



## Review

## Learning to remember: The early ontogeny of episodic memory

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## ABSTRACT

Over the past 60 years the neural correlates of human episodic memory have been the focus of intense neuroscientific scrutiny. By contrast, neuroscience has paid substantially less attention to understanding the emergence of this neurocognitive system. In this review we consider how the study of memory development has evolved. In doing so, we concentrate primarily on the first postnatal year because it is within this time window that the most dramatic shifts in scientific opinion have occurred. Moreover, this time frame includes the critical age (~9 months) at which human infants purportedly first begin to demonstrate rudimentary hippocampal-dependent memory. We review the evidence for and against this assertion, note the lack of direct neurocognitive data speaking to this issue, and question how demonstrations of exuberant relational learning and memory in infants as young as 3-months old can be accommodated within extant models. Finally, we discuss whether current impasses in the infant memory literature could be leveraged by making greater use of neuroimaging techniques, such as magnetic resonance imaging (MRI), which have been deployed so successfully in adults.

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## 1. Introduction

“You have to begin to lose your memory, if only in bits and pieces to realise that memory is what makes our lives. Life without memory is no life at all. . .our memory is our coherence, our reason, our feeling, even our action. Without it, we are nothing. . .” (Bunuel, 1983).

The above quotation attempts to describe life without memory. Similar sentiments have been articulated time and time again by those who have suffered memory loss in adulthood, and studies of amnesic patients have confirmed the devastation that severe memory impairment imposes on people’s lives. And yet, spend time with a young infant, who is considered by many to possess the mnemonic capabilities of a severely amnesic patient (Schacter and Moscovitch, 1984), and it is evident that the sentiments expressed above are not apposite (Rovee-Collier, 1997). Infants are not, as William James (1890) proposed, living in a state of ‘blooming, buzzing confusion’. On the contrary, they appear to possess a remarkable capacity to encode and retain knowledge that is appropriate for their current needs (Spear, 1984). For instance, shortly after birth, the human neonate can distinguish its mother’s voice (DeCasper and Fifer, 1980) and learn to modify its sucking behaviour in response to milk reinforcement (Sameroff, 1971). By 3- to 4-days-old, it can recognise its mother’s face (Bushnell et al., 1989), and by 8- to 10-days-old it can discriminate its mother’s breast milk from that of another mother (MacFarlane, 1975). However, in stark contrast to this mnemonic ability, the human adult will almost certainly be unable to recollect a single episode from their infancy, because during this period the human infant (along with many other species) is considered to suffer from a profound form of memory loss known as infantile amnesia (Howe and Courage, 1993).

In this review we examine the main theoretical framework, adapted from the adult literature, that has attempted to account for these apparent disparities. We discuss the successes and failures of this approach, and ask whether impasses that exist today in the infant memory literature could be leveraged by making greater use of neuroimaging techniques, such as magnetic resonance imaging (MRI), that have been deployed so successfully in adults. We have much to gain by elucidating memory in infancy and early childhood. Knowing what the very young are capable of encoding and retaining over different time periods can inform the educational needs of these populations. In so doing it can guide public policy, for example, by highlighting the benefits that early stimulation, enriched environments and varied experience have on the flexibility and development of infant memory (Cuevas et al., 2006). There are also implications for how young children are dealt with by the legal system, such as the impact of

cross-examination on children’s testimony (Zajac and Hayne, 2003; Hayne, 2007a). Understanding the maturation of the memory system over time, the interactions between it and the emergence of other cognitive processes, such as episodic future thinking and spatial navigation, could also enhance our understanding of these processes in the adult brain.

## 2. Early theoretical influences

The major theoretical influences in the infant memory literature, as it stands today, can be traced back to 1984 when a number of influential papers on infant memory were published. Two of these papers (Nadel and Zola-Morgan, 1984; Schacter and Moscovitch, 1984; see also Bachevalier and Mishkin, 1982) are directly tied to the radical shift in the conceptualisation of memory that was occurring in the adult literature at this time, namely the move away from considering memory as a unitary entity (Squire, 2004). The roots of this departure are grounded in the cognitive and memory profile of one patient in particular – patient H.M. (Scoville and Milner, 1957). At age 27 H.M. underwent bilateral resection of the medial temporal lobes (MTL) to treat intractable epilepsy. This rendered him densely amnesic for new experiences (episodic memories). On this basis the MTL, and in particular the hippocampus (Fig. 1), were identified as critical for the successful acquisition and recollection of episodic memories. H.M.’s ability to acquire new procedural skills such as mirror drawing (Milner, 1962) pointed to a multiple systems account of long-term memory. Although this latter implication was not fully appreciated at the time (because motor memory was considered to be a special, less cognitive, form of memory), intact skills in amnesic patients were subsequently documented across a wide range of perceptual and cognitive tasks (Cohen and Squire, 1980).

These demonstrations, coupled with findings from the animal literature which indicated that the hippocampus supports specific types of memory (e.g. Gaffan, 1974; Hirsh, 1974; O’Keefe and Nadel, 1978; Squire and Zola-Morgan, 1983), led to the idea that there were multiple memory systems (Tulving, 1985). These were subsequently assimilated into a biological framework that listed the memory type along with the supporting brain structures (Fig. 2). In essence, this taxonomy grouped all memory systems that appeared to be preserved in amnesia (and in animals with hippocampal lesions) under the umbrella term ‘nondeclarative memory’ (Squire and Zola-Morgan, 1988). Memory systems which fell under this classification were defined as memories that could be expressed through performance rather than recollection. On the other hand, memories that appeared to be impaired in hippocampal amnesia were ‘declarative’ in nature (Cohen and Squire, 1980), that is, they involved the conscious recollection

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