Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Developmental Review 24 (2004) 6–32
DEVELOPMENTAL REVIEW
www.elsevier.com/locate/dr

Advances in early memory development research: Insights about the dark side of the moon

Mary L. Courage[a,*] and Mark L. Howe[b]

[a] *Memorial University, St. John's, NL, Canada A1B 3X9*
[b] *Lakehead University, Thunder Bay, ON, Canada P7B 5E1*

Received 28 August 2003

Abstract

Over the past three decades impressive progress has been made in documenting the development of encoding, storage, and retrieval processes in preverbal infants and children. This literature includes an extensive and diverse database as well as theoretical conjecture about the underlying processes that drive early memory development. A selective review of some of this literature is provided to illustrate the extent and scope of this research, what is currently known about how memory develops over time, and some of the questions that remain to be answered. Importantly, research on early memory development has provided insights into a number of longstanding issues that have been prominent in the memory literature more generally (e.g., the memory systems question, infantile amnesia). It has also yielded practical information relevant to memory functioning in real world settings (e.g., for forensic and clinical psychology). We conclude that the basic processes needed to encode, store, and retrieve information are present very early in life and that although significant developmental advances take place across early childhood, many of the processes that govern memory in preverbal children are common with those of verbal children and adults. These issues are discussed and future directions for research are suggested.

Keywords: Infantile amnesia; Early memory; Trace integrity; Fuzzy-trace theory; Continuity of memory; Memory development

* Corresponding author. Present address: Department of Psychology, 1521 Pendleton Street, University of South Carolina, Columbia, SC 29208, USA.
E-mail address: mcourage@mun.ca (M.L. Courage).

0273-2297/$ - see front matter
doi:10.1016/j.dr.2003.09.005

We have come a very long way from Piaget's observation that the mental life of the infant was "unhappily, a mysterious abyss for the psychologist" (Piaget, 1927, p. 7) with the chance of revealing its nature as remote as "the dark side of the moon" (Bower, 1977, p. 5). Indeed, the past thirty years have witnessed enormous advances in our understanding of the mental life of infants and toddlers including for example, the viability of the sensory and perceptual systems from birth (or before), the development of discrimination abilities within and across modalities, perceptual and conceptual category formation, problem-solving, recognition and recall memory, language comprehension, and reasoning about the physical and social worlds (for reviews see Baillargeon, 2001; Bauer, Burch, & Kleinknecht, 2002; Chen & Siegler, 2000; Courage & Howe, 2002; Gopnik & Meltzoff, 1997; Haith & Benson, 1998; Howe, 2000; Kellman & Arterbury, 1998; Lacerda, von Hofsten, & Heimann, 2001; Rovee-Collier, Hayne, & Colombo, 2001). This evidence has been garnered with a remarkable array of procedures and paradigms and an assortment of ingenious tasks that have harnessed the enormous curiosity of infants and toddlers whose response repertoire is severely limited by linguistic, perceptual, cognitive, and motor immaturities (e.g., see Hayne, this issue).

Given that the scientific study of early child development goes back at least to Darwin's observations (e.g., Darwin, 1877), this evidence has been a long time coming. There are several reasons for this, but perhaps the most basic was the assumption that infants' cognitive processes were qualitatively different from those of older children and adults because: (1) infants are nonverbal and must therefore process information (or not) without language, (2) the underlying nervous system is structurally and functionally very immature in the first two years and cannot sustain information processing activities, and (3) Piaget had persuaded a generation of researchers that the sensorimotor infant's understanding of people, objects, and events is limited to his or her immediate actions on and perceptions of them, but entails no mental representation. This assumption about the qualitative difference between the nonverbal infant and toddler and the verbal child and adult was affirmed by the repeated failure of early tests of infants' mental development (e.g., the Bayley Scales) to predict IQ in later life (for a review see Colombo, 1993). Interestingly, vestiges of these early assumptions about infant cognition can still be found in current developmental theory and debate (e.g., arguments about the role of language in memory, memory and brain development).

In this article, we provide a historical backdrop for the other articles in this special issue and briefly summarize some of the literature on early memory that illustrates our current knowledge of the factors that effect its development. We will then illustrate how progress to date in early memory research has provided insights into a number of classical issues in the memory development literature. Some of these are of theoretical significance, for example: (1) whether there are multiple memory systems or a single memory system, (2) the longstanding puzzle of infantile amnesia, and (3) whether basic memory processes and mechanisms are continuous or discontinuous from the preverbal infant to the verbal child. Early memory research has also provided answers (and provoked further questions) to a number of difficult practical matters such as (4) how to provide reliable cognitive indices for infants at risk for intellectual impairment, (5) the durability and accuracy of traumatic and nontraumatic memories in forensic contexts, and (6) the difficulty of interpreting nonverbal expressions of memory (especially event memory). We will conclude with some future directions for memory development research in the new millennium.

What we know: The empirical database

In the arena of human memory, Joseph Fagan III conducted a series of elegant studies in the 1970s using the paired-comparison procedure (Fagan, 1970, 1971, 1972, 1973, 1974) that provided three significant insights. First, that encoding, storage, and retrieval processes in preverbal children could be examined objectively and scientifically. Second, that even very young infants were able to recognize stimuli that they had seen before and in certain conditions could retain that information over several weeks. Third, that many of the processes and variables that were known to affect encoding, storage, and retrieval in older children and adults were integral to infant memory processes as well (e.g., interference effects, stimulus complexity, familiarization time). This seminal work motivated a new era of inquiry into the fundamental cognitive and neurological processes that underlie early memory development. This endeavor further fuelled in the past decade or so by pragmatic concerns about the accuracy of memories laid down in infancy and their durability across childhood and the adult years (for reviews see Howe, 2000; Howe & Courage, 1997b; Nelson, 1997; Rovee-Collier et al., 2001).

Since Fagan's influential work, other researchers exploiting infants' visual responsiveness and robust preference for novelty have used habituation, paired-comparison, and other familiarization procedures to show that even neonates can recognize certain patterns and forms seen previously (for reviews, see Rose, Feldman, & Jankowski, this issue; Rovee-Collier & Bhatt, 1993; Slater, 1995; Werner & Perlmutter, 1979). Infants can also recognize stimuli in other modalities. For example, Catherwood (1993) found that 8-month-olds could retain information about the shape of an object explored haptically over a 5-min retention interval, in spite of the presence of interfering haptic stimuli. Swain, Zelazo, and Clifton (1993) used habituation and recovery of a head-turn response to demonstrate that neonates exposed postnatally to speech sounds retained them over a 24-h interval. Finally, Cernoch and Porter (1985) found that neonates could recognize their mother's axillary odor 12 h following a familiarization procedure. Although studies using familiarization procedures attest to infants' readiness to begin processing information from their earliest days, their utility for studying long-term retention is limited (for a discussion see Rovee-Collier & Bhatt, 1993; but see also Bahrick & Pickens, 1995; Courage & Howe, 1998).

Consequently, a variety of alternative procedures were developed to study infants' and toddlers' immediate and long-term retention of both experimentally induced and naturally occurring events. In one of the most comprehensive research programs, Rovee-Collier and her colleagues employed a mobile conjugate reinforcement paradigm to identify the factors that affect 2–6-month-olds' immediate and long-term retention of an operant foot-kick response. They found that 6-month-olds learned the basic contingency faster than 2- and 3-month-olds and that despite similar levels of performance at the end of acquisition, infant age and the length of the retention interval were positively correlated. Further, they found that as with older children and adults, retention was affected by factors such as the amount and distribution of practice, the match between the proximal (mobile) and distal (context) cues present at acquisition and those at long-term retention, and exposure to reinstating or interfering stimuli following simple forgetting and acquisition, respectively (for reviews see Hartshorn et al., 1998b; Rovee-Collier, 1997; Rovee-Collier et al., 2001). The operant conditioning paradigm has also been used to explore neonates' ability to retain auditory information. DeCasper and his colleagues showed that newborn infants can recognize the prosodic characteristics of a story heard in the last trimester of their prenatal life and have identified a number of variables that affect their recognition of auditory stimuli (DeCasper & Prescott, 1984; DeCasper & Spence, 1986, 1991; Spence & Freeman, 1996).

Infants' and toddlers' willingness to imitate motor activities performed by an adult or a peer model has also provided invaluable information on the development of long-term retention. In a series of classic studies Meltzoff and colleagues demonstrated that 6-week-olds will reproduce certain facial expressions and head movements modelled by an adult and can retain these over a 24-h interval (Meltzoff & Moore, 1994). Further advances in infants' recall of actions occur during the second half of the first postnatal year at which time 9-month-olds' show deferred imitation of novel object-specific actions witnessed (but not performed) by them 24 h earlier (Meltzoff, 1988a). Older, 14-month-olds retained 6 novel actions in memory for 1 week following live modeling (Meltzoff, 1988b) and for 24 h following symbolic modeling via television (Meltzoff, 1988c). More recently, Meltzoff (1995) found that 14- and 16-month-olds retained multiple acts across 2- and 4-month retention intervals and that also in their second year infants will imitate actions modelled by peers and will generalize across novel contexts (Hanna & Meltzoff, 1993; Klein & Meltzoff, 1999). A strength of Meltzoff's work is that as the novel activities were modelled only briefly without instruction and were not performed by the infants themselves prior to the retention test, their imitation was likely based on the stored representation of what they had seen previously and, as such, indexes recall rather than simple recognition.

Building on Meltzoff's work, Hayne and colleagues (e.g., Barr, Dowden, & Hayne, 1996; Collie & Hayne, 1999; Hayne, MacDonald, & Barr, 1997; Herbert & Hayne, 2000a, 2000b) investigated developmental changes in deferred imitation by 6–30-month-old infants and found that even the youngest showed some evidence of deferred imitation on a series of up to 8 unique actions with toy props after a 24 h delay. However, substantial developmental improvements were also evident. Younger infants (6-month-olds) required twice as much exposure to the target actions to show deferred imitation and they (6- and 12-month-olds) were less accurate in their imitation (i.e., produced fewer components) than older infants. Moreover, 12-month-olds generalized the modelled actions less readily to a new object at test than did older (18- and 21-month-old) infants, and it was not until about 30 months that infants generalized the actions readily to a new target after a 24-h delay (Herbert & Hayne, 2000a). Finally, the duration of the interval over which observed three-step sequences could be retained increased from 14 days for 18-month-olds up to 3 months for 24-month-olds (Herbert & Hayne, 2000b).

In a variation of deferred imitation, Bauer and her colleagues (e.g., see Bauer, 1995) used *elicited* imitation (in which the infant performs the modelled actions after the demonstration), to show that 11–24-month-olds represent order information in their recall of 2–8 component event sequences. Moreover, their recall was facilitated and prolonged (to several hours in the youngest infants and up to several months in the older children) if the components of the events contained enabling relations, were familiar, and accompanied by verbal cues at the retention test (for reviews see Bauer, 1995; Bauer et al., 2002). More recently, they reported that after multiple exposures to the events, some 9-month-olds showed ordered recall of multistep sequences 1 month later, although their recall was sparse. Subsequent retention tests after increasing delays of 3, 6, 9, or 12 months showed an age-related increase in the robustness of long-term retention (Bauer, Wenner, Dropik, & Wewerka, 2000; Bauer, Wiebe, Waters, & Bangston, 2001).

Finally, using procedures such as behavioral re-enactment, researchers have shown that young children's memory for both naturally occurring and contrived events that occurred during their infant and toddler years are retained and under certain conditions can persist for months or years, although with the passage of time recollection of these events becomes increasingly fragmentary. For example, McDonough and Mandler (1994) found some evidence of recall of single object-specific actions in 2-year-olds who had participated in an experiment a year earlier. Similarly, Sheffield and Hudson (1994) reported that 18-month-olds who experienced a series of toy-play events recalled them after 6 months. However, a longitudinal study of infants' memories of a toy-play event experienced at home when they were 10 and 14 months old and in a laboratory setting when they were 32 and 60 months old, revealed progressively less recollection of the event over time (Myers, Perris, & Speaker, 1994). Similarly, Boyer, Barron, and Farrar (1994) failed to find evidence of recollection of a 9-action event sequence learned by 20-month-olds and tested after a 12–22-month delay. Finally, in an investigation of children's memories for injuries requiring emergency room treatment, Howe, Courage, and Peterson (1994, 1995) reported that children who were younger than 2-years-old expressed recollection of their accidents nonverbally after a 5 day retention interval, but expressed very little recall of the events 6 months later.

Developments in very early memory

The research from these diverse procedures and paradigms indicates clearly that infants and toddlers are remarkably proficient in encoding, storing and retrieving information about characteristics of objects, people and events that they experience (sometimes only once). However, much of the early research was designed to test the effect of specific manipulations on infants' and toddlers' ability to process information rather than to describe the development of the memory system across age per se. For example, researchers have sought to establish: (1) the *earliest age* at which infants show long-term retention (i.e., for at least 24 h) (e.g., Meltzoff & Moore, 1994; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995; Swain et al., 1993), (2) the *duration* of the interval over which information can be retained (e.g., see Bahrick & Pickens, 1995; Courage & Howe, 1998; Fivush, 1997), (3) the *amount* of information (e.g., number of components in a sequence) that can be retained (see Bauer, 1995), (4) the effect of the *organization* of information to be retained—for example, whether it is, causally or arbitrarily ordered (see Bauer, 1997), (5) the impact of *postevent information* or experience and its *timing* on subsequent retention (e.g., see Boller, Grabelle, & Rovee-Collier, 1995; Rovee-Collier, 1995; Sheffield & Hudson, 1994), (6) the effect of variations in *context* on retention (e.g., see Hartshorn & Rovee-Collier, 1997; Hayne & Finlay, 1995; Klein & Meltzoff, 1999), and (7) the nature of the *memory system(s)* (e.g., declarative or nondeclarative/procedural; preexplicit/explicit or implicit) that is (are) hypothesized to mediate the retention of information (e.g., see Bauer, 1995; Mandler & McDonough, 1995; Nelson, 1997; Rovee-Collier, 1997).

Following this progress, memory researchers have focused more directly on identifying the changes in encoding, storage, and retrieval processes that occur with age. For example, it is clear that as infants get older they can encode information more quickly. This is evident from habituation and paired comparison procedures in which older infants habituate faster and require less familiarization time to show novelty preferences than do younger infants (e.g., Bornstein & Seuss, 2000; Hunter & Ames, 1988; Jankowski & Rose, 1997; Rose, Feldman, & Jankowski, 2002). Similarly, in the mobile conjugate reinforcement paradigm, older infants learn the contingency faster and with fewer study trials than do younger infants with 6-, 3-, and 2-month-olds requiring 1-, 3-, and 6 min to reach criterion, respectively (see Hartshorn et al., 1998a; Ohr, Fagen, Rovee-Collier, Vander Linde, & Hayne, 1989). Finally, research findings from deferred and elicited imitation procedures indicate that younger infants (6-month-olds, 9-month-olds) require more exposure time and/or more exposure opportunities to show imitation than do older infants and toddlers (12-, 18-, 24-month-olds) (see Barr et al., 1996; Bauer et al., 2001; Hayne, Boniface, & Barr, 2000; Meltzoff, 1995).

The question of developmental changes in long-term *retention* of information has been more difficult to address. Indeed, the methods that have been used to study infant memory contain a potentially serious threat to the validity of conclusions about development—namely, the failure to control for the effect of age differences in initial learning (for discussions see Howe, 2000; Howe & Brainerd, 1989; Howe & Courage, 1997a). The basic issue is that if, as is the case with adults (see Underwood, 1954), individual differences in learning rates contribute to individual differences in retention rates (i.e., slower learners forget more rapidly) and individual differences in developmental studies are age-related (i.e., younger participants are slower learners), then younger children will forget more rapidly because they are slower learners and age differences found at retention become difficult to interpret.

Although several research groups have routinely controlled for levels of learning at the end of acquisition (e.g Hartshorn et al., 1998b; Howe & Courage, 1997a), this important point has only recently been appreciated by memory development researchers more generally. The consensus from studies that equate initial learning across age is that there are developmental differences in long-term retention that are independent from developmental differences in learning such that as young infants and toddlers get older they remember more information and retain it over longer periods of time. For example, Howe and Courage (1997a) found a developmental decline in 12-, 15-, and 18-month-olds' forgetting of novel activities over a 3-month interval after equating for levels of learning at the end of acquisition. Consistent with this, Hartshorn et al. (1998b) showed that after being trained to the same criterion, infants from 2- to 18-months old showed a linear increase in retention as a function of age, with 2-month-olds retaining the contingency for about 24 h, 3-month-olds for 5 or 6 days, 6-month-olds for 2 weeks, 12-month-olds for 8 weeks, and the 18-month-olds retaining it for up to 13 weeks. Finally, though it is not possible in deferred and elicited imitation studies to equate levels of learning across age directly after the demonstration, those in which immediate retention control groups have been employed indicate that across the ages of 6–24-months there are significant increases in both the amount retained (number of actions; order information) and the duration of retention (e.g., 24 h–12 months) with increasing age (Barr & Hayne, 2000; Bauer et al., 2000; Meltzoff, 1995).

But what develops?

The question remains, what is it that develops? What are the underlying mechanisms and processes that mediate these improvements in infant and toddler memory over time? These theoretical questions have been addressed from a number of different perspectives some of which emphasize advances in brain maturation and others of which focus on developments in cognitive processes themselves, though these two approaches are not mutually exclusive. From the cognitive perspective for example, Howe and colleagues (e.g., Howe, 1991, 1995, 2000, 2002; Howe & Brainerd, 1989; Howe, Courage, & Bryant-Brown, 1993; Marche & Howe, 1995), contend that with increasing age, infants and toddlers (like older children) are better able to maintain information in storage. In a comprehensive series of studies, they used the trace integrity framework and its associated mathematical model to dissever the effects of storage and retrieval processes in infants' and children's long-term retention on a wide variety of tasks (e.g., free and cued-recall) materials (pictures, words, categorized lists, object location pairings, narrative recall, and event memory), manipulations (retroactive interference, reinstatement, intentional forgetting, recoding), and ages (infants to elderly participants) (for a review see Howe & O'Sullivan, 1997). Collectively, this literature shows that forgetting is dominated by storage failure rather than retrieval failure and that storage failure decreases with age in childhood.

In the trace integrity framework, storage and retrieval are processes lying on a single continuum and traces consist of collections of primitive elements (e.g., features, nodes). The key to initial acquisition is integrating features into a single, cohesive structure in memory. Across any retention interval, traces that are not well integrated tend to disintegrate and their stability (both in terms of storage and retrieval) is compromised. When this occurs, the original memory trace begins to lose its cohesion and distinctiveness, and fades into the background noise of other memory traces (for a discussion see Howe & Brainerd, 1989). This view of how storage and retrieval processes operate in children's memory is generally consistent with other views of these processes in both the developmental and adult literatures (e.g., see Estes, 1988; Schneider & Bjorklund, 1998; Tulving, 1984). In addition, the trace integrity framework has the added value afforded by its associated mathematical model, one that permits the extraction of theoretical processes (e.g., storage, retrieval) from the empirical data.

Like all good theories, this one gives rise to the further question of why it is that infants and toddlers are better able to maintain information in storage as they get older. According to the trace integrity framework, the answer lies primarily in developmental advances in a host of cognitive factors that facilitate the cohesion of trace elements or bundles of features in memory (e.g., knowledge, distinctiveness, strategies such as rehearsal, scripts), reduce the likelihood of their modification (e.g., through blending, recoding, reconstruction, reorganization) or disintegration (e.g., interference, trace decay, or disintegration) over time, and that facilitate or promote trace redintegration (e.g., reinstatement, testing, and provision of retrieval cues). Moreover, improved storage maintenance may be facilitated in very young children by neurological developments known to be ongoing in the time frame considered here (e.g., proliferation of dendrites, synapses, fibre bundles, neurotransmitters, and myelin) (see Johnson, 1997, 2000). For example, the process of synaptogenesis peaks in infancy and toddlerhood and following a period of overproduction, connections are pruned back and decline across early childhood (Huttenlocher, 1999). Greenough and colleagues (e.g., Greenough & Black, 1999; Greenough, Black, & Wallace, 1987) have argued that experience is critical to the selective survival or loss of certain synaptic connections and to the growth of new ones. In that sense, experience-based synaptogenesis and related developments likely contribute some of the neural infrastructure or "hardware" that supports the advances in encoding observed in the early years and perhaps contributes to the "glue" that provides cohesion, integration, and consolidation among trace elements in memory. However, the extent and manner in which these neural developments contribute to the malleability of information in storage and to its accessibility at retrieval is less clear but may be related to structural and functional plasticity within the system.

From a more traditional cognitive neuroscience perspective, Nelson (1995, 1997, 2000) has argued that it is primarily the extensive and rapid growth that takes place within the structures of the brain itself in this time frame that underlies improvements in memory performance (also see Rose & Tamis-LeMonda, 1999). Drawing on evidence from the clinical literature on brain injured (and memory impaired) adults, experimental analogues to brain injury conditions provided by lesioning nonhuman species, and the developmental literature documenting memory performance in immature human (intact) and nonhuman (lesioned and intact) subjects, Nelson argued for the existence of multiple memory systems with different developmental time courses. Specifically, he contends that certain neurological structures which develop early in postnatal life (e.g., the hippocampus, striatum, cerebellum, and olivary–cerebellar complex) are sufficient to sustain a "pre-explicit" or procedural memory system which makes possible the types of recognition memory performance expressed in certain early novelty preferences, habituation, operant and classical conditioning, and visual expectancy tasks. In contrast, performance on certain other "explicit" memory tasks (e.g., deferred and elicited imitation, event memory, and cross-modal recognition) depend in addition, on later developing structures of the medial temporal lobe (e.g., the amygdala), inferior temporal cortical regions, and regions of the prefrontal cortex, which do not begin to come "on line" in human infants until the latter half of the first postnatal year. Consistent with this approach, Hayne and colleagues proposed that developmental advances in deferred imitation over the first 2 years can be attributed (at least in part) to an increase in representational flexibility, an inherent characteristic of declarative memory processes that depends on maturing interactions between the hippocampus and the association cortex as well as on experiences at encoding and test (e.g., see Eichenbaum, 1997; Hayne et al., 2000).

Leaving aside for now the contentious issues of: (1) generalizing from the memory performance of brain damaged adults and lesioned animals to that intact human infants, (2) whether or not there are multiple memory systems at all, (3) if so, whether they develop sequentially or in tandem, and (4) what exactly is meant by "representational flexibility", neurological development during the early years of life will at best provide only part of the answer to the progress in memory development over the early years of life. In fact, Bauer (1997) has argued that once the information has been acquired neither age per se nor neurological developments seem to be the primary determinants of whether or for how long an event will be recalled. This is not to diminish the importance of maturational or "hardware" factors in early memory development (especially in early infancy), but simply that in the time frame considered here, such changes are not paramount. Instead, the duration of recall seems to depend on a variety of "software" changes that affect both storage and retrieval processes such as (a) the organization of the event representation (e.g., whether the temporal relations among the event elements are enabling or arbitrary; the familiarity of the event sequence; whether and how often the event is repeated and the timing of that repetition), (b) the availability of and the ability to use cues or reminders of past events (e.g., through passive exposure, direct re-enactment, videotapes, still photos, or verbal narration), and (c) improvements in cognitive, linguistic, and representational processes that enhance and facilitate strategy use.

Finally, Fuzzy Trace Theory is a general model of cognitive development with direct implications for memory development (e.g., see Brainerd & Reyna, 1998, 2001; Reyna & Brainerd, 1995). The basic idea of fuzzy-trace theory is that memory traces exist on a continuum from literal, factual, *verbatim* traces to fuzzy, imprecise, *gist-like* traces. Both children and adults store separate, parallel memory traces about an event's or a test item's verbatim information (e.g., surface forms, item specific properties) and its gist (e.g., semantic, relational, elaborative) information. An important assumption of fuzzy-trace theory is the idea that gist can exist at several different levels for the same information and a single event will be represented in memory by a variety of traces from exact verbatim traces to a variety of inexact fuzzy traces. Fuzzy or gist-like and verbatim traces also differ in important ways. For example, relative to verbatim traces fuzzy traces are easier to access and generally easier to use. In fact, people of all ages generally prefer to use fuzzy traces when solving problems, meaning that there is a bias in human cognition toward thinking and solving problems intuitively rather than logically (the reduction to essence rule). Gist and verbatim representations also have different life spans with verbatim representations being more susceptible to interference and are forgotten more rapidly than gist representations.

Although verbatim memories undergo considerable change, the main source of change is in the ability to encode, store, and retrieve gist information. Essentially, young children are biased towards extracting verbatim information and processing verbatim traces. They do extract gist, but relative to older children and adults, are less likely to do so. A verbatim-to-gist shift occurs sometime during the elementary school years when children begin to show bias for encoding and processing gist information. Thus, verbatim and gist memories of the same inputs develop at different rates. In terms of acquiring information, the assumption is that memory for the gist undergoes a more protracted developmental course, as it is to a large extent knowledge driven (for a discussion see Howe, 2000).

Although this theory is intended to cover a variety of memory development phenomena (e.g., output interference, infantile amnesia), it is perhaps best exemplified by its unique and comprehensive account of the development of false memories in childhood. Consider the fact that the effects of misinformation are thought to decline with age (e.g., see Bruck & Ceci, 1999). For example, older children are less likely than younger children to confuse something that they were told happened during an event that they witnessed with what they actually witnessed. Although such effects can arise because of source monitoring failures, they can also arise because of differential access to verbatim and gist traces in memory. Indeed this latter account can not only explain how suggestibility arises and how false memories occur but it can also explain opposite developmental trends in both (Brainerd & Reyna, 2002a, 2002b; Brainerd, Reyna, & Forrest, 2002).

Memory development and the big picture: Theoretical issues and practical implications

Research on the development of memory in human infants and toddlers has been enormously influential. Collectively, this large corpus of literature has provided insights into a number of theoretical issues relevant to memory development specifically and also to cognitive development more generally. In addition, these research findings have provided practical information that can be applied to a number of "real world" issues in human development. A brief summary of some of these theoretical and pragmatic insights will be presented next.

Theoretical issues

The nature of human memory

The essential question of whether human memory consists of a unitary system that can be accessed through different routes or processes (e.g., implicit or explicit tests) or comprises a number of functionally and structurally separate and different systems (e.g., implicit/explicit; declarative/nondeclarative; and episodic/semantic) has a long, familiar, and contentious history in the adult literature that is well beyond the scope of this article (for reviews see Buchner & Wippich, 2000; Roediger, Rajaram, & Srinvas, 1990; Rovee-Collier et al., 2001; Schacter & Tulving, 1994; Squire, 1987; Tulving, 1984; Willingham & Preuss, 1995). For developmentalists, there are two key aspects of this issue that have been informed by research findings from the early memory literature: (a) the question of establishing a measure of "consciousness" in recall and (b) the developmental order in which memory systems (assuming that there are different memory systems) emerge. Concerning (a), in the adult literature, a key criterion of explicit or declarative memory is that its content is available/accessible to conscious recollection (e.g., verbal recall) whereas implicit (nondeclarative) memory, which is based on unconscious influence, is not. As conscious recollection cannot be assessed directly in preverbal children, the case has been made that 9-month-old infants' robust recollection of novel events in the absence of perceptual support for those events constitutes a nonverbal analogue of verbal recall. By implication then, it is the result of a conscious or deliberate effort and therefore explicit/declarative in nature (e.g., see Bauer, 1995; Mandler, 1990; Meltzoff, 1995).

Consistent with this conclusion, and concerning issue (b), speculation in the cognitive neuroscience literature held that the memory system necessary for explicit or declarative (i.e., conscious) memory does not come "on-line" until the latter half of the first year of life when certain critical brain structures become sufficiently mature. Prior to this the infant brain can only support memories of the implicit or nondeclarative type (e.g., Mandler, 1990; Nelson, 1995, 1997; Schacter & Moscovitch, 1984). Though this conjecture was based largely on comparisons between the memory difficulties experienced by amnesic adults and surgically lesioned animals and those of intact, developing infants (for a critique see Rovee-Collier et al., 2001), the time-frame was consistent with the early studies that showed the onset of robust nonverbal recall in infants at about 9 months (e.g., see Bauer, 1995; Meltzoff, 1988b). However, more recent empirical evidence showing deferred imitation in 6-month-olds (Collie & Hayne, 1999), retention of single events by 3-month-olds (see Rovee-Collier et al., 2001), and deferred imitation of facial gestures by 6-week-olds (see Meltzoff & Moore, 1994) have provoked a re-evaluation of: (1) the wisdom of making conscious recollection the sine qua non of an explicit or declarative memory system given that the level of awareness of infants' recollections cannot be ascertained with confidence, (2) the hypothesis that implicit and explicit memory systems develop hierarchically in infancy, and more generally (3) whether a multiple memory systems model is the appropriate one to characterize human memory more generally (e.g., see Buchner & Wippich, 2000; Rovee-Collier, 1997; Rovee-Collier et al., 2001).

Among those who are re-thinking these questions, Rovee-Collier (1997) has provided a strong evidence-based argument that if indeed there are separate implicit and explicit (or nondeclarative, declarative) memory systems, they are both operational in infants from at least 3 months of age and hence do not develop hierarchically. Further, she contends that the weight of evidence from her own research favors the more parsimonious position that there is a single memory system with multiple routes of access (see Rovee-Collier et al., 2001). The crux of this argument is that a newly acquired memory can be retrieved either using delayed recognition (an explicit memory test) or once forgetting has occurred, following a memory prime or reactivation (an implicit memory test). Importantly, as the characteristics of recognized (explicit) and the reactivated (implicit) memories share many identical properties (e.g., forgetting rate), the case can be made that they are in fact the same memory. What differs between them is the route of access, through an explicit test or an implicit test.

In sum, these difficult and unresolved issues concerning the nature of infants' long-term retention processes call into question the utility of dichotomizing complex memory processes at this point in time. Referring to the adult literature, Buchner and Wippich (2000) recently argued that the ubiquitous performance dissociations between implicit and explicit measures that have been found in the adult literature may not reflect functional dissociations at all, but are (at least in part) methodological artifacts of the low reliability of tests of implicit memory. As we have argued elsewhere (e.g., see Howe & Courage, 1997b) in light of these unresolved issues and until there is clear evidence to the contrary, it is perhaps more prudent to consider the development of infant memory in terms of a unitary memory system that can be accessed through implicit and explicit routes or tasks providing of course, that appropriate and reliable tests can be developed and implemented in research with nonverbal organisms.

Infantile amnesia

A second theoretical issue that has been illuminated (though not entirely resolved) by the examination of early memory development is that of infantile (or childhood) amnesia, the puzzling phenomena whereby adults cannot recollect the events of their past before the age of about 2 years (Eacott & Crawley, 1998; Usher & Neisser, 1993) in spite of having good recall of childhood events after that age (for a review see Howe & Courage, 1993, 1997a, 1997b). This issue is important because to goes the heart of the question of what happens to information in long-term memory. If storage is permanent, then the inability to recall early experiences may be a matter of retrieval failure that can be alleviated by reinstating the appropriate testing conditions. Thus, early memories are intact but cannot be accessed because the context in which they were laid down in infancy in too discrepant from the one in which it is being retrieved (see Hayne, 1990; Hayne et al., 1997; Rovee-Collier, 1997). On the other hand, if storage is labile and not permanent or events were not properly encoded, as might be expected in the neurologically and perceptually immature infant, then recall of early experiences may be impossible and infantile amnesia may be due to storage failure (e.g., Nelson, 1995). Finally, the possibility remains that elements of both storage and retrieval may be involved.

Research on the storage and retrieval of information in infancy and early childhood has clarified some of these issues. As the contributions to this special issue make plain, infants and toddlers have remarkably robust memory for aspects of the events that they have experienced. However, there are also equally dramatic developmental advances in what they encode, how quickly they encode it, how it is organized in storage, in the range of effective cues that can elicit retrieval, and in the duration of the interval over which information can be retained. Importantly, this progress in long-term retention appears to be a steady one with no evidence of abrupt change in neurological, perceptual, or mnemonic processes per se that might account for the infantile amnesia "barrier" in the time frame in question. We contend that the capstone event in the demise of infantile amnesia does not occur in the memory mechanisms themselves, but in the onset of the cognitive sense of self, an event that occurs at about the age of two years (Howe & Courage, 1993, 1997a, 1997b). The cognitive self provides a new organizer of information and experience and facilitates the personalization of memory for events into what becomes autobiographical memory. Prior to the articulation of the self, infants will learn and remember but these experiences will not be recognized as specific events that happened to "me." After the onset of the cognitive self, adults' recollection of childhood events become more numerous, and like increases in memory more generally, are due to increases in storage maintenance.

The Howe and Courage proposition motivated an intense debate in the literature concerning the relative importance of coincident and subsequent developments in language, parent–child interactions, and metacognition to the offset of infantile amnesia and the emergence of autobiographical memory (e.g., see Fivush, 1997; Perner & Ruffman, 1995; Pillemer & White, 1989; Povinelli, Landry, Theall, Clarke, & Castile, 1999). Take for example, the sociolinguistic view that parent–child conversational interactions underlie the emergence of autobiographical memory (e.g., Fivush, Haden, & Reese, 1996; Fivush & Reese, 1992; Hudson, 1990; Nelson, 1993). In this view, autobiographical memory begins when children can share their past experiences linguistically with others, thus developing a life history (i.e., an autobiography) by telling others who they are. Thus, autobiographical memory is predicated on the development of sophisticated language-based representational skills, ones that do not emerge until children are about 5 or 6 years old, a time frame that departs notable from data on the recall of personal events by young children. In any case, research conducted within this framework reveals that individual and cultural differences in the way that parents talk to their children about the past are associated with individual differences in the quantity and quality of children's reports of their own past experiences as well as the age at which adults report their earliest autobiographical memory (e.g., Haden, Haine, & Fivush, 1997; Han, Leitchman, & Wang, 1998; MacDonald, Uesiliana, & Haynes, 2000; Reese, Haden, & Fivush, 1993). What these and other language-based theories of the development of autobiographical memory contribute to the debate is that following the emergence of the cognitive self, the language environment of the child be it familial or cultural serves to teach children that reporting memories is important, that such reports have a particular narrative structure, and a particular social and cognitive function. However, these narrative reports of personally experienced events should not be equated with their representational structure in memory, one that is fundamentally amodal (e.g., Mandler, 1992).

In sum, considerable progress has been made in our understanding of infantile amnesia. Additional insights will be gained once we establish a nonverbal reporting technique for autobiographical memory in preverbal children. As we have yet to develop such a technique for eliciting autobiographical recall prior to the onset of productive language, some researchers have arbitrarily equated the age of the earliest personal memory with the earliest verbal report of that memory—which children spontaneously provide at about the age of 3 years. Not only does this definition confound the representation of an event in memory with its narrative report, it fails to account for the considerable gap between the onset of the cognitive self late in the second year of life and the age of spontaneous verbal report. In any event, pinpointing the onset of autobiographical memory in young children will signal the impending demise of infantile amnesia and open the door to further questions of why a particular individual may or may not recall his or her earliest years.

Continuity of memory processes

The continuity–discontinuity debate has a long history in developmental psychology and has relevance not only for the emergence of memory in infancy and childhood but also for cognitive development more generally (see Courage & Howe, 2002). The issue is an important one as it is fundamental to questions about the nature of development itself, e.g., whether it is stage-like or gradual; whether (and which) aspects of human mental capacity are constant over development and which aspects change (and how) with maturation and experience; whether the complex relationship between underlying psychological processes and their behavioral manifestations is linear or dynamic. Here we illustrate how the findings from research on early memory development have been instructive in this debate.

To some extent, the phenomenon of infantile amnesia served to reinforce the conventional belief that basic memory processes in preverbal infants and toddlers are qualitatively different (and discontinuous) from those of verbal children and adults. However, the extant empirical database on early memory indicates that this assumption is probably incorrect. Instead, the weight of evidence shows that many of the mechanisms that govern storage and retrieval processes in infancy are the same as those that regulate memory processes in older children and adults. Specifically, infant and toddler memory performance varies as a function of: (a) the amount and distribution of practice (see Rovee-Collier & Bhatt, 1993), (b) organization (see Bauer, 1995), (c) reinstatement (Howe et al., 1993; Hudson & Sheffield, 1999), (d) postevent information (Boller et al., 1995; Rovee-Collier, Borza, Adler, & Boller, 1993), (e) retroactive interference (see Rovee-Collier & Boller, 1995), (f) conditions at encoding (e.g., encoding specificity) (see Rovee-Collier & Bhatt, 1993), and (g) the effect of retrieval on subsequent recall (e.g., test effects) (Fivush & Hammond, 1989; Myers et al., 1994), to name a few. All of these effects are well known in the literatures on older children's and adults' memory (e.g., see Howe, 1991, 1995, 2002; Howe et al., 1993; Marche & Howe, 1995; Schneider & Bjorklund, 1998).

Although there is marked continuity in the functioning of the human information processing system across age, it is equally clear that there are also substantial developmental advances in memory performance with age (e.g., faster encoding, storage, and retrieval processes; increases in the ability to maintain information in storage for longer periods of time) which are undoubtedly supported by changes in other cognitive processes (e.g., changes in knowledge, strategies, attentional processes, metamemory). Importantly, considered in a dynamic systems theory framework, this continuity is in no way inconsistent with the emergence of apparently sudden and dynamic changes in memory performance that occur at the behavioral level (e.g., the offset of infantile amnesia and the onset of autobiographical memory) which can be driven by changes in underlying processes that are continuous (see Courage & Howe, 2002).

Practical implications

Prediction and intervention

At a very basic level, early memory development research has informed us about the "starting state" of the human information-processing system. More than a matter of keen academic interest, this knowledge has important practical implications. For example, once the normal course of early human development has been established (be it the development of memory or any other function or process), it becomes possible to identify individuals whose developmental trajectory is abnormal. Early identification in turn, makes earlier intervention and better outcomes possible. In the memory development literature, there have been several such findings. Susan Rose and her colleagues (see Rose et al., this issue) found that compared to full term infants, very low birth weight preterm infants showed poorer performance on visual recognition memory tasks in infancy and continued to do so on tests of memory, language, and cognition across the preschool and school years. The difference was particularly significant on tasks where speed of encoding and retrieval were key for success (for reviews see Rose & Tamis-LeMonda, 1999; Rose et al., 2002). Consistent with this, De Hann, Bauer, Georgieff, and Nelson (2000) found that healthy but very preterm infants (27–34 weeks gestation) showed poorer elicited recall of action sequences than did their full-term counterparts. Similarly, infants of diabetic mothers showed neurological evidence of persistent subtle impairments in hippocampally based recognition memory not apparent in normally developing control infants (Nelson, Wewerka, Borscheid, DeRegnier, & Georgieff, 2003). Although, the extent to which any of these cognitive deficits can be reversed is variable, at the very least their early identification may ameliorate difficulties associated with delays in learning and memory later in childhood.

Forensic issues

Prompted by pressing forensic questions, the starting point in the quest for scientific information about the veracity and durability of long-term memory began with an inquiry onto the nature of basic memory processes in infants and young children. Building on this literature (a sample of which is cited above), researchers have established many of the variables that affect the quality of children's remembering and forgetting as they pertain to these forensic questions (for reviews see Cordon, Pipe, Sayfan, Melinder, & Goodman, this issue; Howe, 2000). This burgeoning literature includes data on the formation and maintenance of false memories in preschoolers and older children (Brainerd & Reyna, 2002a, 2002b; Brainerd et al., 2002; Ghetti, Qin, & Goodman, 2002; Loftus, 1997) and the role of factors such as misinformation, suggestibility, and source misattribution in these (e.g., Bruck & Ceci, 1999; Drummey & Newcombe, 2000; Hyman & Loftus, 2002; Marche & Howe, 1995; Poole & Lindsay, 2002; Sussman, 2001). Researchers have also addressed the question of how best to elicit accurate recall from children across the repeated interviews typical of forensic procedures (Cassidy & DeLoache, 1995; Salmon, Roncolato, & Gleitzman, 2003; Saywitz, Goodman, & Lyon, 2002) and assessed the efficacy of using props (DeLoache & Marzoff, 1995; Goodman & Aman, 1990; Salmon, 2001) and other nonverbal modes of reporting (e.g., drawing) to facilitate accurate recall (Poole & White, 1995; Salmon & Pipe, 1997, 2000; Wesson & Salmon, 2001).

Though enormous progress has been made in understanding memory performance in forensic settings, there are still a number of outstanding issues to be resolved. For example, questions concerning the effects on encoding and retention of stress, trauma, and individual differences (both temperamental and experiential) that children bring to the situation are the focus of active research, though as yet there is little consensus on the individual and interactive effects of those complex variables (e.g., see Alexander, Quas, & Goodman, 2002; Eisen, Qin, Goodman, & Davis, 2002; Engelberg & Christianson, 2002; Goodman & Quas, 1997; Howe, Cicchetti, Toth, & Cerrito, 2003; Toth & Cicchetti, 1998). Second, as the characteristics of true and false memories of an event share many common features, there are no definitive criteria whereby memories for these two types of events can be reliable distinguished (e.g., Brainerd, Reyna, & Brandse, 1995; Pezdek & Taylor, 2000). Even panels of experts watching children's videotaped statements are unable to reach agreement on the veracity of the statements (Ceci & Bruck, 1995). However, recent progress has been made in this regard as a number of statement validity analyses of witness statements have been developed and refined (see Hershkowitz, Lamb, Sternberg, & Esplin, 1997). Third, it is unclear whether traumatic and stressful events have any special status in memory. Traditionally, two hypotheses have been entertained about the fate of early traumatic memories: (1) they are less memorable (i.e., inaccessible) because they are repressed into the unconscious and (2) they are more memorable because of their uniqueness and the stress and arousal that they entail (e.g., see Carlson, Furby, Armstrong, & Shales, 1997; Cordon et al., this issue; Nadel & Jacobs, 1998). However, research on the retention of traumatic events in controlled (e.g., painful or embarrassing medical procedures) (e.g., Merritt, Ornstein, & Spiker, 1994) and naturalistic (e.g., hurricanes, tornadoes) settings (Bahrick, Parker, Fivush, & Levitt, 1998) cast doubt on these alternatives and indicate instead that memory for traumatic events may be governed by the same laws that direct the storage and retrieval of memory for salient but nontraumatic events (e.g., they deteriorate over time, are subject to misinformation effects, become more script-like with repeated experience) (for a discussion see Howe, 2000). In effect then, it may be the case that it is the distinctiveness of the event rather than its valence per se that confers memorability on it (e.g., Howe, 2000; Howe, Courage, Vernescu, & Hunt, 2000).

Issues of measurement

A third practical issue underscored by research on early memory development is the question of how to interpret the data from nonverbal measures of long-term retention. Although the evidence that infants and toddlers have a robust memory system is not in question, exactly what it is that they remember remains an empirical question. For example, when children possess the narrative skill to talk about personally experienced events at about two to three years of age we can normally be confident that they are exercising conscious recall and that the event has been organized autobiographically in memory. However, if their retention of prior events is expressed in single words or simple motor responses we cannot be sure that their behavior reflects anything more than conditioned responding or reenacted sequences cued by the situation. This does not mean that autobiographical memories do not exist prior to language, just that in the absence of verbal confirmation the organizational structure of the memory is unknown. Indeed, as we have argued elsewhere, autobiographical organization is theoretically possible after the onset of the cognitive self, an event that precedes the onset of language about the self (e.g., Courage & Howe, 2002; Howe & Courage, 1997a, 1997b). Yet because this measurement issue is unresolved, there is no litmus test for identifying a memory as autobiographical prior to its verbal report (but see Howe, Courage, & Edison, 2003).

To deal with the issue of interpreting nonverbal memory, some researchers (see Bauer, 1995; Mandler, 1990; Meltzoff, 1995) have distinguished between nonverbal methods that simply provide evidence of "retention over time" (e.g., novelty preference, operant conditioning) and those that indicate recollection of a specific event provided in the absence of perceptual support for the event (e.g., deferred or elicited imitation). From this perspective, visual preference behavior following familiarization does not unambiguously index recall (but see Rose et al., this issue), as these procedures do not require infants to generate actions based on stored representations. In contrast, as deferred and elicited imitation procedures do require the infant to reproduce an action or a sequence of actions from a stored representation, the case has been made that these behaviors are analogous to cued verbal recall in older children and adults (see Bauer, 1995; Mandler, 1990; Meltzoff, 1995).

This interpretation of nonverbal or behavioral indices of memory continues to be problematic in the developmental literature however (see Rovee-Collier et al., 2001), and has wider implications for interpreting behavioral indices of the recall of traumatic events in forensic and clinical venues. Concerning these latter cases, there is also a recognition that although the cohesiveness and detail of a specific event may be lost to conscious verbal recollection, this does not preclude the possibility that a residue of the event might still exist in memory in some form with the potential to influence current behavior, though to date scientific evidence for this has not been reported. The difficulty faced by researchers and professionals alike is in establishing the correspondence between the current behavior in question (e.g., a phobic reaction; depression) and its source (e.g., a fearful event) in the absence of any objective standard of validation. This is especially problematic after lengthy retention intervals (e.g., years, decades) and when verbal recollection is predictably fragmentary and subject to the constructive and reconstructive forces that can degrade and distort all memories over time. Thus, there is an inherent danger in using current maladaptive behavior patterns to make inferences about events that might (or might not) have happened in the past (e.g., see Terr, 1994), a judgement that is especially problematic when, as is usually the case, the information that was encoded from the initial event at the time it occurred is also an unknown.

These measurement and interpretation issues are extremely important and some of them may never be resolved. Infants will never provide us with verbal reports that we can use to validate their behavior and it is unlikely that adults will ever be able to recall their past experiences with the accuracy that good science requires. What remains then, is to interpret nonverbal behavior parsimoniously, using it to make inferences about memory processes and performance that are guided by the appropriate caveats.

From the past to the future: Quo vadis?

This overview of the early memory development literature has highlighted just some of the research findings and theoretical and empirical issues that currently dominate this growing field. This work has enabled us to answer a number of longstanding questions and has left us still struggling with others. Importantly, in the quest to understand the structure and functioning of the human memory system, new questions have emerged and new directions of inquiry and methodology are being undertaken. To conclude this review, we will highlight just a few of these.

First, there is a growing interest in both cognitive and noncognitive factors that underlie individual differences in memory performance in infancy and also in the longer term. Much of the literature summarized and discussed in this article has concerned normative trends in the development of early memory and in the factors that facilitate or impede its functioning over time. However, it is also becoming increasingly apparent that there are individual differences in memory performance among infants and young children, with some children able to encode, store and retrieve more information than their same-aged peers. For example, Bauer and her colleagues (e.g., Bauer et al., 2002) have recently examined how infants' temperamental characteristics relate to their long-term recall of event sequences. They reported that between about 9 and 13 months of age, infants' recall is positively associated with positive affect, whereas by about 20 months of age, the ability to sustain and focus attention becomes more important to recall. Likewise, individual differences in early visual recognition memory have been associated with performance on tests of memory, language, and IQ in later childhood such that infants with brief look durations on early tests outperform those with longer look durations (e.g., see Colombo, 1993; Rose et al., this issue). The fundamental question is to discover why this is so and to establish the underlying mechanisms and processes as well as the interactions among them and the interactions of these variables with the neurological (e.g., speed), constitutional (e.g., temperament), and experiential factors (e.g., maternal interactive style) that children bring with them to any testing situation.

A second area of research that has enjoyed increasing prominence over the past decade is the cognitive neuroscience of memory development. To date however, brain structures and processes identified in the clinical and animal literatures have been related only imprecisely to memory functioning in normal adults (e.g., Squire & Schacter, 2002). The relevance of these sources of information to the developing human infant needs to be substantiated and better models that tie changes in the brain to changes in memory performance more precisely need to be developed. Though progress to date has been focused on identifying the structures that are likely to mediate performance on certain tasks (e.g., visual recognition, A-not-B, deferred imitation) (e.g., Nelson, 1995, 1997), the behavior-brain inferences that have been made are largely based on whether or not they pass through an "amnesia filter" (see Hayne, this issue). That is, if infants as a group are unsuccessful at a particular task and amnesic patients with medial-temporal damage are also unsuccessful, the inference is that that region is immature in infants of that age. Though this line of research has merit, as Hayne notes, it should not preclude the more rigorous standard afforded by passing a "parameter filter," which depends on the finding of experimental dissociations. That is, retention on tasks that are thought to index declarative or explicit memory are influenced by independent variables that do not influence performance on tasks that are thought to index nondeclarative or implicit memory, and vice versa. In addition, recent advances in neuroimaging technology (fMRI; PET) and high-density EEG/ERP have given the search for the neural substrates of memory and its development new direction. These techniques involve analysis of the brain activity (e.g., electrical potentials, cerebral blood flow) that occurs during the performance of memory tasks (e.g., visual recognition, deferred imitation) and the subsequent localization of the source of this activity within the brain (e.g., see Nelson, 2000; Richards, 2003). The ultimate utility of this approach in informing us about the complex processes inherent in long-term memory development remains to be seen, but will likely remain front-and-center in the immediate future (see Spelke, 2002).

A third (and not unrelated) direction for future research comes from computational cognitive neuroscience, specifically the connectionist modeling of memory behavior (e.g., see Munakata, this issue). Connectionist networks are built of interconnected processing elements (nodes, units), akin to neurons which can modify themselves as a consequence of their interaction with the environment in which they are placed (e.g., see Elman et al., 1996). The behavior of the network is determined by the connection weights among all the units. Initially the connection weight values are random but with experience are tuned to produce meaningful and task appropriate internal representations across the hidden units. Thus, learning consists of adjusting the connection weights in the network—as the weights change so does the behavior. An important implication of this is that networks develop their own internal representations as part of the learning process and have the capacity for self-orgainzation and change and as such are ideal systems for modeling development (see Shultz, 2001, 2003). Importantly, as small changes in the weights can lead to dramatic changes in observable behavior, abrupt changes in behavior can be explained without necessarily postulating the existence of a new underlying mechanism or process. These characteristics of connectionist models have already provided important insights into why different neural regions (e.g., posterior cortical, hippocampal, and prefrontal cortical) might be specialized for different types of memory (e.g., semantic, episodic, and working) and how this may effect early memory development (Munakata, this issue; Munakata & Stedron, 2001).

In conclusion, these new directions in early memory development research will no doubt provide us with the answers to some old questions and will also generate further questions and new challenges for the future. However, it is also clear that the traditional questions and the research methods that have been so remarkably provocative and fruitful over the past three decades will continue to generate and resolve theoretical and pragmatic questions in early memory development. Indeed, it has been the revelation of the early viability and competency of infants' mental processes provided by this basic work that has motivated the examination of their origins and developmental course, wherein may ultimately lie the key to understanding the adult mind.

Acknowledgments

The writing of this article was supported by grants from the Natural Sciences and Engineering Research Council of Canada to Mary L. Courage and Mark L. Howe.

References

Alexander, K. W., Quas, J. A., & Goodman, G. S. (2002). Theoretical advances in understanding children's memory for distressing events: The role of attachment. *Developmental Review, 22*, 490–519.

Bahrick, L. E., Parker, J. F., Fivush, R., & Levitt, M. (1998). The effects of stress on young children's memory for a natural disaster. *Journal of Experimental Psychology: Applied, 4*, 308–331.

Bahrick, L. E., & Pickens, J. N. (1995). Infant memory for object motion across a period of three months: Implications for a four-phase attention function. *Journal of Experimental Child Psychology, 59*, 343–371.

Baillargeon, R. (2001). Infants' physical knowledge: Of acquired expectations and core principles. In E. Dupoux (Ed.), *Language, brain, and cognitive development: Essays in honor of Jacques Mehler* (pp. 341–361). Cambridge, MA: The MIT Press.

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6–24-month-old infants. *Infant Behavior and Development, 19*, 159–170.

Barr, R., & Hayne, H. (2000). Age-related changes in imitation: Implicatoins for memory development. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Progress in infancy research* (Vol. 1, pp. 21–67). Hillsdale, NJ: Erlbaum.

Bauer, P. J. (1995). Recalling past events: From infancy to early childhood. *Annals of Child Development, 11*, 25–71.

Bauer, P. J. (1997). The development of memory in early childhood. In N. Cowan (Ed.), *The development of memory in children* (pp. 83–111). Hove, England: Psychology Press.

Bauer, P. J., Burch, M. M., & Kleinknecht, E. E. (2002). Developments in early recall memory: Normative trends and individual differences. *Advances in Child Development and Behavior, 29*, 103–152.

Bauer, P. J., Wenner, J. A., Dropik, P. L., & Wewerka, S. S. (2000). Parameters of remembering and forgetting in the transition from infancy to early childhood. *Monographs of the Society for Research in Child Development, 65*(4, Serial No. 263).

Bauer, P. J., Wiebe, S. A., Waters, J. M., & Bangston, S. K. (2001). Re-exposure breeds recall: Effects of experience on 9-month-olds ordered recall. *Journal of Experimental Child Psychology, 80*, 174–200.

Boller, K., Grabelle, M., & Rovee-Collier, C. (1995). Effects of postevent information on infants' memory for a central target. *Journal of Experimental Child Psychology, 59*, 372–396.

Bornstein, M. H., & Seuss, P. E. (2000). Physiological self-regulation and information processing in infancy: Cardiac vagal tone and habituation. *Child Development, 71*, 273–287.

Bower, T. G. R. (1977). *A primer of infant development*. Freeman: San Francisco.

Boyer, M. E., Barron, K. L., & Farrar, M. J. (1994). Three-year-olds remember a novel event from 20 months: Evidence for long-term memory in children? *Memory, 2*, 417–445.

Brainerd, C. J., & Reyna, V. F. (1998). Fuzzy-trace theory and children's false memories. *Journal of Experimental Child Psychology, 71*, 81–129.

Brainerd, C. J., & Reyna, V. F. (2001). Fuzzy-trace theory: Dual processes in reasoning, memory, and cognitive neuroscience. *Advances in Child Development and Behavior, 28*, 49–100.

Brainerd, C. J., & Reyna, V. F. (2002a). Fuzzy-trace theory and false memory. *Current Directions in Psychological Science, 11*, 164–169.

Brainerd, C. J., & Reyna, V. F. (2002b). Recollection rejection: How children edit their false memories. *Developmental Psychology, 38*, 156–172.

Brainerd, C. J., Reyna, V. F., & Brandse, E. (1995). Are children's false memories more persistent than their true memories? *Psychological Science, 6*, 359–364.

Brainerd, C. J., Reyna, V. F., & Forrest, T. J. (2002). Are young children susceptible to the false memory illusion? *Child Development, 73*, 1363–1377.

Bruck, M., & Ceci, S. J. (1999). The suggestibility of children's memory. *Annual Review of Psychology, 50*, 419–439.

Buchner, A., & Wippich, W. (2000). On the reliability of implicit and explicit memory measures. *Cognitive Psychology, 40*, 227–259.

Carlson, E. B., Furby, L., Armstrong, J., & Shales, J. (1997). A conceptual framework for the long-term psychological effects of severe and chronic childhood abuse. *Child Maltreatment, 2*, 272–295.

Cassidy, D. J., & DeLoache, J. S. (1995). The effects of questioning on young children's memory for an event. *Cognitive Development, 10*, 109–130.

Catherwood, D. (1993). The robustness of infant haptic memory: Testing its capacity to withstand delay and haptic interference. *Child Development, 64*, 702–710.

Ceci, S. J., & Bruck, M. (1995). *Jeopardy in the courtroom: A scientific analysis of children's testimony*. Washington, DC: American Psychological Association.

Cernoch, J. M., & Porter, R. H. (1985). Recognition of maternal axillary odors by infants. *Child Development, 56*, 1593–1598.

Chen, Z., & Siegler, R. S. (2000). Across the great divide: Beidging the gap between understanding of toddlers' and children's thinking. *Monographs of the Society for Research in Child Development, 65*(2 serial No. 261).

Collie, R., & Hayne, H. (1999). Deferred imitation by 6- and 9-month-old infants: More evidence of declarative memory. *Developmental Psychobiology, 35*, 83–90.

Colombo, J. (1993). *Infant cognition: Predicting childhood intellectual function*. Newbury Park, CA: Sage.

Cordon, I. M., Pipe, M. E., Sayfan, L., Melinder, A., & Goodman, G. S. (this issue). Memory for traumatic experiences in early childhood. *Developmental Review, 24*.

Courage, M. L., & Howe, M. L. (1998). The ebb and flow of infant attentional preferences: Evidence for long-term recognition memory in 3-month-olds. *Journal of Experimental Child Psychology, 70*, 26–53.

Courage, M. L., & Howe, M. L. (2002). From infant to child: The dynamics of cognitive change in the second year of life. *Psychological Bulletin, 128*, 250–277.

Darwin, C. R. (1877). Biographical sketch of an infant. *Mind, 2*, 285–294.

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.
DeCasper, A. J., & Spence, M. J. (1991). Auditory mediated behavior during the prenatal period: A cognitive view. In M. Weiss & P. Zelazo (Eds.), *Newborn attention: Biological constraints and the influence of experience* (pp. 142–176). Norwood, NJ: Ablex.
De Hann, M., Bauer, P. J., Georgieff, M. K., & Nelson, C. A. (2000). Explicit memory in low-risk toddlers born between 27 and 42 weeks of gestation. *Developmental Medicine and Child Neurology, 42*, 304–312.
DeLoache, J. S., & Marzoff, D. P. (1995). The use of dolls to interview young children: Issues of symbolic representation. *Journal of Experimental Child Psychology, 60*, 15–173.
Drummey, A. B., & Newcombe, N. S. (2000). Developmental changes in source memory. *Developmental Science, 5*, 502–513.
Eacott, M. J., & Crawley, R. A. (1998). The offset of childhood amnesia: Memory for events that occurred before age 3. *Journal of Experimental Psychology: General, 127*, 22–33.
Eichenbaum, H. (1997). Declarative memory: Insights from cognitive neurobiology. *Annual Review of Psychology, 48*, 547–572.
Eisen, M. L., Qin, J., Goodman, G. S., & Davis, S. L. (2002). Memory and suggestibility in maltreated children: Age, stress arousal, dissociation, and psychopathology. *Journal of Experimental Child Psychology, 83*, 167–212.
Elman, J. L., Bates, E. A., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness: A connectionist perspective on development*. Cambridge, MA: MIT Press.
Engelberg, E., & Christianson, S. (2002). Stress, trauma and memory. In M. L. Eisen, J. A. Quas, & G. S. Goodman (Eds.), *Memory and suggestibility in the forensic interview* (pp. 143–163). Mahwah, NJ: Erlbaum.
Estes, W. K. (1988). Human learning and memory. In R. C. Anderson, R. J. Hernstein, G. Lindzey, & R. D. Luce (Eds.), *Steven's handbook of experimental psychology: Vol. 2 Learning and cognition* (351, (2nd ed., pp. 351–415). New York: Wiley.
Fagan, J. F. (1970). Memory in the infant. *Journal of Experimental Child Psychology, 9*, 217–226.
Fagan, J. F. (1971). Infants' recognition memory for a series of visual stimuli. *Journal of Experimental Child Psychology, 11*, 244–250.
Fagan, J. F. (1972). Infants' recognition memory for faces. *Journal of Experimental Child Psychology, 14*, 453–476.
Fagan, J. F. (1973). Infants' delayed recognition memory and forgetting. *Journal of Experimental Child Psychology, 16*, 424–450.
Fagan, J. F. (1974). Infant recognition memory: The effects of length of familiarization and type of discrimination task. *Child Development, 45*, 351–356.
Fivush, R. (1997). Event memory in early childhood. In N. Cowan (Ed.), *The development of memory in childhood* (pp. 139–161). Hove, England: Psychology Press.
Fivush, R., Haden, C. A., & Reese, E. (1996). Remembering, recounting, and reminiscing: The development of autobiographical memory in social context. In D. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 341–359). Cambridge, MA: Cambridge University Press.
Fivush, R., & Hammond, N. (1989). Time and time again: Effects of repetition and retention interval on 2-year-olds event recall. *Journal of Experimental Child Psychology, 47*, 259–273.
Fivush, R., & Reese, E. (1992). The social construction of autobiographical memory. In M. A. Conway, D. C. Rubin, H. Spinnler, & W. A. Wagenaar (Eds.), *Theoretical perspectives on autobiographical memory* (pp. 115–132). Dordrecht, The Netherlands: Kluwer Academic Publishers.
Ghetti, S., Qin, J., & Goodman, G. (2002). False memories in children and adults: Age, distinctiveness, and subjective experience. *Developmental Psychology, 38*, 705–718.
Goodman, G. S., & Aman, C. (1990). Children's use of anmatomically detailed dolls to recount an event. *Child Development, 61*, 1859–1871.
Goodman, G. S., & Quas, J. A. (1997). Trauma and memory: Individual differences in children's recounting of a stressful experience. In N. L. Stein, P. A. Ornstein, B. Tversky, & C. J. Brainerd (Eds.), *Memory for everyday and emotional events* (pp. 267–294). Mahwah, NJ: Erlbaum.
Gopnik, A., & Meltzoff, A. N. (1997). *Words, thoughts and theories*. Cambridge, MA: The MIT Press.

Greenough, W. T., & Black, J. E. (1999). Experience, neural plasticity and psychological development. In N. A. Fox, L. A. Leavitt, & J. G. Warhol (Eds.), *The role of early experience in infant development* (pp. 29–40). Pompton Plains, NJ: Johnson and Johnson Pediatric Institute.

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

Haden, C. A., Haine, R. A., & Fivush, R. (1997). Developing narrative structure in parent–child reminiscing across the preschool years. *Developmental Psychology, 33*, 295–307.

Haith, M. M., & Benson, J. B. (1998). Infant cognition. In D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception and language* (5th ed., pp. 199–254). New York: Wiley.

Han, J. J., Leitchman, M. D., & Wang, Q. (1998). Autobiographical memory in Korean, Chinese, and Americam children. *Developmental Psychology, 34*, 701–713.

Hanna, & Meltzoff, A. N. (1993). Peer imitation by toddlers in laboratory, home, and day care contexts: Implications for social learning and memory. *Developmental Psychology, 29*, 701–710.

Hartshorn, K., & Rovee-Collier, C. (1997). Infant learning and long-term memory at 6-months: A confirming analysis. *Developmental Psychobiology, 30*, 71–85.

Hartshorn, K., Rovee-Collier, C., Gerhardstein, P. C., Bhatt, R. S., Klein, P., Aaron, F., Wondoloski, T. L., & Wurtzel, N. (1998a). Developmental changes in the specificity of memory over the first year of life. *Developmental Psychobiology, 33*, 61–78.

Hartshorn, K., Rovee-Collier, C., Gerhardstein, P. C., Bhatt, R. S., Wondoloski, T. L., Klein, P., Glich, J., Wurtzel, N., & Campos-de-Carvalho, M. (1998b). Ontogeny of long-term memory over the first year-and-a half of life. *Developmental Psychobiology, 33*, 271–282.

Hayne, H. (1990). The effects of multiple reminders on long-term retention in human infants. *Developmental Psychobiology, 23*, 453–477.

Hayne, H. (this issue). Infant memory development: Implications for childhood amnesia. *Developmental Review, 24*.

Hayne, H., Boniface, J., & Barr, R. (2000). The development of declarative memory in human infants: Age-related changes in deferred imitation. *Behavioral Neuroscience, 114*, 77–83.

Hayne, H., & Finlay, N. (1995). Contextual control of memory retrieval in infancy: Evidence for associative priming. *Infant Behavior and Development, 18*, 195–208.

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

Herbert, J., & Hayne, H. (2000a). Memory retrieval by 18–30-month-olds: Age-related changes in representational flexibility. *Developmental Psychology, 36*, 473–484.

Herbert, J., & Hayne, H. (2000b). The ontogeny of long-term retention during the second year of life. *Developmental Science, 3*, 50–56.

Hershkowitz, I., Lamb, M. E., Sternberg, K. J., & Esplin, P. E. (1997). The relationships among interviewer utterance type, CBCA scores and the richness of children's responses. *Legal and Criminological Psychology, 2*, 169–176.

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

Howe, M. L. (1995). Interference effects in young children's long-term retention. *Developmental Psychology, 31*, 579–596.

Howe, M. L. (2000). *The fate of early memories: Developmental science and the retention of childhood experience*. Washington, DC: American Psychological Association.

Howe, M. L. (2002). The role of intentional forgetting in relieving children's retroactive interference. *Developmental Psychology, 38*, 3–14.

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

Howe, M. L., Cicchetti, D., Toth, S. L., & Cerrito, B. (2003). True and false memories in maltreated children. Manuscript submitted for publication.

Howe, M. L., & Courage, M. L. (1993). On resolving the enigma of infantile amnesia. *Psychological Bulletin, 113*, 305–326.

Howe, M. L., & Courage, M. L. (1997a). Independent paths in the development of infant learning and forgetting. *Journal of Experimental Child Psychology, 67*, 131–163.
Howe, M. L., & Courage, M. L. (1997b). The emergence and early development of autobiographical memory. *Psychological Review, 104*, 499–523.
Howe, M. L., Courage, M. L., & Bryant-Brown, L. (1993). Reinstating preschoolers' memories. *Developmental Psychology, 29*, 854–869.
Howe, M. L., Courage, M. L., & Edison, S. C. (2003). When autobiographical memory begins. In M. Conway, S. Gathercole, S. Algarabel, A. Pitarque, & T. Bajo (Eds.), *Theories of memory* (Vol. III). Hove, UK: Psychology Press.
Howe, M. L., Courage, M. L., & Peterson, C. (1994). How can I remember when I wasn't there: Long-term retention of traumatic experiences and emergence of the cognitive self. *Consciousness and Cognition, 3*, 327–355.
Howe, M. L., Courage, M. L., & Peterson, C. (1995). Intrusions in preschoolers' recall of traumatic childhood events. *Psychonomic Bulletin & Review, 2*, 130–134.
Howe, M. L., Courage, M. L., Vernescu, R., & Hunt, M. (2000). Distinctiveness effects in children's long-term retention. *Developmental Psychology, 36*, 778–782.
Howe, M. L., & O'Sullivan, J. T. (1997). What children's memories tell us about recalling our childhoods: A review of storage and retrieval processes in the development of long-term retention. *Developmental Review, 17*, 148–204.
Hudson, J. A. (1990). Constructive processing in children's event memory. *Developmental Psychology, 26*, 180–187.
Hudson, J. A., & Sheffield, E. G. (1999). The role of reminders in young children's memory development. In E. Balter & C. S. Tamis-LeMonda (Eds.), *Child psychology: A handbook of contemporary issues* (pp. 199–214). Philadelphia, PA: Psychology Press.
Hunter, M., & Ames, E. (1988). A multi-factor model of infant preferences for novel and familiar stimuli. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in Infancy Research* (Vol. 5, pp. 69–95). Norwood, NJ: Ablex.
Huttenlocher, P. R. (1999). Synaptogenesis in human cerebral cortex and the concept of critical periods. In N. A. Fox, L. A. Leavitt, & J. G. Warhol (Eds.), *The role of early experience in infant development* (pp. 15–28). Pompton Plains, NJ: Johnson and Johnson Pediatric Institute.
Hyman, I. E., & Loftus, E. F. (2002). False childhood memories and eyewitness testimony errors. In M. L. Eisen, J. A. Quas, & G. S. Goodman (Eds.), *Memory and suggestibility in the forensic interview* (pp. 63–84). Mahwah, NJ: Erlbaum.
Jankowski, J. J., & Rose, S. A. (1997). The distribution of visual attention in infants. *Journal of Experimental Child Psychology, 65*, 127–140.
Johnson, M. H. (1997). *Developmental cognitive neuroscience*. Cambridge, MA: Blackwell Publishers.
Johnson, M. H. (2000). Functional brain development in infants. *Child Development, 71*, 75–81.
Kellman, P. J., & Arterbury, M. E. (1998). *The cradle of knowledge: Development of perception in infancy*. Cambridge, MA: The MIT Press.
Klein, P. J., & Meltzoff, A. N. (1999). Long-term memory, forgetting, and deferred imitation in 12-month-old infants. *Developmental Science, 2*, 102–113.
Lacerda, F., von Hofsten, C., & Heimann, M. (2001). *Emerging cognitive abilities in early infancy*. Mahwah, NJ: Erlbaum.
Loftus, E. F. (1997). Creating childhood memories. *Applied Cognitive Psychology, 11*, S75–S86.
MacDonald, S., Uesiliana, K., & Haynes, H. (2000). Cross-cultural and gender differences in childhood amnesia. *Memory, 8*, 365–376.
Mandler, J. M. (1990). Recall of events in preverbal children. In A. Diamond (Ed.), *Annals of the New York Academy of Sciences: Vol. 68. The development and neural bases of higher cognitive functions* (pp. 485–503). New York: New York Academy of Sciences.
Mandler, J. M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review, 99*, 587–604.
Mandler, J. M., & McDonough, L. (1995). Long-term recall of event sequences in infancy. *Journal of Experimental Child Psychology, 59*, 457–474.

Marche, T. A., & Howe, M. L. (1995). Children report misinformation despite accurate memory. *Developmental Psychology, 31*, 553–567.

McDonough, L., & Mandler, J. M. (1994). Very long-term recall in infants: Infantile amnesia reconsidered. *Memory, 2*, 339–352.

Meltzoff, A. N. (1988a). Imitation of televised models by infants. *Child Development, 59*, 1221–1229.

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

Meltzoff, A. N. (1988c). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Child Development, 59*, 217–255.

Meltzoff, A. (1995). What infant memory tells us about infantile amnesia: Long-term recall and deferred imitation. *Journal of Experimental Child Psychology, 59*, 497–515.

Meltzoff, A., & Moore, K. (1994). Imitation, memory, and the representation of persons. *Infant Behavior and Development, 17*, 83–100.

Merritt, K. A., Ornstein, P. A., & Spiker, B. (1994). Children's memory for a salient medical procedure: Implications for testimony. *Pediatrics, 94*, 17–23.

Munakata, Y. (this issue). Computational cognitive neuroscience of early memory development. *Developmental Review, 24*.

Munakata, Y., & Stedron, J. M. (2001). Neural network models of cognitive development. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (pp. 159–171). Cambridge, MA: MIT Press.

Myers, N. A., Perris, E. E., & Speaker, C. J. (1994). Fifty months of memory: A longitudinal study in early childhood. *Memory, 2*, 383–415.

Nadel, L., & Jacobs, W. J. (1998). Trauma memory is special. *Current Directions in Psychological Science, 7*, 154–157.

Nelson, C. A. (1995). The ontogeny of human memory: A cognitive neuroscience perspective. *Developmental Psychology, 31*, 723–738.

Nelson, C. A. (1997). The neurobiological basis of early memory development. In N. Cowan (Ed.), *The development of memory in early childhood* (pp. 41–82). Hove East Sussex, UK: Psychology Press.

Nelson, C. A. (2000). Neural plasticity in human development: The role of early experience in sculpting memory systems. *Developmental Science, 3*, 115–130.

Nelson, C. A., Wewerka, S. S., Borscheid, A. J., DeRegnier, R., & Georgieff, M. K. (2003). Electrophysiologic evidence of impaired cross-modal recognition in 8-month-old infants of diabetic mothers. *The Journal of Pediatrics, 142*, 575–582.

Nelson, K. (1993). The psychological and social origins of autobiographical memory. *Psychological Science, 4*, 7–14.

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

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabre-Grenet, M. (1995). Mothers' face recognition by neonates: A replication and extension. *Infant Behavior and Development, 18*, 79–86.

Perner, J., & Ruffman, T. (1995). Episodic memory and autonoetic consciousness: Developmental evidence and a theory of childhood amnesia. *Journal of Experimental Child Psychology, 59*, 516–548.

Pezdek, K., & Taylor, J. (2000). Discriminating between accounts of true and false events. In D. F. Bjorklund (Ed.), *False memory creation in children and adults: Theory, research and implications* (pp. 69–91). Mahwah, NJ: Erlbaum.

Piaget, J. (1927). La premier annee de l'infant. *British Journal of Psychology, 18*, 97–120.

Pillemer, D. B., & White, S. H. (1989). Childhood events recalled by children and adults. *Advances in Child Development and Behavior, 21*, 297–340.

Poole, D. A., & Lindsay, D. S. (2002). Children's suggestibility in the forensic context. In M. L. Eisen (Ed.), *Memory and suggestibility in the forensic interview* (pp. 355–381). Mahwah, NJ: Erlbaum.

Poole, D. A., & White, L. T. (1995). Tell me again and again: Stability and change in the repeated testimonies of children and adults. In M. Zaragosa & J. R. Graham (Eds.), *Memory and testimony in the child witness. Applied psychology: Individual, social, and community issues, Vol. 1* (pp. 24–43). Thousand Oakes, CA: Sage Publications.

Povinelli, D., Landry, A. M., Theall, L. A., Clarke, B. R., & Castile, C. M. (1999). Development of young children's understanding that the recent past is causally bound to the present. *Developmental Psychology, 35*, 1426–1439.

Reese, E., Haden, C. A., & Fivush, R. (1993). Mother–child conversations about the past: Relationships of style and memory over time. *Cognitive Development, 8*, 403–430.

Reyna, V. F., & Brainerd, C. J. (1995). Fuzzy-trace theory: An interim analysis. *Learning and Individual Differences, 7*, 1–75.

Richards, J. E. (2003). Attention affects the recognition of briefly presented visual stimuli in infants: An ERP study. *Developmental Science, 6*, 312–328.

Roediger, H. L., III, Rajaram, S., & Srinvas, K. (1990). Specifying criteria for postulating memory systems. *Annals of the New York Academy of Sciences, 608*, 572–595.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2002). Processing speed in the 1st year of life: A longitudinal study of preterm and full-term infants. *Developmental Psychology, 38*, 895–902.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (this issue). Infant visual recognition memory. Developmental Review 24.

Rose, S. A., & Tamis-LeMonda, C. S. (1999). Visual information processing in infancy: Reflections on underlying mechanisms. In L. Balther & C. S. Tamis-LeMonda (Eds.), *Child psychology: A handbook of contemporary issues* (pp. 64–88). Philadelphia, PA: Psychology Press.

Rovee-Collier, C. (1995). Time windows in cognitive development. *Developmental Psychology, 31*, 147–169.

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

Rovee-Collier, C., & Bhatt, R. S. (1993). Evidence of long-term memory in infancy. *Annals of Child Development, 9*, 1–45.

Rovee-Collier, C., & Boller, K. (1995). Interference or facilitation in infant memory?. In F. Dempster & C. J. Brainerd (Eds.), *Interference and inhibition in cognition* (pp. 61–103). San Diego, CA: Academic Press.

Rovee-Collier, C., Borza, M., Adler, S. A., & Boller, K. (1993). Infants' eyewitness testimony: Integrating postevent information with a prior memory representation. *Memory & Cognition, 21*, 267–279.

Rovee-Collier, C., Hayne, H., & Colombo, M. (2001). *The development of implicit and explicit memory*. Amsterdam: John Benjamins Publishing Company.

Salmon, K. (2001). Remembering and reporting by children: The influence of cues and props. *Clinical Psychology Review, 21*, 267–300.

Salmon, K., & Pipe, M. E. (1997). Pros and children's event reports: The impact of a 1-year delay. *Journal of Experimental Child Psychology, 65*, 261–292.

Salmon, K., & Pipe, M. E. (2000). Recalling an event one year later: The impact of props, drawing, and a prior interview. *Applied Cognitive Psychology, 14*, 99–120.

Salmon, K., Roncolato, W., & Gleitzman, M. (2003). Children's reports of emotionallyladen events: Adapting the interview to the child. *Applied Cognitive Psychology, 17*, 65–79.

Saywitz, K. J., Goodman, G. S., & Lyon, T. D. (2002). Interviewing children in and out of court: Current research and practical implications. In J. E. B. Myers & L. Berlinger (Eds.), *The APSAC handbook on child maltreatment* (2nd ed., pp. 349–377). Thousand Oakes, CA: Sage Publications.

Schacter, D. L., & Moscovitch, M. (1984). Infants, amnesics, and dissociable memory systems. In M. Moscovitch (Ed.), *Advances in the study of communication and affect: Vol. 9. Infant memory* (pp. 173–216). New York: Plenum.

Schacter, D. L., & Tulving, E. (1994). What are the memory systems of 1994?. In D. L. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 1–38). Cambridge, MA: MIT Press.

Schneider, W., Bjorklund, D. F. (1998). Memory. In W. Damon (Series Ed.) & D. Kuhn & R. S. Seigler (Vol. Eds.), *Handbook of child psychology: Vol. 2 Cognition, perception and language* (5th ed.). New York: Wiley.

Sheffield, E. G., & Hudson, J. A. (1994). Reactivation of toddlers' event memory. *Memory, 2*, 447–465.

Shultz, T. R. (2001). Connectionist models of development. In N. J. Smelser & P. B. Baltes (Eds.), *International encyclopaedia of the social and behavioral science* (Vol. 4, pp. 2577–2580). Oxford: Pergamon.

Shultz, T. R. (2003). *Computational developmental psychology*. Cambridge, MA: The MIT Press.

Slater, A. (1995). Visual perception and memory at birth. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 9, pp. 107–162). Norwood, NJ: Ablex.

Spelke, E. (2002). Developmental neuroimaging: A developmental psychologist looks ahead. *Developmental Science, 5*, 392–396.

Spence, M. J., & Freeman, M. S. (1996). Newborn infants prefer the maternal low-pass filtered voice but nor the maternal whispered voice. *Infant Behavior and Development, 19*, 199–212.

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

Squire, L. R., & Schacter, D. L. (2002). *Neuropsychology of memory*. New York: The Guilford Press.

Sussman, A. L. (2001). Reality monitoring of performed and imagined interactive events: Developmental and contextual effects. *Journal of Experimental Child Psychology, 79*, 115–136.

Swain, I., Zelazo, P., & Clifton, R. (1993). Newborn infants' memory for speech sounds retained over 24 h. *Developmental Psychology, 29*, 312–323.

Terr, L. (1994). *Unchained memories: True stories of traumatic memories, lost, and found*. New York: Basic Books.

Toth, S. L., & Cicchetti, D. (1998). Remembering, forgetting and the effects of trauma on memory: A developmental psychopathological perspective. *Development and Psychopathology, 10*, 589–605.

Tulving, E. (1984). Précis of elements of episodic memory. *Behavioral and Brain Sciences, 7*, 223–238.

Underwood, B. J. (1954). Speed of learning and amount retained: A consideration of methodology. *Psychological Bulletin, 51*, 276–282.

Usher, J. A., & Neisser, U. (1993). Childhood amnesia and the beginnings of memory for four early life events. *Journal of Experimental Psychology: General, 122*, 155–165.

Werner, J. S., & Perlmutter, M. (1979). Development of visual recognition memory infants. *Advances in Child Development and Behavior, 14*, 1–56.

Wesson, M., & Salmon, K. (2001). Drawing and showing: Helping children to report emotionally laden events. *Applied Cognitive Psychology, 15*, 301–320.

Willingham, D. B., & Preuss, L. (1995). The death of implicit memory. *Psyche, 2*, 1–10.