphenomenon rather than a phenomenon. Clearly, our review has shown that infants from 3 months of age and upward exhibit memory, albeit nonverbal, for events that occurred weeks, months, and even years earlier. We also showed that preschool children, even 2-year-olds, similarly remember events for considerable periods of time, both nonverbally and verbally (once language is available). Although we certainly do not claim that memory development is complete early in life, we do claim, and have amply demonstrated, that it is sufficiently mature to support the types of encoding, storage, and retrieval necessary for long-term retention.

Reframing the Problem of Infantile Amnesia

It is clear from this review that memory is more sophisticated in infancy than previously thought. It is also true, however, that autobiographical memory (i.e., personal memories of specific events coded with respect to time and place) apparently emerges later (i.e., around 2 years of age) than the "simpler" memory infants have of events (i.e., reaching for a "sounding" object as in the Perris et al., 1990, study or the foot-kick response used by Rovee-Collier and colleagues). The emergence of personally coded memories, we believe, does not herald some structural–functional change in long-term memory, as is so often assumed, but rather is the result of basic developments in the establishment of one's self-concept. Although neurobiological maturation is an important factor underlying many of the cognitive changes during infancy, its relationship to cognitive functioning per se remains elusive. Therefore, the conclusion that the "software," not the "hardware," may be the primary source of change in memory development is not entirely radical and, in fact, is completely consistent with more general theories of how memory develops. For example, our proposal about infantile amnesia is consistent with more global theories of memory development in which improvements in memory functioning are brought about by corresponding changes in a number of processing rather than architectural features (e.g., strategies, categorization, schemata, knowledge, resource allocation; see Howe & O'Sullivan, 1990, for a review). What is unique is that we are proposing that developments in cognition about the self are what brings an end to infantile amnesia. Because, by definition, autobiographical memory is memory for information and events pertaining to the self, it is only with knowledge of one's self as an independent entity that experiences can be organized in memory as personal or autobiographical. In effect, we are claiming that the development of the self-concept (or self-schema), like that of other schemata, has a dramatic impact on the way in which memories are organized (encoded, stored, and retrieved), not on the structural components of memory itself. It is not until the development of the self achieves a "critical mass" that we witness the emergence of autobiographical memory. In the remainder of this article, we sketch what is known about the early development of the self, including the emergence of self-relevant language, and outline a theory of how these developments usher in the appearance of autobiographical memory.

Cognitive Development of the Self

Although speculation about the nature and function of the self has a long history, it has remained a slippery and elusive concept, defying precise definition (see Damon & Hart, 1988, for a discussion). However, over the years there has been a consensus among theorists from diverse perspectives that in the

[3] Although there is a literature on infantile amnesia in nonhuman species (for reviews, see Nadel & Zola-Morgan, 1984; Spear, 1979), we have not included it in our review. We believe that the phenomenon called *infantile amnesia* in these species is fundamentally different from the inability to recall the events of infancy that defines infantile amnesia in humans. Two points are of note. First, in nonhuman populations, infantile amnesia is defined as any deficit in retention that is associated with immaturity (Spear, 1979). As we have noted in several places throughout our review, there are many such deficits in human infants that gradually diminish throughout the course of cognitive development. However, infantile amnesia refers to a specific type of deficit—the inability of the mature human to recall events time-locked in the first few years of life despite the fact that memory during those early years is quite robust and that these same adults can readily recall early events that occurred after this "amnesic" period. The second point is that the period of infantile amnesia in nonhuman species is closely correlated with maturation of the central nervous system and offsets with the completion of certain critical structures. As we have already reviewed, there is no evidence that a similar parallel exists in humans.

early weeks of life infants are unaware of their separateness from the surrounding environment and that only following a gradual process of individuation do they achieve such awareness (Bowlby, 1969; Freud, 1915/1959; James, 1892/1961; Mahler, Pine, & Bergman, 1975; Mead, 1934; Piaget, 1954). This view has recently been echoed in a special issue of *Developmental Review* (Kopp & Brownell, 1991) devoted to the early development of self. Here, the contributors agreed that there exists a primitive, presymbolic self that serves as the foundation for subsequent representations of the self. Furthermore, historically, most have acknowledged that there exist at least two fundamental facets of the self—the "I," a subjective sense of the self as a thinker, knower, and causal agent, and the "me," an objective sense of the self endowed with the unique and recognizable features and characteristics that comprise one's self-concept. Although intuitively distinguishable, these two aspects of the self are intimately and complexly related in a manner that is currently being investigated in both theoretical and empirical domains (Bullock & Lutkenhaus, 1990; Case, 1991; Cicchetti, 1991; Damon & Hart, 1982, 1988; Emde, Biringen, Clyman, & Oppenheim, 1991; Harter, 1983; Lewis, 1991; Lewis & Brooks-Gunn, 1979; Neisser, 1991; Pipp, Fischer, & Jennings, 1987).

Given the formidable challenge of tracing the origin and development of the intangible self in the inscrutable infant, an impressive beginning has been made. With elegant simplicity, researchers have recorded the behavior of infants to their visual images in mirrors, on videotape, and in photographs. The self-image has proven to be a compelling stimulus for the young infant, and its use as a research tool has opened a powerful window on the ontogeny of self-recognition. Before briefly reviewing this literature, we should note that self-recognition is only one facet of the self-concept, one that is relatively easy to operationalize for research with infants. The self-concept implies much more than recognition of one's physical features and is a fundamental aspect of social cognitive development that continues to evolve throughout childhood and adolescence (see Damon & Hart, 1988, for a review). We return to this point later.

The basic research on the development of visual self-recognition has involved measurement of infants' reactions to their mirror images (Amsterdam, 1972; Berenthal & Fischer, 1978; Bullock & Lutkenhaus, 1990; Darwin, 1877; Dixon, 1957; Johnson, 1983; Lewis & Brooks-Gunn, 1979; Lewis, Brooks-Gunn, & Jaskir, 1985; Lewis, Sullivan, Stanger, & Weiss, 1989; Pipp et al., 1987; Preyer, 1893; Priel & De Schonen, 1986; Schulman & Kaplowitz, 1977). Collectively, these reports have documented that from about 3 months of age infants are both attentive and positive toward mirrors. They respond by smiling, bouncing, vocalizing, and reaching toward the image. Beginning at about 9 months, they show awareness of the contingency cues provided by the tandem movement of the image with themselves and use such cues for deliberate play and imitation. They also know something of the reflective properties of mirrors and will turn to locate spatially objects and people that they see reflected. However, full self-recognition of the mirror image as their own is not apparent in most infants until they are about 18 months of age. At this time they first respond to a spot of rouge that has been surreptitiously applied to their noses by touching their own noses rather than the mirror image, clearly indicating that they have a schema for their faces that does not include a red spot. Coincident with mark-directed behavior, infants begin to show self-consciousness (shy smiling, gaze aversion, and self-touching) when confronted with their images, and by about 22 months of age they will correctly label the image. Although self-consciousness and labeling do not on their own provide evidence of self-recognition, their co-occurrence with mark-directed behavior toward the spot of rouge provides a consistent picture of an infant who recognizes the mirror image as "me."

It is interesting that a lively interest in mirrors has also been reported in species of fish, birds, and mammals (see Gallup, 1979, for a review). Most of these creatures respond toward the image as if it were a conspecific and direct both social and antisocial behavior toward it. Nonhuman primates, given a period of exposure to mirrors, will also respond to the contingent movement cues and use the reflective properties of the mirror to locate objects. However, only chimpanzees and orangutans demonstrate self-recognition when rouge is placed on their faces. As Lewis and Brooks-Gunn (1979) pointed out, this is a striking and intriguing discontinuity between the great apes and the lower primates, the meaning of which is speculative.

Subsequent research by Lewis and his colleagues (see Brooks-Gunn & Lewis, 1984, for a review) clarified the relative importance of movement-contingent and featural cues in the self-recognition process. They recorded infants' responses (attention, interest, imitation, affect) to live and prerecorded videotapes of themselves and to a prerecorded tape of a same-sex peer. They found that whereas 9-month-old infants discriminated between contingent and noncontingent videos of themselves on some of the measures, it was not until about 18 months that most infants began to show discrimination between the noncontingent videotapes of themselves and the peer, the discrimination not being evident on all measures until about 24 months. This discrimination between noncontingent self and peer could only have been made on the basis of featural recognition. Lewis argued that it is recognition of the self on the basis of features, independent of contingency cues, that is the hallmark of full self-recognition. Perhaps not surprisingly given the language limitations in infants of this age, correct labeling of the self from photos in a self–peer comparison is not evident until somewhat later, at about 22 months of age. However, if allowed to respond nonverbally, many 18-month-olds are able to point to their photo from among a group of peer photos.

Although the developmental trends for self-recognition in the second year of life are quite consistent, substantial individual differences have been noted. For example, Lewis and Brooks-Gunn (1979) found that whereas some of their 15-month-old subjects showed mark-directed behavior to the red spot, others did not show self-recognition until the end of the second year. Although these individual differences have not been fully explored, they are believed to be a function of both social interaction and cognitive developmental variables. For example, Lewis et al. (1985) reported that whereas general measures of social experience such as mother's education, family socioeconomic status, birth order, and number of siblings were unrelated to onset of self-recognition, security of attachment was related. Insecurely attached infants showed earlier self-recognition than did securely attached infants, a finding that the authors explained in terms of the insecure infant's earlier separation from the caretaker (but see Schneider-Rosen & Cicchetti, 1991). In another study, Brooks-Gunn and Lewis (1984) found that recovery to a novel stimulus following habituation was related to onset of self-recognition, with the infant's ability to notice subtle stimulus change suggested as the causal link. Delay in cognitive development is also associated with delay in self-recognition. Mentally handicapped and autistic infants and children do not show self-recognition at least until they have achieved a developmental age of about 18 months, regardless of their chronological age (S. D. Hill & Tomlin, 1981; Loveland, 1987; Mans, Cicchetti, & Sroufe, 1978; Spiker & Ricks, 1984).

The convergent evidence from the research on infants' responsiveness to their images in various visual media indicates that by about 18 to 24 months of age infants possess an important piece of self-knowledge, the ability to recognize their physical features. However, before discussing the significance of this knowledge for autobiographical memory, two issues must be addressed. The first concerns the validity of visual recognition as the sine qua non of self-recognition. One could argue that because vision is poorly developed at birth and slower to mature than the other senses (Salapatek & Cohen, 1987), other modalities (e.g., auditory, olfactory, proprioceptive) might provide better or earlier indexes of self-recognition. Several interesting findings are pertinent. For example, Simner (1971) found some evidence that infants can recognize their own cry in the early weeks of life. Also, Priel and De Schonen (1986) reported no age difference in the onset of self-recognition between a sample of Bedouin infants who had never seen their facial images prior to testing with mirrors and a sample of babies who had prior mirror experience. Clearly, the Bedouins were able to construct a body image from sensory cues that they could coordinate and map onto the visual stimulus provided by the mirror. It is interesting that the performance of the Bedouin babies stands in marked contrast to that of a group of blind children, who showed no recognition of self in language or imaginative play until they were 4 to 5 years old (Fraiberg, 1977). Thus, vision may be uniquely suited to synthesize information about the self provided by other modalities, and its absence in the blind child significantly delays this achievement. At the very least, then, the face is an important representation of the self, and its recognition in the mirror is a reasonable operational criterion of self-recognition. Furthermore, from a practical perspective, infants are very responsive to face stimuli from birth, are able to discriminate among faces from about 3 months, and become increasingly sophisticated in processing information provided by faces in subsequent months (Maurer, 1985).

The second and more difficult issue concerns the significance of self-recognition in the broader picture of the emerging self. Specifically, what does self-recognition imply beyond knowledge of one's physical features? Lewis and his colleagues (Brooks-Gunn & Lewis, 1984; Lewis & Brooks-Gunn, 1979) argued that although their procedures directly assessed only one aspect of the self in one modality, infants' recognition of their images as their own implies more than simple discrimination of body features and presupposes an existing (albeit rudimentary) knowledge of a self that is continuous through time and space, a sense of the self as "I." They proposed that the infant's sense of self, of which self-recognition is only a part, evolves for many months prior to mirror recognition. The infant first develops an existential sense of "I," which gradually emerges from the numerous contingent interactions that take place between infants and their physical and social environments. Feedback from such encounters facilitates the development of a sense of the self as a controller of action and is clearly evident in the mirror studies when 9-month-olds use movement-contingent cues for deliberate play and imitation. Lewis did not deny that this existential sense of self as causal agent could be present even earlier. Indeed, Piaget wrote extensively on the emergence of circular reactions in the early months of the sensorimotor period, and more recently, evidence such as that of Rovee-Collier and her colleagues (e.g., Rovee-Collier & Hayne, 1987) clearly shows 2-month-olds in control of the movement-contingent action of an overhead mobile. Lewis further stated that this knowledge of the self as the subject of experience is a logical prerequisite to an understanding of the self as object, the categorical "me" with recognizable features and characteristics that is first evident at about 18 months in the mirror-image paradigm. This early sense of self facilitates the acquisition of more comprehensive self-knowledge as the child continues to define himself or herself in relation to others for some years to come.

Although cogently argued and quite possibly correct, this treatise on the early development of the self goes well beyond the data on visual self-recognition and serves to illuminate certain longstanding theoretical issues central to the development of social cognition in infancy. Although detailed discussion of these is beyond the scope and purpose of this article, two of these issues that have recently been investigated empirically are of note. The first concerns the definition of and relationship between "I" and "me" and their development over time. Although historically it has been assumed that these concepts evolve in an interactive fashion, it has recently been suggested that they may follow different developmental paths (Bullock & Lutkenhaus, 1990). The second issue concerns the emergence of knowledge of the self and knowledge of others, the primary question being whether they emerge simultaneously (Lewis & Brooks-Gunn, 1979) or whether knowledge of the self precedes (Piaget, 1962) or is derived from (Mead, 1934) knowledge of the other. Recent research with infants suggests that the answer may depend on the domain of the self (I or me) that is assessed by a particular measure (Pipp et al., 1987).

To date, the issue of precisely how the sense of self emerges in infancy is unresolved. What is clear and is relevant to our thesis that a sense of self is basic to the development of autobiographical memory is that by 18 to 24 months the infant has a concept of himself or herself that is sufficiently viable to serve as a referent around which personally experienced events can be organized in memory. Indeed, there is a recent consensus that a significant shift in one's sense of self occurs at about this time (see contributions to the special issue of *Developmental Review* "Development of the Self," 1991). Although the exact nature of this change remains elusive, it is clear that the self at this point achieves the "critical mass" necessary to serve as an organizer and regulator of experience (also see Emde et al., 1991). Although recognition of certain features of the self may emerge even earlier via other modalities, extant empirical evidence points to the latter half of the second year as the likely time frame. The fact that this period corresponds with the onset of autobiographical memory is, we believe, more than mere coincidence and makes this estimate a reasonable one.

Corresponding Developments in Language

The concept of the self receives further elaboration and refinement as children achieve mastery of language (e.g., Miller, Potts, Fung, Hoogstra, & Mintz, 1990), which enables them to think and talk about "I" and to expand their categorical knowledge of "me." Not surprisingly, these pronouns are the first that toddlers acquire at about 22 months of age, followed about 2 months later by "you" (Brown, 1973; de Villiers & de Villiers, 1978). Correct use of these pronouns is a challenging task that requires an inversion of point of view. The young child has to realize that he or she is "I" when speaking but "you" when spoken to and furthermore that other people can also be "I" and "you." Yet normal 2-year-olds rarely mix these up (de Villiers & de Villiers, 1978; Reich, 1986). The facility with which toddlers acquire correct pronoun use probably reflects in part their mastery of the sense of self as both subject and object and their awareness of the distinction between self and other. However, children who are handicapped by blindness or autism have great difficulty with correct pronoun usage and continue to reverse "I" and "you" well into the preschool years (Dawson & McKissick, 1984; Fraiberg, 1977; Kanner, 1946; Neuman & Hill, 1978). It is interesting that acquisition of correct pronoun use by blind children at about 4 or 5 years of age correlates with the onset of self-recognition as assessed in this population by identification of their own voices on tape and by the emergence of imaginative play. Furthermore, it is only when blind children acquire self-recognition and stable pronoun use that they begin to talk about past events (Fraiberg, 1977). However, autistic children, who also persistently reverse pronouns, do show mark-directed behavior on the rouge task. Thus, self-recognition may be a necessary but not a sufficient condition for stable pronoun use. Unfortunately, nothing has been reported on memory for events in these children.

It may also be important to know whether the individual differences in the onset of self-recognition in normal children noted earlier are correlated with the individual differences in the onset of pronoun use and memory for events. In any case, with the emergence of the sense of self, represented in sensory and linguistic modes, there exists a referent for the structuring of personally experienced events in memory.

The representation of the self in language is followed shortly by another important linguistic achievement, the use of markers that designate the past tense. This enables the child to describe events that have happened at an earlier time. Toddlers between 1 and 2 years old converse in one- and two-word utterances, but only about events that are in the present. Beginning at about 2 years of age, toddlers lengthen their utterances to include simple sentences of a subject-verb-object construction, and they begin to add grammatical morphemes to their repertoire (Brown, 1973; de Villiers & de Villiers, 1978). The first morpheme to appear is the present progressive verb ending *-ing,* which may reflect the child's first distinction between events that have been completed and those still in progress (Sachs, 1983). Next, children begin to talk directly about events in the past, first using irregular verb forms (*ran, broke*) followed shortly by regular verb forms (*-ed*). Brown (1973) argued that this shift from the "here and now" to the "there and then" is an important transition in early child language.

However, children's comprehension and use of the past tense continue to evolve over an extended period of time. Sachs (1983) studied 1 child (Naomi) longitudinally, when she was between 11 and 36 months old. Predictably, Naomi's early conversations referred only to events in the present. However, between 17 and 25 months she began to talk about events in the immediate past ("I did it," "I fell down") which, Sachs suggested, seemed to signal a change in state rather than past time. Not until she was between 26 and 31 months of age did she begin to talk about events in the earlier past, indicating a growing awareness of temporal relations in her use of such lexical items as *yet, already, still,* and *yestermorning.* However, Naomi's conversations about the past were closely prompted, or *scaffolded,* by the listener in order to elicit additional pertinent information. Only when she was between 32 and 36 months of age did she spontaneously and easily talk about the past.

With the acquisition of a self-concept symbolically represented in language and grammatical morphemes that mark the past, the child is ready to begin talking about past events in narrative form. Narrative has been defined as the recounting of specific events that occurred in the earlier past (at least several hours ago) and that contain at least two relevant utterances (Peterson, 1990). Beginning at about 2 years of age, children relate information about novel and routine events in a coherent fashion (Fivush, Gray, & Fromhoff, 1987; Fivush, Hudson, & Nelson, 1984; Hudson & Nelson, 1986; Nelson, 1989; Todd & Perlmutter, 1980), although, as described by Sachs (1983), these early narratives are heavily scaffolded, with structure and prompts provided by the listener. Furthermore, Peterson (1990) reported that temporal references to the recent past (*yesterday, last night*), conventional references (*once, before*), and absolute time references (*last Saturday, a long time ago*) were slow to develop in children between 2 and 3.5 years old, at which time only about a third of the narratives contained any orientation to time at all.

In spite of these limitations, early narrative provides an outlet for autobiographical memory. However, McCabe, Capron, and Peterson (1991) cautioned that narrative is much more than memory and is strongly influenced by the nature of the event, the perspective of both speaker and listener, and the age of the narrator. For example, Fivush and Hamond (1990) found that 4-year-olds reported different (but accurate) information about events that had happened to them when they were 30 months old than they had reported at 30 months, shortly after the events occurred.

A number of writers have suggested that narrative is much more than an outlet for autobiographical memory, arguing that the root of infantile amnesia lies in the paucity of early language skills and the interaction of language and memory skills. For example, Nelson and her colleagues (e.g., Fivush & Hamond, 1990; Hudson, 1990; Nelson, 1990), like Pillemer and White (1989), suggested that infantile amnesia is overcome through the linguistic sharing of memories with others; that is, young children learn to talk about the past, particularly with adults, something that facilitates both the ability to narrate events as well as the organization of personal events in memory. Clearly, however, it is our contention that these (language) developments, though important, follow the principal ontological shift that is the development of a sense of self.[4]

In conclusion, a series of significant developmental events take place when infants are between 18 and 30 months of age that prepare them to talk about personally experienced events. First, at about 18 months of age infants learn to recognize their features in the mirror. The next acquisition is a more advanced representation of the self reflected in the pronominal reference to the self as "I" and "me" in the early months of the second year. Finally, the child learns to talk about immediate and then more distant past events in narrative, the language of autobiographical memory. Both narrative and autobiographical memory continue to develop in structure, organization, and content over the preschool years (Fivush & Hamond, 1990; McCabe & Peterson, 1991), but by that time infantile amnesia is indeed a phenomenon of the past.

Although we believe that the cognitive sense of self most likely emerges logically prior to important language developments, and that it is this sense of self that serves as the catalyst for the onset of autobiographical memory, we recognize that this remains an empirical question. However, as we have already shown, autobiographical memory does not require verbal competence for its expression and, indeed, is oftentimes communicated nonverbally (e.g., Terr, 1988). As Eisenberg (1985) showed, many specific memories of early, unique events are reflected in nonverbal reactions (the example she used was of a child imitating a priest at 23 months, after her first visit to church in nearly 6 months). Thus, in our view autobiographical memory does not demand language for its existence but does require, at least logically, a cognitive sense of self, something that emerges gradually across the early months of life predating the use of language.

Having said this, however, we should point out that we also believe there are a number of other factors that conspire to spawn this sense of self. As we have noted throughout this article, the disappearance of infantile amnesia and the appearance of the cognitive sense of self do not happen in isolation. It is clear that the emergence of both autobiographical memory and a sense of self involves a confluence of factors, including neurological and socioemotional ones. For example, we have shown how affective reactions (e.g., shyness) are coincident with more cognitive reactions (e.g., mark-directed behaviors) in children's responses to their own mirror images. In line with these latter observations, a number of researchers have noted that deviations from normal development are reflected not in children's cognitive reactions to their own mirror images but rather in terms of their affective reactions. That is, autistic, Down syndrome, and maltreated children, although they recognize themselves in the mirror, fail to show positive reactions to their own images, oftentimes exhibiting flat or negative (e.g., gaze aversion) affect (e.g., Cicchetti, 1991; Loveland, 1987; Schneider-Rosen & Cicchetti, 1991; Spiker & Ricks, 1984).

Afterword

We began this article by suggesting that the enigma of infantile amnesia represents a problem not of memory per se but rather of changes in another cognitive domain—namely, the development of the self as a cognitive entity. We argued further that it is the developing sense of self, not the development of language (in and of itself; e.g., Nelson, 1990) or of a secondary memory system (e.g., Pillemer & White, 1989), that is crucial to the offset of infantile amnesia. We believe such a case has been well fashioned in our review. We have amply demonstrated that the neurological, perceptual, and memorial capacities of even very young infants are sufficiently well established to satisfy the encoding, storage, and retrieval needs of at least an elementary event memory system. Similarly, we found that the maturational changes that transpire during the first 2 years, although important, are not sufficient in and of themselves to explain the offset of infantile amnesia. Clearly, what is lacking in infants' early event memory is not simply some memory capacity or language system but rather a personal frame of reference that makes memory uniquely autobiographical.

As our review has shown, we do not disagree that developments in language, socioemotional, and memory factors are important in fine-tuning autobiographical memory. However, it is the emergence of the cognitive self that is pivotal to the establishment of autobiographical memory, a hypothesis that carries with it a number of key predictions. For example, a number of authors have noted considerable individual variation in the age at which infantile amnesia abates (e.g., Usher & Neisser, in press; Winograd & Killinger, 1983). As we have already pointed out in our review, individual differences are also present in the onset of self-recognition (e.g., Brooks-Gunn & Lewis, 1984). Subsequent research may show that it is these differences in the emergence of self-recognition, and not chronological age per se, that are related to variations in the offset of infantile amnesia. Similar relationships may exist in special populations between a delayed sense of self and a delayed onset of autobiographical memory.

In addition to these between-individual differences in the offset of infantile amnesia, age differences in the types of memories being retrieved have been noted within individuals (Usher & Neisser, in press; Winograd & Killinger, 1983). Although within-individual age differences in the types of events being recalled do not appear to vary in any systematic manner (e.g., they are not regularly associated with the presence, absence, or type of emotion experienced at the time of the event; see Usher & Neisser, in press), it may turn out that these variations will be directly related to corresponding changes in the sense of self. Unfortunately, although the idea of such a relationship is provocative, its discovery must await progress in operationalizing the sense of self.

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[4] After we had written this article, one of the reviewers pointed out to us that the idea of the self in relationship to autobiographical memory had been alluded to earlier in a commentary by Fivush (1988). The gist of her comments concerning the self and autobiographical memory was that the self provides a time line, one that integrates or links events across time. Although we agree that the self provides a mechanism that links events across time, we argue that the development of a cognitive sense of self serves a more global function. That is, it provides an overarching organizational process, one that serves to interpret and integrate information and events with respect to the self. Furthermore, we consider that the development of a cognitive sense of self is pivotal to the unfolding of autobiographical memory.

Although any number of additional predictions can be culled from the hypothesized relationship between autobiographical memory and the sense of self, further speculation must be tempered by additional research. It is our contention, however, that this research must focus on questions concerning the early relationship between the self and event memory, as well as on subsequent developments in language and social cognition, and not on the search for some mythical source of infantile amnesia. If nothing else, our review has clearly demonstrated that infantile amnesia is a chimera of the relationship between the emergence of a cognitive sense of self and changes in the organization of personal event memory.

We hope that the present review has also provided a sufficient framework for establishing a new agenda for research on the ontogeny of early autobiographical memory. In particular, because much of what we have said concerning the relationship between the emergence of a cognitive sense of self, autobiographical memory, and the decline of infantile amnesia is based on logic and an observed temporal contiguity among these variables, future research should endeavor to establish the nature of the causal linkages between these components. Once again, however, a necessary prerequisite for this research will be the development of a more comprehensive measure of the self, especially as it is "mirrored" cognitively. Moreover, such research should seek to establish a more varied repertoire of autobiographical memory measures, particularly ones that are sensitive to nonverbal, behavioral expressions. With these constructs better operationalized, considerable progress in delineating the independent and conjoint influences of the factors affecting the self and its relation to autobiographical memory should be forthcoming.

References

Ackerman, B. P. (1985). Children's retrieval deficit. In C. J. Brainerd & M. Pressley (Eds.), *Basic processes in memory development* (pp. 1–46). New York: Springer-Verlag.

Aggleton, J. P., & Mishkin, M. (1983). Visual recognition impairment following medial thalamic lesions in monkeys. *Neuropsychologia, 21,* 189–197.

Amsterdam, B. (1972). Mirror self-image reactions before age two. *Developmental Psychobiology, 5,* 297–305.

Aslin, R. N. (1987). Visual and auditory development in infancy. In J. D. Osofsky (Ed.), *Handbook of infant development* (pp. 5–97). New York: Wiley.

Bachevalier, J., & Mishkin, M. (1984). An early and a late developing system for learning and retention in infant monkeys. *Behavioral Neuroscience, 98,* 770–778.

Baillargeon, R., & Graber, M. (1988). Evidence of location memory in 8-month-old infants in a nonsearch AB task. *Developmental Psychology, 24,* 502–511.

Banks, M. S., & Salapatek, P. (1983). Infant visual perception. In P. Mussen (Series Ed.) and M. M. Haith & J. J. Campos (Vol. Eds.), *Handbook of child psychology: Vol. 2. Infancy and developmental psychobiology* (pp. 435–571). New York: Wiley.

Bauer, P. J., & Mandler, J. (1989). One thing follows another: Effects of temporal structure on 1- to 2-year-olds' recall of events. *Developmental Psychology, 25,* 197–206.

Bauer, P. J., & Mandler, J. M. (1990). Remembering what happened next: Very young children's recall of event sequences. In R. Fivush & J. A. Hudson (Eds.), *Knowing and remembering in young children* (pp. 9–29). New York: Cambridge University Press.

Bauer, P. J., & Shore, C. M. (1987). Making a memorable event: Effects of familiarity and organization on young children's recall of action sequences. *Cognitive Development, 2,* 327–338.

Bauer, P. J., & Thal, D. J. (1990). Scripts or scraps: Reconsidering the development of sequential understanding. *Journal of Experimental Child Psychology, 50,* 287–304.

Berenthal, B. I., & Fischer, K. W. (1978). Development of self-recognition in the infant. *Developmental Psychology, 14,* 44–50.

Bernstein, A. E. H., & Blacher, R. S. (1967). The recovery of a memory from three months of age. *Psychoanalytic Study of the Child, 22,* 156–161.

Bjorklund, D. F. (1987). How age changes in knowledge base contribute to the development of children's memory: An interpretive review. *Developmental Review, 7,* 93–103.

Boller, K., Rovee-Collier, C., Borovsky, D., O'Connor, J., & Shyi, G. (1990). Developmental changes in the time-dependent nature of memory retrieval. *Developmental Psychology, 26,* 770–779.

Bowlby, J. (1969). *Attachment and loss* (Vol. 1). New York: Basic Books.

Brainerd, C. J., Reyna, V. F., Howe, M. L., & Kingma, J. (1990). Development of forgetting and reminiscence. *Monographs of the Society for Research in Child Development, 55* (3–4, Serial No. 222).

Brooks-Gunn, J., & Lewis, M. (1984). The development of early visual self-recognition. *Developmental Review, 4,* 215–239.

Brown, R. (1973). *A first language: The early stages.* Cambridge, MA: Harvard University Press.

Bullock, M., & Lutkenhaus, P. (1990). Who am I? Self-understanding in toddlers. *Merrill-Palmer Quarterly, 36,* 217–238.

Case, R. (1991). Stages in the development of the young child's first sense of self. *Developmental Review, 11,* 210–230.

Chugan, H. T., & Phelps, M. E. (1986). Maturational changes in cerebral function in infants determined by ^{18}FDG positron emission tomography. *Science, 231,* 840–843.

Cicchetti, D. (1991). Fractures in the crystal: Developmental psychopathology and the emergence of the self. *Developmental Review, 11,* 271–287.

Cohen, N. J., & Squire, L. R. (1980). Preserved learning and retention of pattern-analyzing skill in amnesia: Dissociation of knowing how and knowing that. *Science, 210,* 207–210.

Cornell, E. H., & Heth, C. D. (1983). Spatial cognition: Gathering strategies used by preschool children. *Journal of Experimental Child Psychology, 35,* 93–110.

Crain, B., Cotman, C. W., Taylor, D., & Lynch, G. (1973). A quantitative electron microscopic study of synaptogenesis in the dentate gyrus of the rat. *Brain Research, 63,* 195–204.

Cutts, K., & Ceci, S. J. (1989). *Long-term recall of experiences from the first two years of life: Memory for cheerios, or, cheerio, memory?* Unpublished manuscript, Cornell University, Ithaca, NY.

Damon, W., & Hart, D. (1982). The development of self-understanding from infancy through adolescence. *Child Development, 53,* 841–864.

Damon, W., & Hart, D. (1988). *Self-understanding in childhood and adolescence.* Cambridge, England: Cambridge University Press.

Darwin, C. R. (1877). An autobiographical sketch of an infant. *Mind, 2,* 186–294.

Dawson, G., & McKissick, F. C. (1984). Self-recognition in autistic children. *Journal of Autism and Developmental Disorders, 14,* 383–394.

DeCasper, A. J., & Prescott, P. A. (1984). Human newborns' perception of male voices: Preference, discrimination, and reinforcing value. *Developmental Psychobiology, 17,* 481–491.

DeCasper, A. J., & Spence, M. J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. *Infant Behavior and Development, 9,* 133–150.

DeLoache, J. S., & Brown, A. L. (1983). Very young children's memory for the location of objects in a large-scale environment. *Child Development, 54,* 888–897.

DeLoache, J. S., & Brown, A. L. (1984). Where do I go next? Intelligent searching by very young children. *Developmental Psychology, 20,* 37–44.

DeLoache, J. S., Cassidy, D. J., & Brown, A. L. (1985). Precursors of mnemonic strategies in very young children's memory. *Child Development, 56,* 125–137.

DeLoache, J. S., & Todd, C. M. (1988). Young children's use of spatial categorization as a mnemonic strategy. *Journal of Experimental Child Psychology, 46,* 1–20.

Dempster, F. N. (1988). The spacing effect: A case study in the failure to apply the results of psychological research. *American Psychologist, 43,* 627–634.

de Villiers, J. G., & de Villiers, P. A. (1978). *Language acquisition.* Cambridge, MA: Harvard University Press.

Diamond, A. (1985). Development of the ability to use recall to guide action as indicated by infants' performance on AB. *Child Development, 56,* 868–883.

Diamond, A., & Doar, B. (1989). The performance of human infants on a measure of frontal cortex function, the delayed response task. *Developmental Psychobiology, 22,* 271–294.

Diamond, A., & Goldman-Rakic, P. S. (1983). Comparison of performance on a Piagetian object permanence task in human infants and rhesus monkeys: Evidence for involvement of the prefrontal cortex. *Society for Neuroscience Abstracts, 9,* 641.

Diamond, A., & Goldman-Rakic, P. S. (1989). Comparison of human infants and rhesus monkeys on Piaget's AB task: Evidence for dependence on dorsolateral prefrontal cortex. *Experimental Brain Research, 74,* 24–40.

Dixon, J. C. (1957). Development of self-recognition. *Journal of Genetic Psychology, 91,* 251–256.

Dudycha, G. J., & Dudycha, M. M. (1941). Childhood memories: A review of the literature. *Psychological Bulletin, 38,* 668–682.

Eckenhoff, M. F., & Rakic, P. S. (1981). Synaptogenesis in the dentate gyrus of primates: Quantitative EM study in the rhesus monkey. *Society for Neuroscience Abstracts, 7,* 6.

Eckenhoff, M. F., & Rakic, P. S. (1988). Nature and fate of proliferative cells in the hippocampal dentate gyrus during the lifespan of the rhesus monkey. *Journal of Neuroscience, 8,* 2729–2747.

Eisenberg, A. R. (1985). Learning to describe past experiences in conversation. *Discourse Processes, 8,* 177–204.

Emde, R. N., Biringen, Z., Clyman, R. B., & Oppenheim, D. (1991). The moral self of infancy: Affective core and procedural knowledge. *Developmental Review, 11,* 251–270.

Enright, M. K., Rovee-Collier, C., Fagen, J. W., & Caniglia, K. (1983). The effects of distributed training on retention of operant conditioning in human infants. *Journal of Experimental Child Psychology, 36,* 209–225.

Estes, W. K. (1988). Human learning and memory. In R. C. Atkinson, R. J. Herrnstein, G. Lindzey, & R. D. Luce (Eds.), *Stevens' handbook of experimental psychology: Vol. 2. Learning and cognition* (2nd ed., pp. 351–415). New York: Wiley.

Fischer, K. W. (1987). Relations between brain and cognitive development. *Child Development, 58,* 623–632.

Fivush, R. (1988). The functions of event memory: Some comments on Nelson and Barsalou. In U. Neisser & E. Winograd (Eds.), *Remembering reconsidered* (pp. 277–282). New York: Cambridge University Press.

Fivush, R., Gray, J. T., & Fromhoff, F. A. (1987). Two-year-olds talk about the past. *Cognitive Development, 2,* 393–409.

Fivush, R., & Hamond, N. R. (1989). Time and again: Effects of repetition and retention interval on 2 year olds' event recall. *Journal of Experimental Child Psychology, 47,* 259–273.

Fivush, R., & Hamond, N. R. (1990). Autobiographical memory across the preschool years: Toward reconceptualizing childhood amnesia. In R. Fivush & J. A. Hudson (Eds.), *Knowing and remembering in young children* (pp. 223–248). New York: Cambridge University Press.

Fivush, R., Hudson, J. A., & Nelson, K. (1984). Children's long-term memory for a novel event: An exploratory study. *Merrill-Palmer Quarterly, 30,* 303–316.

Fraiberg, S. (1977). *Insights from the blind.* New York: Basic Books.

Freedman, M., & Oscar-Berman, M. (1986). Bilateral frontal lobe disease and selective delayed response deficits in humans. *Behavioral Neuroscience, 100,* 337–342.

Freud, S. (1938). The psychopathology of everyday life. In A. A. Brill (Ed.), *The writings of Sigmund Freud* (35–178). New York: Modern Library. (Original work published 1914)

Freud, S. (1953). Three essays on the theory of sexuality. In J. Strachey (Ed.), *The standard edition of the complete psychological works of Sigmund Freud* (Vol. 7, pp. 135–243). London: Hogarth Press. (Original work published 1905)

Freud, S. (1959). Instincts and their vicissitudes. In E. Jones (Ed.), *Collected papers of Sigmund Freud* (pp. 317–385). New York: Basic Books. (Original work published 1915)

Freud, S. (1963). Introductory lectures on psycho-analysis. In J. Strachey (Ed.), *The standard edition of the complete psychological works of Sigmund Freud* (Vol. 15–16, 243–496). London: Hogarth Press. (Original work published 1916–1917)

Gallup, G. G. (1979). Self-recognition in chimpanzees and man: A developmental and comparative perspective. In M. Lewis & L. Rosenblum (Eds.), *The child and its family: The genesis of behavior* (Vol. 2, pp. 107–126). New York: Plenum Press.

Gold, P. E. (1987). Sweet memories. *American Scientist, 75,* 151–155.

Goldman-Rakic, P. S. (1987a). Circuitry of the prefrontal cortex and the regulation of behavior by representational knowledge. In F. Plum & V. Mountcastle (Eds.), *Handbook of physiology* (Vol. 5, pp. 373–417). Bethesda, MD: American Physiological Society.

Goldman-Rakic, P. S. (1987b). Development of cortical circuitry and cognitive function. *Child Development, 58,* 601–622.

Goodman, G. S., Aman, C., & Hirschman, J. (1987). Child sexual and physical abuse: Children's testimony. In S. J. Ceci, M. P. Toglia, & D. F. Ross (Eds.), *Children's eyewitness memory* (pp. 1–23). New York: Springer-Verlag.

Goodman, G. S., Hirschman, J. E., Hepps, D., & Rudy, L. (1991). Children's memory for stressful events. *Merrill-Palmer Quarterly, 37,* 109–158.

Greco, C., Rovee-Collier, C., Hayne, H., Griesler, P., & Early, L. A. (1986). Ontogeny of early event memory: I. Forgetting and retrieval by 2- and 3-month-olds. *Infant Behavior and Development, 9,* 441–460.

Greenough, W. T., Black, J. E., & Wallace, C. S. (1987). Experience and brain development. *Child Development, 58,* 539–559.

Haith, M. M., Hazan, C., & Goodman, G. S. (1988). Expectation and anticipation of dynamic visual events by 3.5-month-old babies. *Child Development, 59,* 467–479.

Hargreaves, E. L., Cain, D. P., & Vanderwolf, C. H. (1990). Learning and behavioral-long-term potentiation: Importance of controlling for motor activity. *Journal of Neuroscience, 10,* 1472–1478.

Harris, K. M., & Teyler, T. J. (1984). Developmental onset of long-term potentiation in area CA1 of the rat hippocampus. *Journal of Physiology, 346,* 27–48.

Harter, S. (1983). Developmental perspectives on the self-system. In E. M. Hetherington (Ed.), *Handbook of child psychology: Vol. 4. So-*

cial and personality development (4th ed., pp. 275–385). New York: Wiley.

Hayne, H., Greco, C., Early, L. A., Griesler, P., & Rovee-Collier, C. (1986). Ontogeny of early event memory: II. Encoding and retrieval by 2- and 3-month-olds. *Infant Behavior and Development, 9,* 461–472.

Hazen, N. L., & Volk-Hudson, S. (1984). The effect of spatial context on young children's recall. *Child Development, 55,* 1835–1844.

Hebb, D. O. (1949). *The organization of behavior.* New York: Wiley.

Hickey, T. L., & Peduzzi, J. D. (1987). Structure and development of the visual system. In P. Salapatek & L. Cohen (Eds.), *Handbook of infant perception* (Vol. 1, pp. 1–42). San Diego, CA: Academic Press.

Hill, S. D., & Tomlin, C. (1981). Self-recognition in retarded children. *Child Development, 52,* 145–150.

Hill, W. L., Borovsky, D., & Rovee-Collier, C. (1988). Continuities in infant memory development. *Developmental Psychobiology, 21,* 43–62.

Hoffding, H. (1891). *Outlines of psychology.* New York: Macmillan.

Hoving, K. L., & Choi, K. (1972). Some necessary conditions for producing reinstatement effects in children. *Developmental Psychology, 7,* 214–217.

Hoving, K. L., Coates, L., Bertucci, M., & Riccio, D. C. (1972). Reinstatement effects in children. *Developmental Psychology, 6,* 426–429.

Howard, D. V. (1988). Implicit and explicit assessment of cognitive aging. In M. L. Howe & C. J. Brainerd (Eds.), *Cognitive development in adulthood* (pp. 3–37). New York: Springer-Verlag.

Howe, M. L. (1991). Misleading children's story recall: Forgetting and reminiscence of the facts. *Developmental Psychology, 27,* 746–762.

Howe, M. L., & Brainerd, C. J. (1989). Development of children's long-term retention. *Developmental Review, 9,* 301–340.

Howe, M. L., Courage, M. L., & Bryant-Brown, L. (1992). *Reinstating preschoolers' memories.* Manuscript submitted for publication.

Howe, M. L., & Hunter, M. A. (1986). Long-term memory in adulthood: An examination of the development of storage and retrieval processes at acquisition and retention. *Developmental Review, 6,* 334–364.

Howe, M. L., Kelland, A., Bryant-Brown, L., & Clark, S. L. (1992). Measuring the development of children's amnesia and hypermnesia. In M. L. Howe, C. J. Brainerd, & V. F. Reyna (Eds.), *Development of long-term retention* (pp. 56–102). New York: Springer-Verlag.

Howe, M. L., & O'Sullivan, J. T. (1990). The development of strategic memory: Coordinating knowledge, metamemory, and resources. In D. F. Bjorklund (Ed.), *Children's strategies: Contemporary views of cognitive development* (pp. 129–155). Hillsdale, NJ: Erlbaum.

Hudson, J. A. (1990). The emergence of autobiographical memory in mother–child conversation. In R. Fivush & J. A. Hudson (Eds.), *Knowing and remembering in young children* (pp. 166–196). New York: Cambridge University Press.

Hudson, J. A., & Nelson, K. (1986). Repeated encounters of a similar kind: Effects of familiarity on children's autobiographic memory. *Cognitive Development, 1,* 253–271.

Hurlock, E. B., & Schwartz, R. (1932). Biographic records of memory in preschool. *Child Development, 3,* 230–239.

Huttenlocher, P. R. (1979). Synaptic density in human frontal cortex—developmental changes and effects of aging. *Brain Research, 163,* 195–205.

Jacoby, L. (1982). Knowing and remembering: Some parallels in the behavior of Korsakoff patients and normals. In L. S. Cermak (Ed.), *Human memory and amnesia* (pp. 97–122). Hillsdale, NJ: Erlbaum.

Jacoby, L., & Kelley, C. M. (1987). Unconscious influences of memory for a prior event. *Personality and Social Psychology Bulletin, 13,* 314–336.

James, W. (1961). *Psychology: The briefer course.* New York: Harper. (Original work published 1892)

Johnson, D. B. (1983). Self-recognition in infants. *Infant Behavior and Development, 6,* 211–222.

Jones, D. C., Swift, D. J., & Johnson, M. A. (1988). Nondeliberate memory for a novel event among preschoolers. *Developmental Psychology, 24,* 641–645.

Kail, R. (1984). *The development of memory in children* (2nd ed.). New York: Freeman.

Kanner, L. (1946). Irrelevant and metaphorical language in early infantile autism. *American Journal of Psychiatry, 103,* 242–246.

Kausler, D. H., & Lichty, W. (1988). Memory for activities: Rehearsal-independence and aging. In M. L. Howe & C. J. Brainerd (Eds.), *Cognitive development in adulthood* (pp. 93–131). New York: Springer-Verlag.

Kihlstrom, J. F., & Harackiewicz, J. M. (1982). The earliest recollection: A new survey. *Journal of Personality, 50,* 134–147.

Kinsbourne, M., & Wood, F. (1982). Theoretical considerations regarding the episodic–semantic memory distinction. In L. S. Cermak (Ed.), *Human memory and amnesia* (pp. 195–217). Hillsdale, NJ: Erlbaum.

Kohler, W. (1929). *Gestalt psychology.* New York: Liveright.

Kohler, W. (1941). On the nature of associations. *Proceedings of the American Philosophical Society, 84,* 489–502.

Komatsu, Y., Toyama, K., Maeda, J., & Sakaguchi, H. (1981). Long-term potentiation investigated in a slice preparation of striate cortex of young kittens. *Neuroscience Letters, 26,* 269–274.

Kopp, C. B., & Brownell, C. A. (Eds.). (1991). The development of the self: The first three years [Special issue]. *Developmental Review, 11*(3).

Lewis, M. (1991). Ways of knowing: Objective self-awareness or consciousness. *Developmental Review, 11,* 231–243.

Lewis, M., & Brooks-Gunn, J. (1979). *Social cognition and the acquisition of self.* New York: Plenum Press.

Lewis, M., Brooks-Gunn, J., & Jaskir, J. (1985). Individual differences in early visual self-recognition. *Developmental Psychology, 21,* 1181–1187.

Lewis, M., Sullivan, M. W., Stanger, C., & Weiss, M. (1989). Self development and self-consciousness emotions. *Child Development, 60,* 146–156.

Loftus, E. F., Hoffman, H. G., & Wagenaar, W. A. (1992). The misinformation effect: Transformations in memory induced by postevent information. In M. L. Howe, C. J. Brainerd, & V. F. Reyna (Eds.), *Development of long-term retention* (pp. 159–183). New York: Springer-Verlag.

Loftus, E. F., & Loftus, G. R. (1980). On the permanence of stored information in the human brain. *American Psychologist, 35,* 409–420.

Loveland, K. A. (1987). Behavior of young children with Down syndrome before the mirror: Finding things reflected. *Child Development, 58,* 928–936.

Madison, D. V., Malenka, R. C., & Nicoll, R. A. (1991). Mechanisms underlying long-term potentiation of synaptic transmission. *Annual Review of Neuroscience, 14,* 379–397.

Mahler, M., Pine, F., & Bergman, A. (1975). *The psychological birth of the infant.* New York: Basic Books.

Malamut, B., Saunders, R., & Mishkin, M. (1984). Monkeys with combined amygdala-hippocampal lesions succeed in object discrimination learning despite 24-hour retention intervals. *Behavioral Neuroscience, 98,* 759–769.

Mandler, J. M. (1983). Representation. In P. Mussen (Series ed.) and J. Flavell & E. Markman (Vol. eds.), *Handbook of child psychology: Vol. 3. Cognitive development* (pp. 420–494). New York: Wiley.

Mandler, J. M. (1984). Representation and recall in infancy. In M. Moscovitch (Ed.), *Infant memory* (pp. 75–101). New York: Plenum Press.

Mans, L., Cicchetti, D., & Sroufe, L. A. (1978). Mirror reaction of Down's syndrome infants and toddlers: Cognitive underpinnings of self-recognition. *Child Development, 49,* 1247–1250.

Maurer, D. (1985). Infants' perception of facedness. In T. Field & N. Fox (Eds.), *Social perception in infants* (pp. 73–100). Norwood, NJ: Ablex.

McCabe, A., Capron, E., & Peterson, C. (1991). The voice of experience: The recall of early childhood and adolescent memories by young adults. In A. McCabe & C. Peterson (Eds.), *New directions in developing narrative structure* (pp. 137–173). Hillsdale, NJ: Erlbaum.

McCabe, A., & Peterson, C. (Eds.). (1991). *Developing narrative structure.* Hillsdale, NJ: Erlbaum.

McDonough, L., & Mandler, J. M. (1990, April). *Very long-term recall in two-year-olds.* Poster presented at the International Conference on Infant Studies, Montreal, Canada.

McNaughton, B. L., & Morris, R. G. M. (1987). Hippocampal synaptic enhancement and information storage within a distributed memory system. *Trends in Neuroscience, 10,* 408–415.

Mead, G. H. (1934). *Mind, self, and society.* Chicago: University of Chicago Press.

Meltzoff, A. N. (1985). Immediate and deferred imitation in fourteen- and twenty-four-month-old infants. *Child Development, 56,* 62–73.

Meltzoff, A. N. (1988a). Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychology, 24,* 470–476.

Meltzoff, A. N. (1988b). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Child Development, 59,* 217–225.

Meltzoff, A. N. (1990). Towards a developmental cognitive science: The implications of cross-modal matching and imitation for the development of representation and memory in infancy. In A. Diamond (Ed.), Annals of the The New York Academy of Sciences: Vol. 608. *The development and neural bases of higher cognitive functions* (pp. 1–37). New York: New York Academy of Sciences.

Meltzoff, A. N., & Gopnik, A. (1989). On linking nonverbal imitation, representation, and language learning in the first two years of life. In G. E. Speidel & K. Nelson (Eds.), *The many faces of imitation in language learning* (pp. 23–51). New York: Springer-Verlag.

Millar, W. S. (1972). A study of operant conditioning under delayed reinforcement in early infancy. *Monographs of the Society for Research in Child Development, 37* (2, Serial No. 147).

Millar, W. S., & Schaffer, H. R. (1972). The influence of spatially displaced feedback on infant operant conditioning. *Journal of Experimental Child Psychology, 14,* 442–453.

Miller, P. J., Potts, R., Fung, H., Hoogstra, L., & Mintz, J. (1990). Narrative practices and the social construction of self in childhood. *American Ethnologist, 17,* 292–311.

Mishkin, M., Malamut, B., & Bachevalier, J. (1984). Memories and habits: Two neural systems. In G. Lynch, J. McGaugh, & N. Weiberger (Eds.), *Neurobiology of learning and memory* (pp. 65–77). New York: Guilford Press.

Mishkin, M., Spiegler, B. J., Saunders, R. C., & Malamut, B. L. (1982). An animal model of global amnesia. In S. Corkin, K. Davis, J. Growden, E. Usdin, & R. Wurthman (Eds.), *Alzheimer's disease: A report in progress* (Vol. 19, pp. 235–247). New York: Raven Press.

Morris, R. G. M. (1984). Is the distinction between procedural and declarative memory useful with respect to animal models of amnesia? In G. Lynch, J. McGaugh, & N. Weinberger (Eds.), *Neurobiology of learning and memory* (pp. 119–124). New York: Guilford Press.

Moscovitch, M. (1982). Multiple dissociations of function in amnesia. In L. S. Cermak (Ed.), *Human memory and amnesia* (pp. 337–370). Hillsdale, NJ: Erlbaum.

Myers, N. A., Clifton, R. K., & Clarkson, M. G. (1987). When they were very young: Almost-threes remember two years ago. *Infant Behavior and Development, 10,* 123–132.

Myers, N. A., & Mervis, C. B. (1989). A case study of early event representation development. *Cognitive Development, 4,* 31–48.

Myles-Worsley, M., Cromer, C. C., & Dodd, D. H. (1986). Children's preschool script reconstruction: Reliance on general knowledge as memory fades. *Developmental Psychology, 22,* 22–30.

Nadel, L., & Zola-Morgan, S. (1984). Infantile amnesia: A neurobiological perspective. In M. Moscovitch (Ed.), *Infant memory* (pp. 145–172). New York: Plenum Press.

Nash, M. (1987). What, if anything, is regressed about hypnotic age regression? A review of the empirical literature. *Psychological Bulletin, 102,* 42–52.

Neisser, U. (1991). Two perceptually given aspects of the self and their development. *Developmental Review, 11,* 197–209.

Nelson, K. (1986). *Event knowledge: Structure and function in development.* Hillsdale, NJ: Erlbaum.

Nelson, K. (1988). The ontogeny of memory for real events. In U. Neisser & E. Winograd (Eds.), *Remembering reconsidered: Ecological and traditional approaches to memory* (pp. 244–276). New York: Cambridge University Press.

Nelson, K. (Ed.). (1989). *Narratives from the crib.* Cambridge, MA: Harvard University Press.

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

Nelson, K., & Ross, G. (1980). The generalities and specifics of long-term memory in infants and young children. In M. Perlmutter (Ed.), *Children's memory: New directions for child development* (pp. 87–101). San Francisco: Jossey-Bass.

Neuman, C. J., & Hill, S. D. (1978). Self-recognition and stimulus preference in autistic children. *Developmental Psychobiology, 11,* 571–578.

Nisbett, R. E., & Wilson, T. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84,* 231–259.

Nowakowski, R. S., & Rakic, P. S. (1981). The site of origin and route and rate of migration of neurons to the hippocampal region of the rhesus monkey. *Journal of Comparative Neurology, 196,* 129–154.

Ohr, P. S., Fagen, J. W., Rovee-Collier, C., Hayne, H., & Vander Linde, E. (1989). Amount of training and retention by infants. *Developmental Psychobiology, 22,* 69–80.

Perris, E. E., & Myers, N. A. (1990, April). *Expressing memory for an infant event.* Poster presented at the International Conference on Infant Studies, Montreal, Canada.

Perris, E. E., Myers, N. A., & Clifton, R. K. (1990). Long-term memory for a single infancy experience. *Child Development, 61,* 1796–1807.

Peterson, C. (1990). The who, when, and where of early narratives. *Journal of Child Language, 17,* 433–455.

Piaget, J. (1954). *The construction of reality in the child.* New York: Basic Books.

Piaget, J. (1962). *Play, dreams, and imitation in childhood.* New York: Norton.

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). San Diego, CA: Academic Press.

Pipp, S., Fischer, K., & Jennings, S. (1987). Acquisition of self- and mother-knowledge in infancy. *Developmental Psychology, 23,* 86–96.

Polster, M. R., Nadel, L., & Schacter, D. (1991). Cognitive neuroscience analyses of memory: A historical perspective. *Journal of Cognitive Neuroscience, 3,* 95–116.

Postman, L., & Knecht, K. (1983). Encoding variability and retention. *Journal of Verbal Learning and Verbal Behavior, 22,* 133–152.

Preyer, W. (1893). *Mind of the child* (Vol. 2). New York: Appleton.

Priel, B., & De Schonen, S. (1986). Self-recognition: A study of a population without mirrors. *Journal of Experimental Child Psychology, 41,* 237–250.

Racine, R. J., Milgram, N. W., & Hafner, S. (1983). Long-term potentiation phenomena in the rat limbic forebrain. *Brain Research, 260,* 217–231.

Rakic, P., Bourgeois, J. A., Eckenhoff, M., Zecevic, N., & Goldman-Rakic, P. (1986). Concurrent overproduction of synapses in diverse regions of the primate cerebral cortex. *Science, 232,* 232–235.

Ramey, C. T., & Ourth, L. L. (1971). Delayed reinforcement and vocalization rates of infants. *Child Development, 42,* 291–297.

Reber, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General, 118,* 219–235.

Reich, P. A. (1986). *Language development.* Englewood Cliffs, NJ: Prentice-Hall.

Represa, A., Tremblay, E., & Ben-Ari, Y. (1989). Transient increase of NMDA-binding sites in human hippocampus during development. *Neuroscience Letters, 99,* 61–66.

Richardson, R., Riccio, D. C., & McKenney, M. (1988). Stimulus attributes of reactivated memory: Alleviation of ontogenetic forgetting in rats is context specific. *Developmental Psychobiology, 21,* 135–143.

Roediger, H. L. (1990). Implicit memory: Retention without remembering. *American Psychologist, 45,* 1043–1056.

Rose, S. A., Gottfried, A. W., & Bridger, W. H. (1979). Effects of haptic cues on visual recognition memory in fullterm and preterm infants. *Infant Behavior and Development, 2,* 55–67.

Rovee-Collier, C. (1987). Learning and memory in infancy. In J. D. Osofsky (Ed.), *Handbook of infant development* (2nd ed., pp. 98–148). New York: Wiley.

Rovee-Collier, C., Early, L., & Stafford, S. (1989). Ontogeny of early event memory: III. Attentional determinants of retrieval at 2 and 3 months. *Infant Behavior and Development, 12,* 147–161.

Rovee-Collier, C., & Hayne, H. (1987). Reactivation of infant memory: Implications for cognitive development. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 20, pp. 185–238). San Diego, CA: Academic Press.

Rovee-Collier, C., & Shyi, G. (1992). A functional and cognitive analysis of infant long-term retention. In M. L. Howe, C. J. Brainerd, & V. F. Reyna (Eds.), *Development of long-term retention* (pp. 3–55). New York: Springer-Verlag.

Sachs, J. (1983). Talking about the there and then: The emergence of displaced reference in parent–child discourse. In K. Nelson (Ed.), *Children's language* (Vol. 4, pp. 1–28). New York: Gardner Press.

Salapatek, P., & Cohen, L. (1987). *Handbook of infant perception* (Vol. 1). San Diego, CA: Academic Press.

Schacter, D., & Moscovitch, M. (1984). Infants, amnesia, and dissociable memory systems. In M. Moscovitch (Ed.), *Infant memory* (pp. 173–216). New York: Plenum Press.

Schacter, D., & Tulving, E. (1982). Amnesia and memory research. In L. S. Cermak (Ed.), *Human memory and amnesia* (pp. 1–32). Hillsdale, NJ: Erlbaum.

Schneider-Rosen, K., & Cicchetti, D. (1991). Early self-knowledge and emotional development: Visual self-recognition and affective reactions to mirror self-images in maltreated and non-maltreated toddlers. *Developmental Psychology, 27,* 471–478.

Schulman, A., & Kaplowitz, C. (1977). Mirror image response during the first two years of life. *Developmental Psychobiology, 10,* 133–142.

Sheingold, K., & Tenney, Y. J. (1982). Memory for a salient childhood event. In U. Neisser (Ed.), *Memory observed: Remembering in natural contexts* (pp. 201–212). New York: Freeman.

Shimamura, A. (1990). Aging and memory disorders: A neuropsychological analysis. In M. L. Howe, M. J. Stones, & C. J. Brainerd (Eds.), *Cognitive and behavioral performance factors in atypical aging* (pp. 37–65). New York: Springer-Verlag.

Simner, M. (1971). Newborn's response to the cry of another infant. *Developmental Psychology, 5,* 136–150.

Smith, P. H., Arehart, D. M., Haaf, R. A., & deSaintVictor, C. M. (1989). Expectancies and memory for spatiotemporal events in 5-month-old infants. *Journal of Experimental Child Psychology, 47,* 210–235.

Solheim, G. S., Hensler, J. G., & Spear, N. E. (1980). Age-dependent contextual effects on short-term active avoidance retention in rats. *Behavioral and Neural Biology, 30,* 250–259.

Spear, N. E. (1979). Experimental analysis of infantile amnesia. In J. F. Kihlstrom & F. J. Evans (Eds.), *Functional disorders of memory* (pp. 75–102). Hillsdale, NJ: Erlbaum.

Spear, N. E. (1984). Behaviors that indicate memory: Levels of expression. *Canadian Journal of Psychology, 38,* 348–367.

Spear, N. E., & Isaacson, R. L. (1982). The problem of expression. In R. L. Isaacson & N. E. Spear (Eds.), *The expression of knowledge: Neurobehavioral transformations of information into action* (pp. 1–32). New York: Plenum Press.

Spence, M. J., & DeCasper, A. J. (1987). Prenatal experience with low-frequency maternal-voice sounds influences neonatal perception of maternal-voice samples. *Infant Behavior and Development, 10,* 133–142.

Spiker, D., & Ricks, M. (1984). Visual self-recognition in autistic children: Developmental relationships. *Child Development, 55,* 214–225.

Squire, L. R. (1986). Mechanisms of memory. *Science, 232,* 1612–1619.

Squire, L. R. (1987). *Memory and brain.* New York: Oxford University Press.

Squire, L. R., & Cohen, N. J. (1984). Human memory and amnesia. In G. Lynch, J. McGaugh, & N. Weinberger (Eds.), *Neurobiology of learning and memory* (pp. 3–64). New York: Guilford Press.

Squire, L. R., & Frambach, M. (1990). Cognitive skill learning in amnesia. *Psychobiology, 18,* 109–117.

Squire, L. R., & Shimamura, A. P. (1986). Characterizing amnesic patients for neurobehavioral study. *Behavioral Neuroscience, 100,* 866–877.

Squire, L. R., Shimamura, A. P., & Amaral, D. G. (1989). Memory and the hippocampus. In J. H. Byrne & W. O. Berry (Eds.), *Neural models of plasticity: Experimental and theoretical approaches* (pp. 208–239). San Diego, CA: Academic Press.

Squire, L. R., & Zola-Morgan, S. (1983). The neurology of memory: The case for correspondence between the findings for human and nonhuman primates. In J. A. Deutsch (Ed.), *The physiological basis of memory* (pp. 199–268). San Diego, CA: Academic Press.

Squire, L. R., & Zola-Morgan, S. (1988). Memory: Brain systems and behavior. *Trends in Neuroscience, 11,* 170–175.

Sullivan, M. W., Rovee-Collier, C., & Tynes, D. N. (1979). A conditioning analysis of infant long-term memory. *Child Development, 50,* 152–162.

Terr, L. (1988). What happens to early memories of trauma? A study of twenty children under age five at the time of documented traumatic events. *Journal of the American Academy of Child and Adolescent Psychiatry, 27,* 96–104.

Teyler, T., & Discenna, P. (1984). Long-term potentiation as a candidate mnemonic device. *Brain Research Reviews, 7,* 15–28.

Teyler, T., & Fountain, S. (1987). Neuronal plasticity in the mammalian brain: Relevance to behavioral learning and memory. *Child Development, 58,* 698–712.

Todd, C. M., & Perlmutter, M. (1980). Reality recalled by preschool children. In M. Perlmutter (Ed.), *Children's memory: New directions for child development* (pp. 69–85). San Francisco: Jossey-Bass.

Umiker-Sebeok, D. J. (1979). Preschool children's intraconversational narratives. *Journal of Child Language, 6,* 91–109.

Usher, J. A., & Neisser, U. (in press). Childhood amnesia and the beginnings of memory for four early life events. *Journal of Experimental Psychology: General.*

Vander Linde, E., Morrongiello, B. A., & Rovee-Collier, C. (1985). Determinants of retention in 8-week-old infants. *Developmental Psychology, 21,* 601–613.

Warrington, E. K., & Weiskrantz, L. (1982). Amnesia: A disconnection syndrome. *Neuropsychologia, 20,* 233–248.

Wetzler, S. E., & Sweeney, J. A. (1986). Childhood amnesia: An empirical demonstration. In D. C. Rubin (Ed.), *Autobiographical memory* (pp. 191–201). Cambridge, England: Cambridge University Press.

Wickelgren, W. A. (1979). Chunking and consolidation: A theoretical synthesis of semantic networks, configuring in conditioning, S–R versus cognitive learning, normal forgetting, the amnesic syndrome, and the hippocampal arousal system. *Psychological Review, 86,* 44–60.

Willatts, P. (1990). Development of problem-solving strategies in infancy. In D. F. Bjorklund (Ed.), *Children's strategies: Contemporary views of cognitive development* (pp. 23–66). Hillsdale, NJ: Erlbaum.

Willingham, D. B., Nissen, M. J., & Bullemer, P. (1989). On the development of procedural knowledge. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1047–1060.

Winograd, E., & Killinger, W. A., Jr. (1983). Relating age at encoding in early childhood to adult recall: Development of flashbulb memories. *Journal of Experimental Psychology: General, 112,* 413–422.

Zola-Morgan, S., & Squire, L. R. (1985). Medial-temporal lesions in monkeys impair memory on a variety of tasks sensitive to human amnesia. *Behavioral Neuroscience, 99,* 22–34.

Zola-Morgan, S., Squire, L. R., & Mishkin, M. (1982). The neuroanatomy of amnesia: Amygdala-hippocampus versus temporal stem. *Science, 218,* 1337–1339.

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