

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/292514522>

# Mental Time Travel and the Evolution of the Human Mind

Article in *Genetic Social and General Psychology Monographs* · June 1997

CITATIONS

835

READS

4,194

2 authors:



**Thomas Suddendorf**

The University of Queensland

160 PUBLICATIONS 7,670 CITATIONS

[SEE PROFILE](#)



**Michael C Corballis**

University of Auckland

450 PUBLICATIONS 14,909 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



The evolution of language [View project](#)



Experimental Investigation of Cognitive, Language and Social Processes in Tool Making and Tool Innovation in Children [View project](#)

# Mental Time Travel and the Evolution of the Human Mind

THOMAS SUDDENDORF  
MICHAEL C. CORBALLIS

*Department of Psychology  
University of Auckland, New Zealand*

**ABSTRACT.** This article contains the argument that the human ability to travel mentally in time constitutes a discontinuity between ourselves and other animals. Mental time travel comprises the mental reconstruction of personal events from the past (episodic memory) and the mental construction of possible events in the future. It is not an isolated module, but depends on the sophistication of other cognitive capacities, including self-awareness, meta-representation, mental attribution, understanding the perception-knowledge relationship, and the ability to dissociate imagined mental states from one's present mental state. These capacities are also important aspects of so-called theory of mind, and they appear to mature in children at around age 4. Furthermore, mental time travel is generative, involving the combination and recombination of familiar elements, and in this respect may have been a precursor to language. Current evidence, although indirect or based on anecdote rather than on systematic study, suggests that nonhuman animals, including the great apes, are confined to a "present" that is limited by their current drive states. In contrast, mental time travel by humans is relatively unconstrained and allows a more rapid and flexible adaptation to complex, changing environments than is afforded by instincts or conventional learning. Past and future events loom large in much of human thinking, giving rise to cultural, religious, and scientific concepts about origins, destiny, and time itself.

*This monograph draws in part on the first author's master's thesis, *Discovery of the Fourth Dimension*, 1994. We thank Richard W. Byrne for comments on an earlier draft of the manuscript. Address correspondence to Thomas Suddendorf, Department of psychology, University of Auckland, Private Bag 92019, Auckland, New Zealand. [E-mail: t.suddendorf@auckland.ac.nz](mailto:t.suddendorf@auckland.ac.nz).*

THE QUESTION of whether there is a discontinuity between humans and other species is one that continues to haunt us. Despite Darwin's admonition "never to say higher or lower," most people continue to believe that humans are at the top of the evolutionary tree. Perhaps this conceit is simply an example of a "false consensus bias" (Ross, Green, & House, 1977) created by Western scholars raised in the Christian tradition, which perpetuates an unbridgeable gap separating humans from other animals. Certainly, there are other religious traditions that emphasize continuity rather than discontinuity; Hinduism, for example, views animal and human minds as stages differing in merely quantitative fashion in the progression toward Nirvana.

In some respects, modern scientific enquiry is also narrowing the gap. There is evidence that aspects of thought that only a few years ago were assumed to be uniquely human, such as symbolic thought, the use and manufacture of tools, or self-awareness, may also be present in the great apes (Gallup, 1983; Goodall, 1986; Greenfield & Savage-Rumbaugh, 1990). To sustain the belief in the division between us and our nearest primate relatives, some researchers have resorted to increasingly restrictive definitions of qualities, such as language, that have been traditionally considered uniquely human (Gibson, 1990, 1993). Where it was once believed that only humans manufacture tools, for example, recent evidence has forced the more restrictive claim that only humans use tools to make tools (Beck, 1980). Now even this can be disputed (Toth, Schick, Savage-Rumbaugh, Sevcik, & Rumbaugh, 1993; Westergaard & Suomi, 1994; Wynn & McGrew, 1989).

There is also recent evidence that some great apes, in contrast to monkeys, may have at least some of the elements of a "theory of mind" (Premack, 1988; Premack & Woodruff, 1978) that is manifest in a number of ways. These include the use of pedagogy in both the laboratory (Fouts, Fouts, & van Cantfort, 1989) and the field (Boesch, 1991), deception of conspecifics (Whiten & Byrne, 1991), displays of apparent empathy and compassion (Boesch, 1992), the ability to imitate (Byrne, 1994; Meador, Rumbaugh, Pate, & Bard, 1987), and the more general ability to imagine other possible worlds (Byrne & Whiten, 1992). On the basis of such evidence, one may even be tempted to relocate the "gap" so that it separates the great apes, rather than only humans, from the other animals (Savage-Rumbaugh, 1994b).

Despite all this, there remains a strong case for a substantial gap between humans and the great apes, if only because of the profound effect that humans have had on the physical environment. As Passingham (1982) put it: "Our species is unique because, in only 35,000 years or so, we have revolutionized the face of the earth" (p. 21). This rampant exploitation of the environment may be regarded as part of a more general human capacity for *generativity* – a capacity that also underlies propositional language, mathematics, and perhaps music and dance (Chomsky, 1988; Corballis, 1992, 1994). The origins of this capacity, however, remain in doubt (Bloom, 1994).

In this article we suggest one aspect of thought that may conceivably claim priority as uniquely human. We refer to the ability to travel mentally in time – an ability that is itself characterized by generativity and combinatorial flexibility. The idea that mental time travel might be uniquely human was proposed by the German psychologist Wolfgang Kohler, whose pioneering work on the mentality of apes anticipated many of the more recent discoveries. Although he was able to show that chimpanzees are capable of using mental processes such as insight solve problems, he was compelled to acknowledge an important limitation: "The 'time in which the chimpanzee lives' is limited in past and future" (Kohler, 1917/1927, p. 272; our italics).

In a recent review, Donald (1991) remarked similarly that the lives of apes "are lived entirely in the present" (p. 149), and the same idea has been expressed by Bischof (1978, 1985), Tulving (1983), Savage-Rumbaugh (1994a, 1994b), and Suddendorf (1994). We humans, by contrast, make persistent reference to events that are not limited to the present. Events as remote as the crucifixion of Christ exert a profound influence on large numbers of people. We even tackle questions about the extent of time itself by developing religious or scientific concepts such as genesis, Judgment Day, or the "big bang." Much of what we talk or write about refers to events that happened in the past, or could happen in the future, suggesting that language itself may be intimately related to time travel. Indeed it may not be too far-fetched to suppose that mental time travel lies at the heart of human consciousness.

Although our concern is with mental time travel in both directions, we begin by considering the ability to mentally reconstruct the past.

### **Mental Travel Into the Past**

Before people could concern themselves with history they must have been able to remember their personal past. It has often been suggested that there is a fundamental difference between animal and human memory (Bischof, 1985; Marshall, 1982; Tulving, 1983). So long as we regard memory as simply the ability to learn from past experience, however, the difference must be considered one of degree, at most, as other animals obviously possess memory in this sense. The case for a memory that is distinctly and uniquely human therefore depends on the proposition that there is more than one kind of memory, at least one of which is possessed only by humans.

The idea that there is at least a dual memory system arose from work on amnesia. The famous subject H.M. has dense amnesia for events and knowledge dating from his temporal lobe surgery in 1953, and indeed for memories dating some years prior to that, yet his behavior can still be influenced by past events without his being aware of it (see Ogden & Corkin, 1991, for a recent review). His amnesia seems to apply only to so-called explicit memories, or what Squire (1992) alternatively described as declarative memories; these represent memories that can be brought into conscious awareness. Memories that seem to be unaffected in amnesia are those that we are not aware of, and include those implied by such phenomena as learned motor and cognitive skills, classical and operant conditioning, priming, habituation, and sensitization. Such memories have been called implicit or nondeclarative memories.

As the case of H.M. illustrates, declarative memories appear to be critically dependent on structures in the medial temporal lobe, including the hippocampus. Squire (1992) summarized evidence that these structures appear to mediate similar memory systems in rats, monkeys, and humans, implying that the distinction between declarative and nondeclarative memory cannot provide the basis for a discontinuity between humans and other mammalian species.

However, Tulving (1972, 1983) proposed a further division between semantic and episodic memory systems, and Squire (1992) suggested that this distinction lies within the declarative system. As formulated by Tulving, semantic memory has to do with general knowledge about the world, of the sort that is normally common to people of a given culture, whereas episodic memory represents the individual's personal experiences. Whereas semantic memories transcend space and time, episodic memories are linked to particular events in one's personal past that are spatially and temporally located. Tulving (1983, 1984) further conjectured that, although semantic memory may be common to humans and other animals, episodic memory is uniquely human.

Not surprisingly, this conjecture has met with opposition. Following Roitblat (1982), Olton (1984) noted that animal behavior often seems to indicate the existence of a trace of an earlier event, as in a trial of a delayed conditioned discrimination task, or in foraging, where an animal must remember not to go to the same flower twice to obtain nectar. According to Olton, such observations imply that the animal "represents" a past event, and therefore possesses episodic memory. But, as Dretske (1982) pointed out, an event A might produce a cognitive change B that affects behavior C at a later point in time, but this need not imply that B carries any information about A itself. That is, the mediator B might be causal rather than informational.

Tulving appears to have accepted that this is so, and in his latest formulation of the nature of episodic memory, he is clear that it holds the key to mental time travel:

The owner of an episodic memory system is not only capable of remembering the temporal organization of otherwise unrelated events, but is also capable of mental time travel: Such a person can transport at will into the personal past, as well as into the future, a feat not possible for other kinds of memory. (Tulving, 1993, p. 67)

Tulving also refers to evidence (Shimamura, Janowsky, & Squire, 1990) that episodic memory may depend on frontal lobe structures rather than-or perhaps as well as the medial temporal lobe and diencephalic structures that appear to be critical to semantic memory. Given the prominent expansion of the frontal lobes in hominid evolution (Deacon, 1990), this might be taken as a further indication that episodic memory is unique to humans.

### *Preconditions for Episodic Memory*

There is evidence that episodic memory is not simply a memory system, but is critically dependent on other mental capacities, and it may even be these capacities, rather than the nature of the storage involved, that distinguishes humans from other species. The term *memory is* often associated with a fixed data bank (e.g., a library), but this metaphor seems more appropriate for semantic knowledge than for episodic memory. Unlike retrieval of facts, retrieval of past episodes usually recodes, or updates, the information (Tulving, 1984)<sup>1</sup>. Freud (1895/1966) long ago observed that even memories that reveal themselves as images require a story grammar if they are to be distinguished from random hallucinations. The storyline, however, is often reconstructed on the basis of general knowledge (semantic memory) rather than on what actually happened (Bartlett, 1932), so that the memory trace itself may play a relatively small part. Thus, active reconstruction, rather than mere retrieval, appears to be essential to episodic memory, and this necessitates the involvement of certain cognitive faculties. We now consider some of them.

*The role of the self.* According to Tulving (1985), the different kinds of memory are linked to different levels of "knowing." Nondeclarative memory is anoetic (non-knowing), semantic memory is noetic (knowing), whereas episodic memory is auto-noetic (self-knowing). This suggests that episodic memory is critically dependent on the concept of self. The relation between the two may actually be bidirectional: In providing autobiographical information about one's own past, episodic memories may be said to provide the basis for personal identity. Or, one may also need an awareness of self in the present in order to be able to relate memory representations to experiences of one's self in the past (Howe & Courage, 1993). It is therefore necessary to dissociate a self-concept in the present from personal identity (or self-concept through time), the former being a prerequisite for mental time travel and the latter the consequence of mental time travel.

In human ontogeny, the development of self-awareness is commonly assessed in terms of children's ability to recognize themselves in a mirror (Amsterdam, 1972). Some marker, such as red paint or a sticker, is placed on the child's forehead in the absence of his or her knowledge. A mirror is then placed in front of the child, and the question is whether or not the child notices and responds to the marker. Although this test may measure a basic sense of self, necessary for episodic memory, it clearly falls short of measuring the temporal aspect that underlies the personal identity of an adult. The latter may be characterized by what, according to Humphrey (1986), are the most crucial of all questions: Where have we come from? What are we? Where are we going? These self-defining questions signify the existence of mental time travel, but the mirror test alone does not uncover their presence.

The self-awareness that the test reveals may also be limited in other ways. According to Hart and Fegley (1994), it reveals objective but not subjective self awareness; that is, chimpanzees or children who recognize themselves in a mirror may understand that the body they see is their own, but do not necessarily endow that body with their own subjective states. If Hart and Fegley's distinction is valid, then it is presumably subjective self-awareness that is required in mental time travel into the past, since one must identify episodic memories with one's own *experience*, not merely with one's own body. There is evidence that subjective self-awareness is lost after prefrontal lobotomies (Freeman & Watts, 1942), which may explain the dependence of episodic memory on frontal lobe function.

Mitchell (1994) made a similar point. He identified three levels of self:

---

<sup>1</sup> H.M.'s amnesia is based not merely on failure of storage or retrieval, but also on an inability to actively reconstruct the past. He can recall some episodes from about 16 years prior to the operation that led to his amnesia, but these are recounted in highly stereotyped fashion. He is apparently unable to "update" these memories (Ogden & Corkin, 1991), but recalls them, like semantic knowledge; without further reconstruction.

1. The self as largely implicit, a point of view that experiences, acts and, at least in the case of mammals and birds, has emotions and feelings;
2. The self as built on kinesthetic-visual matching, leading to [mirror self recognition], imitation, pretense, planning, self-conscious emotions, and imaginative experiences of fantasy and daydreams; and contributing to perspective taking and the beginnings of a theory of mind; and
3. The self as built on symbols, language, and artifacts, which provides external support for shared cultural beliefs, social norms, inner speech, dissociation, and evaluation by others as well as self-evaluation (p. 99).

These of course correspond at least roughly to Tulving's three categories of anoetic, noetic, and auto-noetic thought, except that Mitchell's Level 2 seems to involve a more active concept of self than Tulving's notion of noetic thought. However, Mitchell placed autobiography in Level 3, implying that episodic memory belongs there rather than in Level 2.

The critical aspect of episodic memory that raises it above Level 2 may in fact be dissociation, which Mitchell identified with such phenomena as multiple personality disorders, hypnosis, self-deception, denial, or simply driving on a well-known route while thinking about something else. We shall contend that episodic memory requires the dissociation of past from present, or more accurately, the dissociation of past from present *self*, and it is this critical feature that elevates it to Level 3.

*Temporal components.* One aspect of episodic memory that appears not to be encoded in the trace itself is the order of events. Reviewing the evidence, Friedman (1993) recently concluded:

In spite of the common intuition that chronology is a basic property of autobiographical memory, the research reviewed demonstrates that there is no single, natural temporal code in human memory. Instead, a chronological past depends on a process of active, repeated construction. (p. 44)

Even the sense of "pastness" of an episode may not be inherent in the memory itself and may need to be added. One illustration of this is the phenomenon of *deja vu*, in which we have the experience of reliving a past episode in the absence of an actual memory (Bowers & Hilgard, 1986). Conversely, "[h]aving – and even using – a memory representation of a prior event is not sufficient to ensure the subjective experience of remembering" (Jacoby, Kelley, & Dywan, 1989, p. 417). These examples suggest that the sense of pastness may be doubly dissociated from actual memories.

*Meta-representation.* The conferring of "pastness" on a remembered episode further implies the ability to form meta-representations of one's knowledge. Meta-representation, according to Perner (1991), is representing a representation as a representation. That is, in addition to the primary representation (e.g., I am in a park), one has to understand that this representation is a memory. Other primary representations that comprise memories (e.g., I go shopping; I play ball) can then be constructed into a past episode (I was in a park, played ball, then went shopping). The ability to selectively choose representations and organize them into past episodes is a characteristic of human mental time travel that demands flexible access to one's own mind.

*Attribution.* The conferring of pastness may also be regarded as an act of attribution. That is, in recollecting some past event we attribute it to the experience of an earlier self. Such attributions may well parallel our ability to attribute mental states, such as beliefs, desires, and emotions, to other people. Even memory states may be attributed to others as well as to ourselves; we usually assume that if we have shared an experience with another person, then that person will remember it too. A good deal of human conversation consists of mutual time travels down memory lane. Shared memories are the glue for the enlarged and complex social nets that characterize our species and that go well beyond mere kinship.

*Understanding the relation between perception and knowledge.* As pointed out earlier, in addition to knowing something about a past event, one has to meta-represent this knowledge and attribute it to the experience of an earlier self in order to travel mentally into the past. Re-experiencing the event, that is, representing how this information became known, demands some understanding of the contingency between perception and the formation of knowledge (Perner, 1991; Perner & Ruffman, 1995). If one does not know that knowledge is the result of experience and that experience depends on the different channels of sensation and perception, one can scarcely reconstruct a particular experience from current information. Knowledge about the taste, color, shape, temperature, and so forth, of an object can have entered one's system only in specific ways. The awareness that one knows something because it has been experienced (auto-noetic, or self-knowing,

consciousness) and the subsequent ability to mentally re-experience it require an understanding about how experience is formed.

We have identified several basic cognitive capacities that seem to be required for a fully fledged episodic memory system. Mental travel into the past demands some level of self-awareness, an imagination capable of reconstructing the order of events, an understanding of the perception-knowledge contingency, an ability to meta-represent one's knowledge, to dissociate from one's current mental states and to attribute past mental states to one's earlier self. Some of these capacities seem to overlap, and they seem so basic and natural to us that we find it hard to conceive of a mind without them. Yet, only by about the age of 4 are they properly installed in the human brain.

### **Human Ontogeny of Mental Travel Into the Past**

Nondeclarative memory can be shown to exist right after birth. Visual habituation (Friedman, 1972) and auditory recognition (DeCasper & Fifer, 1980) confirm that information is stored right from the start. In fact, familiarity effects can be observed even prior to birth (DeCasper & Spence, 1986). At the age of 3 months, experience with a particular stimulus has effects for up to a week (Rovee-Collier, Sullivan, Enright, Lucas, & Fagan, 1980). Recent studies, such as that of Bauer, Hertsgaard, and Dow (1995) using elicited imitation, showed that experiences of 1-year-olds can influence responses a year later.

Recall, in its widest sense, can first be observed at about 7 months when infants will begin to look for objects that moved out of sight (Ashmead & Perlmutter, 1980). The development of "object-permanence" (Piaget, 1954), that is, the understanding that objects continue to exist independent of our perception, is, however, far from complete at this age. By the age of 10 months, infants can correctly locate an object hidden under one of two identical cloths if there is a delay of up to 8 s between witnessing the placement of the object and being allowed to choose (Diamond, 1985). At longer delays, performance deteriorates to a chance level. By 16-18 months, the critical delay period has expanded to 20 s (Daechler, Bukatko, Benson, & Myers, 1976).

Declarative memory is evident when, by 2 to 3 years of age, children begin to reproduce details about past events (Fivush, Gray, & Fromhoff, 1987) and this knowledge can be retained for a year and a half (Fivush & Hamond, 1990). However, Perrier and Ruffman (1995) cited evidence that these memory reports differ substantially from those of older children. They require a lot more cuing, and the questions asked by adults strongly influence the structure of the recall. Perner and Ruffman argued that these young children *know* (semantic memory) rather than *remember* (episodic memory) what has happened. We will come back to their argument shortly. Others, for example Nelson (1992), argued that these early memories are episodic, but that they do not become truly autobiographic until age 4. Only then can they later be recalled and become part of one's life story. Here, the phenomenon of *childhood amnesia* comes into play.

Childhood amnesia, or the inability of adults to remember their early childhood, begins to fall away at about age 3 to 4 (Loftus, 1993; Pillemer & White, 1989; Sheingold & Tenny, 1982). If adults can have an episodic memory (recollective experience) of events from that age, then it follows that episodic memory must exist by that age. The question that remains is therefore whether episodic memory exists prior to the fading of childhood amnesia. The fact that younger children can report knowledge about events when prompted may reflect only semantic rather than episodic memory, just as the early use of the words "remember" and "forget" appears to be misleading. Lyon and Flavell (1994) showed recently that 4- but not 3-year-olds understand the sense of pastness implied by those words. The younger children use these terms merely to describe current success (remember) or failure (forget).

But what about the development of those capacities that we argued to be essential for a fully fledged episodic memory system? Do their maturations converge at the age of 3 to 4? If so, then mental travel into the past, as outlined in this article, can only emerge at this age.

#### *Preconditions for Episodic Memory in Children*

*Self-awareness.* At the age of 18-24 months, children pass the mirror-recognition test (Amsterdam, 1972). We may assume that at this stage the prerequisite for episodic memory is achieved. However, as stated earlier, the self-concept implied by the mirror test need not extend to the more general adult sense of personal identity that extends through time. The emergence of the latter might be tested by introducing a delayed condition to the mirror test. Povinelli (1995) has reported intriguing preliminary results bearing on this issue. In studies with his colleagues Landau and Perilloux, he marked 2-, 3-, and 4-year-old children by putting stickers on their foreheads. When he showed the children a video of this action 3 min later, 75% of the 4-year-olds reached up immediately to remove the sticker, whereas none of the 2-year-olds and only 25% of the 3-year olds did so. All of the 2- and 3-year-olds immediately removed the sticker when the video was replaced by a mirror, providing direct feedback, confirming the earlier evidence that even 2-year-olds pass the mirror test (e.g., Amsterdam,

1972). So, although the mirror test demonstrates the onset of a self concept at around age 2, the temporal dimension appears not to emerge until age 3 to 4.

*Temporal reconstruction.* Mental time travel also implies that the order of events in time can be reconstructed, and Friedman (1991, 1992) has shown that 4-year-olds are capable of making correct earlier versus later judgments about past events. Between the ages of about 4 to 8, children acquire an explicit knowledge about the culturally dependent time scales (days, weeks, months, etc.) that assist the structuring of one's own past experiences. The basic reconstructive capacity, however, might be in place in children even younger than 4.

*Meta-representation.* It has been argued that meta-representation first manifests in the form of pretense (Leslie, 1987). Whether the representations of the pretended and real worlds are hierarchically organized is still debated (see Jarrold, Carruthers, Smith, & Boucher, 1994, for a critical appraisal). Pretend play develops in the 2nd year and therefore clearly precedes the proposed time frame for the emergence of mental travel into the past. However, complex social pretend play as well as individual pantomime develop later, at around age 3V2, and only then, it has been argued, may pretend play be based on meta-representation (Jartold et al., 1994; Suddendorf & Fletcher-Flinn; 1996). This argument would be consistent with the emergence of meta-representation in other domains, such as mental attribution.

*Mental attribution.* Using representational skills for the attribution of mental states develops progressively between ages 2 and 4, from attributing desires and intention to knowledge and belief and, finally, false beliefs (Gopnik, 1993; Wellman, 1991; Whiten, 1991; Wimmer & Perner, 1983). At first, the new attribution of mentality is characterized by overgeneralization or what has been called animism. By 3 1/2 to 4 years, when they finally pass appearance-reality and false belief tasks (Astington, Harris, & Olson, 1988; Flavell, 1993; Gopnik & Astington, 1988; Wimmer & Perrier, 1983), children are said to have a "theory of mind," a truly representational view of the world, including the meta-understanding that representations can be wrong, can be changed, and depend on informational access (Perner, 1991). Meta-representational dissociation from primary mental states becomes evident.

For our purposes, it is important to note that this development is not restricted to the attribution of current mental states to others, but appears to include the attribution of past mental states (to a past self and others). In a classical false belief paradigm, for example, 3-year-olds fail to understand that their current knowledge that there are pencils and not Smarties in the candy box is not available to others; that is, they wrongly predict that another child also believes the box to contain pencils. They also fail to understand that, before they were shown to the contrary, they once believed the box to contain Smarties (Gopnik & Astington, 1988). This is also true of intentions, desires, and beliefs. Gopnik and Slaughter (1991) showed that 3-year-olds, although able to recall past mental states of pretense, imagination, and perception, have severe difficulties remembering past mental states of desire, intention, and belief.

With regard to past knowledge, Gopnik and her colleagues (Gopnik & Graf, 1988; O'Neill & Gopnik, 1991) demonstrated young children's difficulty in recalling the source of their current knowledge even though the learning event may have occurred only minutes ago. The children can report the content of learning before they become able to recall the learning event itself. Taylor, Esbensen, and Bennett (1994) found that even older children (of 4 and 5 years) have problems with source memory for recently acquired skills and color names. Those children who claim to have known the names yesterday, when in fact they learned them today, also tend to claim that they have always known them.

Thus, 2- and 3-year-olds have problems representing their own (and others') former mental states of desire, intention, knowledge, and belief. This severely limits their potential ability for mental travel into the past. Gopnik and Slaughter (1991) acknowledged this point when they wrote that their findings (see above) "may have implications for the development of fully-fledged, autobiographic, episodic memory. One characteristic of such memory is that we not only know that past events took place, but we also know that we experienced and represented them in a particular way" (p. 109). The ability to reconstruct the narrative of past events is severely limited if one cannot represent what one (and others involved) wanted, intended, knew, and believed, and how these mental states changed.

Perhaps mental attribution and mental travel in time develop similarly. One view on how children develop mental state attribution is by simulation (Gordon, 1986; Harris, 1991; Humphrey, 1986; Johnson, 1988). At first, the child's own state may interfere with the simulation of conflicting states, but by the age of 4, children, by then consummate actors, can detach from their own states to assume the states of others. At this point, then, there is dissociation.

We suggest that a similar pattern may characterize the development of episodic memory. That is, young children may have difficulty simulating their own past experiences because they cannot escape their present one. Interestingly, Kinsbourne (1989) attributed the memory failures shown by patients with Korsakoff syndrome to the same difficulty, and not to the loss of memory per se. By the age of 4, however, the child can

escape the present and simulate the past without interference. The simulation account for the development of mental attribution is, however, not undisputed (see "Mental Simulation," 1992, for a thorough discussion). It may therefore be premature to assume the validity of the proposed parallel development of mental time travel and mind reading via simulation.

Be this as it may, the development of the final precondition adds further empirical evidence to the argument for the late (around age 4) emergence of episodic memory.

*Understanding the relationship between perception and knowledge.* The research on source memory discussed earlier already indicates that children younger than 4 years old may not understand much about the relationship between perception and knowledge. Wimmer, Hogrefe, and Perner (1988) studied this understanding explicitly and found that 4-year-olds, but not 3-year-olds, correctly answered questions regarding informational access (e.g., seeing) and current knowledge.

Perner (Perner, 1991; Perner & Ruffman, 1995) saw the connection to episodic memory and sought empirical support for the claim. He appealed to Tulving's (1985) finding that individuals tend to report items in a free-recall condition as "remembered," whereas items in cued-recall conditions are deemed "known." Perner and Ruffman (1995) cited several other studies (e.g., Gardiner & Java, 1990) in support of the claim that the adult judgment of whether items are remembered or known is a valid measure. The argument, then, is that in recognition one can use semantic cues to retrieve the items (which results in *knowing*), whereas, in free recall, retrieval depends largely on internal *episodic traces*, especially the awareness of having experienced, that is, perceived, the item (which results in *remembering*). The target group, preschool children, cannot, of course, be asked to make a valid judgment about this (see the results of Lyon & Flavell, 1994, discussed earlier). But, if the reasoning is correct, one would expect to find a correlation between free recall and children's performance on tests that measure their understanding of the relationship between informational access and knowing. Those who pass these tests should do much better on free-recall tasks than those who fail, whereas no significant difference would be expected in their performance on cued-recall (recognition) tasks.

This hypothesis has been tested in four experiments instigated by Perner (1991) and Perner and Ruffman (1995). And, indeed, a significant correlation was found ( $r > .4$ ) between free recall and various measures of an understanding of how perception leads to knowledge. This correlation remained significant even after correlations with cued recall and intelligence (i.e., scores on the BPVS) were partialled out. Thus, the results strongly support the idea that understanding the perception-knowledge relationship is essential for episodic memory (performance in free recall) because it entails the ability to represent the experiential origin of one's knowledge (a so-called episodic trace). This understanding, according to Perner's results, develops gradually between the ages of 3 and 6. Prior to this, a child can know something about past events but cannot re-experience the event in the way required for true episodic memory.

Perner and Ruffman (1995) also concluded that their findings provide an explanation for the phenomenon of childhood amnesia in that the development of true episodic memory causes it to fade somewhere between ages 3 and 4. We believe this claim is supported by our analysis of the development of the other cognitive capacities that we hold to be important for mental travel into the past. Only by 3 1/2 to 4 years of age can children use meta-representation to attribute past mental states (such as desires, intentions, knowledge, belief, and false beliefs) to their past selves. Only then can their personal past experiences be properly reconstructed. This, in turn, is necessary to the formation of a record of one's history—the foundation of a personal identity.

Howe and Courage (1993) proposed a relationship between the cognitive sense of self and childhood amnesia. Whereas the first empirical evidence for a sense of self develops at 18 to 24 months, it may rather be Povinelli's (1995) delayed paradigm that accurately measures the emergence of an identity through time. Taken together with the results of Perner's studies, we believe that we have an explanation for both—childhood amnesia and the subsequent emergence of episodic memory at about the age of 3 1/2.

### **Support for the Model From a Clinical Population: The Case of Autism**

Finally, we consider a disorder that, we believe, supports most of the points we have made so far. If our argument is correct, then clinical populations that lack one or more of the proposed requirements should consequently be impaired in their mental time travel ability. On the other hand, if clinical populations exist who, despite a lack of these proposed prerequisites, show a capacity for mental time travel, then this would clearly contradict our argument.

Autism is one disorder that has been claimed to be based on a lack of *theory of mind* (Baron-Cohen, 1995; Baron-Cohen, Leslie, & Frith, 1985). Deficits have been shown in autistic children's ability to meta-represent (Baron-Cohen, 1989; Frith, 1989), to understand the perception-knowledge relationship (Baron-Cohen & Goodhart, 1994; Leslie & Frith, 1988), to distinguish appearance from reality (Baron-Cohen, 1989), and to attribute mental states to others and themselves (Baron-Cohen, 1995; Perrier, Frith, Leslie, & Leekam, 1989). It



has to be noted that a small minority of autistic people do overcome these deficits to some extent. In fact, various degrees of autism (e.g., regarding IQ and verbal ability) make this clinical group very heterogeneous. Our hypothesis, therefore, predicts that most (i.e., those without the proposed requirements) autistic children are impaired in their ability to travel mentally in time.

Although people with autism can have a good and sometimes even extraordinary ability for rote memory (e.g., associative and cued memory; Boucher & Warrington, 1976), episodic memory seems to be impaired (Boucher & Lewis, 1989; Powell & Jordan, 1993). Powell and Jordan speak of a lack of "personal episodic memory," wherein events can be recalled but individuals are unable to "remember *themselves* performing actions, participating in events or possessing knowledge and strategies" (p. 362). They further argue that an "experiencing self," much like the one invoked by Perner and Ruffman (1995), is needed to code episodes as part of a personal dimension. In accordance with Perner and Ruffman's (1995) findings, then, Boucher and Lewis (1989) as well as Tager-Flusberg (1991) found autistic children to be impaired in free, but not in cued, recall. Tager-Flusberg acknowledged that, as suggested by Perrier for young children, lack of experiential awareness may be responsible for autistic children's impaired episodic memory and consequent deficits in free recall.

According to Powell and Jordan (1992), a "continuing sense of self 'from the inside'" (p. 362) rather than a mere sense of self as seen "from the outside" is needed for this kind of memory. "Sense of self from the outside" clearly reminds us of what is measured by the mirror self-recognition task, and the distinction from self "from the inside" strikingly resembles that of Hart and Fegley's (1994) between subjective and objective self-awareness. Without this subjective or *inside* sense of self and the accompanying *theory of mind*, children with autism, as was predicted, appear to be unable to mentally transport themselves into their past, re-experience the events, and see the causal relation between past and present self. We would therefore predict that, although autistic children can recognize themselves in a mirror (Dawson & McKissick, 1984), they will fail the delayed video version of the task. Further research is needed to address this issue and to determine and investigate only those individuals who lack our proposed prerequisites.

We have argued that one crucial underpinning of theory of mind and mental time travel might be the ability to dissociate from one's current state. This ability also appears to be impaired in most autistic children. "Executive function" is an umbrella term for the mental operations which enable an individual to disengage from the immediate context in order to guide behaviour by reference to mental models and future goals" (Hughes, Russel, & Robbins, 1994, p. 477), and evidence for executive dysfunction in autistic children has accumulated in recent years (Hughes & Russel, 1993; Hughes, Russel, & Robbins, 1994; Ozonoff, Pennington, & Rogers, 1991). Although the relationship between executive functions and theory of mind is still debated (Baron-Cohen, 1995; Russel, Jarrold, & Potel, 1994), autistic children's inability to disengage or dissociate from the present and to form strategic plans demonstrates impairment of mental travel into the future. Harris (1991) noted the lack of planning that is a typical characteristic of autism: lack of flexibility and the tendency to engage in stereotyped and routinized actions. Thus, although further research is needed, current knowledge about autism supports our theory.

### **Evidence for the Existence of the Required Capacities in Animals**

The vast literature on animal memory (see Kendrik, Rilling, & Denny, 1986, for a review) demonstrates clearly that we are not the only species benefiting from past experience. However, the question of whether other animals mentally reconstruct the past, have recollective experience, or, in other words, travel mentally into the past, cannot be answered by these data.

#### *Preconditions for Episodic Memory in Animals*

*Self-awareness.* The role of the self may not be sufficient to deny all other animals the capacity for episodic memory, because there is evidence that the concept of self is not restricted to humans. Chimpanzees (Gallup, 1970), gorillas (Patterson, 1991), and orangutans (Suarez & Gallup, 1981) appear to demonstrate self-recognition in a mirror (see also Parker, Mitchell, & Boccia, 1994, for a recent review). Monkeys and even elephants and parrots can learn how a mirror works (e.g., correctly using mirrored information about approaching objects), but unlike the great apes, they do not attend to markings viewed in a mirror if these are on their own bodies (Anderson, 1986; Gallup, 1994; Pepperberg, Garcia, Jackson, & Marconi, 1995; Povinelli, 1989).

This area of research is somewhat controversial, however, since there is also evidence that some chimpanzees do not show self-recognition on the mirror test, even after extended exposure to their own mirror images (Swartz & Evans, 1991), and the data on gorillas are also somewhat equivocal (Povinelli, 1993). Even so, this work at least raises the possibility that the great apes are capable of a concept of self and therefore possess one

of the prerequisites for episodic memory. Whether they can pass Povinelli's delayed version remains to be seen. We would expect them not to pass this test for reasons that will become clear in the following discussions.

*Temporal order.* Great apes have provided some evidence for the ability to imagine other possible worlds (Byrne & Whiten, 1992). Furthermore, even monkeys and pigeons have been shown to learn serial orders (Terrace & McGonigle, 1994). Whether great apes can use their imagination to reconstruct the order of past events, however, remains questionable. For what it is worth, it can be noted that none of the ape-language studies has resulted in apes acquiring tense or terms for time scales.

*Meta-representation.* There is some evidence that great apes may be capable of some degree of meta-representation. There are some records of seemingly pretend play with imaginary objects (Hayes, 1951; Savage-Rumbaugh, 1986; Savage-Rumbaugh & McDonald, 1988). Furthermore, Whiten and Byrne (1991) argued that tool manufacture and insightful spontaneous problem solving (Kohler, 1917/1927) by great apes also indicate more than primary representation. It remains debatable whether these observations indicate representation of a higher order, but if we accept similar behavioral evidence for children (Leslie, 1987), then we should also grant it to apes. It is interesting to note that, just as with mirror self-recognition, only the great apes show these behaviors; monkeys do not.

*Mental attribution and the perception-knowledge relationship.* A similar discrepancy can be observed with regard to knowledge representation and mental attribution. On the basis of extensive observations in the wild, Cheney and Seyfarth (1990) inferred that monkeys are not able to recognize and internally represent their own knowledge. Just as people with "blindsight" are not consciously aware that they have vision, so monkeys do not seem to know what they know, or even *that* they know (Gallup, 1983; Humphrey, 1986). If this were the case, we could hardly expect them to know how they got to know what they currently know; that is, they could not have Perner and Ruffman's "experiential awareness" and thus episodic memory. Great apes, on the other hand, have provided at least suggestive evidence that they may have some elements of a theory of mind.

In fact, the whole enterprise of studying theory of mind development was triggered by Premack and Woodruff's (1978) experiments suggesting that chimpanzees attribute intention. This has received at least some support. Records of apparent compassion (Goodall, 1986), perhaps even empathy (Boesch, 1992), cooperation (de Waal, 1982, 1989; Menzel, 1974), imitation (Byrne, 1994; Meador et al., 1987), role taking (Povinelli, Nelson, & Boysen, 1992; Povinelli, Parks, & Novak, 1992) and tactical deception (Byrne & Whiten, 1990, 1992; Whiten & Byrne, 1988) can be cited in support of the claim that great apes may have at least some understanding of motivational mental states. There is virtually no evidence for these qualities in monkeys.

Evidence for the attribution of informational states, such as knowledge and belief, is less extensive. There are at least two recorded incidences of teaching (Boesch, 1992; Fouts et al., 1989). Although several ingenious attempts to prove experimentally that chimpanzees attribute informational states (Povinelli, Nelson, & Boysen, 1990; Premack, 1988) have been published, none has provided unequivocal evidence (Heyes, 1993; Gagliardi, Kirkpatrick-Steger, Thomas, Allen, & Blumberg, 1995). The only published attempts to show that apes may represent false beliefs, and thus have a fully fledged theory of mind, were unsuccessful (Premack, 1988; Premack & Dasser, 1991).

Heyes (1993) recently argued that all of the ape behavior that has been cited as evidence for theory of mind can be explained by learning processes without the need to postulate the attribution of mental states. Accepting her position would mean that there is no reason to believe that even apes have the capacity for mental travel into the past. But even if we suppose that Heyes wielded Occam's razor a little too vigorously, and that chimpanzees *can* draw some inferences about the mental states of others (a view favored by the authors), there may still be a significant gap between chimpanzees and humans (Premack, 1988).

Apes may have developed only to the level of attributing motivational states. This, in the light of the importance of understanding past knowledge and belief, would render proper episodic memory impossible. If apes fail *only* to understand false beliefs, then they would still be short of comprehending the full extent of the perception-knowledge relationship. According to Perner and Ruffman's (1995) analysis, this shortcoming alone would make episodic memory impossible. Furthermore, if our proposed model is correct, then dissociation – the ability to simultaneously entertain different, even opposing, mental states – is required for both mental time travel and attribution of false beliefs. We have no reason to believe that chimpanzees, or any other nonhuman animals, have mastered this mental feat.

Finally, although we acknowledge the risk of arguing from ontogeny to phylogeny, the timing of the onset of episodic memory in humans may put it out of reach for chimpanzees. Premack (1988) and Parker and Gibson (1979) have proposed as a rule of thumb that what a child of 3 1/2 years cannot do also cannot be done by a chimpanzee. This is certainly true, for example, of language development (Bickerton, 1986; Pinker, 1994). This need not imply that chimpanzees are simply developmentally arrested children (cf. Povinelli, 1993); species-specific differences in mental capacities surely exist, and may be qualitative as well as quantitative.

Nevertheless, if we are to ask whether chimpanzees have the ability to travel mentally in time, it seems reasonable to ask whether they can master the steps that humans have to master in the process of acquiring that ability. On present evidence we have to answer this question in the negative.

### **Mental Travel Into the Future**

In view of the generative aspect of episodic memory, it seems reasonable to suppose that basically the same mechanisms might be involved in imagining the future as in constructing the past. Time travel into the future is in a sense an extrapolation from time travel into the past, similarly involving the ability to escape the influence of the current mental state. The same mental platform might be used to entertain scenarios in different modes (such as what *was*, *would*, *could*, *should*, *might*, or *will be*).

It is important to distinguish mental time travel into the future from anticipatory behavior. This is a distinction that in some respects parallels that between episodic and other memory systems, which may reflect the influence of the past without necessarily involving mental time travel into the past. Similarly, many behaviors involve anticipation of future events in some way, but need not involve the actual simulation or imagining of future events. The link with memory runs even closer; learning and memory are themselves as much oriented to the future as to the past, because they increase the organism's chances of future survival. Insight-free instincts, such as hibernation, provide a further mechanism for dealing with recurring environmental changes, but again there is no need for the organism to actually *imagine* the future. Hibernators prepare for winter even if they have not experienced that season before. True anticipation of the future, involving the imagining of different scenarios, is what we might consider intelligent rather than instinctual. The distinction may sometimes be elusive, however, and Gibson (1990) suggested that instinct and intelligence should be regarded, not as polar opposites, but as the two ends of a continuum, which she calls "mental constructional ability."

Be that as it may, the insightful behavior shown by Kohler's (1917/1927) apes implies constructive thought with an eye to the future solution of a problem and seems clearly more intelligent than instinctive. Even more strikingly, Dohl (1970) showed that the chimpanzee Julia was able to look several steps ahead in a sequential problem-solving task. She had to choose between two keys in a transparent box that opened further boxes with keys until she arrived at a final box that contained either nothing or a food reward. Only by choosing the right keys at each point was she able to obtain the reward. Julia learned to act, not by chance, but by determining the route leading to reward before she chose the initial key. Since each trial involved a different sequence, this learning could not be accomplished by simple chaining. Julia was able to look as many as five steps ahead in pursuit of the final goal, an anticipatory skill that some chess players might envy.

Chimpanzee tool cultures also suggest flexible forethought. For example, the chimpanzees at Gombe manufactured pointed tools from sticks at one place to use them later for termite fishing at another place that was out of sight (Goodall, 1986). Because the stick is trimmed to give it a pointed end, Whiten and Byrne (1991) argued that besides seeing the stick as a stick, the animal must also generate a representation of it as a termite probe.

But despite this evidence for chimpanzees' capacity to imagine the future, Kohler (1917/1927) earlier suggested an important restriction: The anticipations do not go beyond the *context* of the present. Sultan's construction of the future, which enabled him to solve the problem and get the bananas, was bound by the context of his present hunger. The same is true of the more recent examples: Julia's performance was driven by her present desire for food reward and the Gombe chimpanzees' manufacture of sticks by their appetite for termites. Kohler viewed such anticipations as essentially belonging to the present. The same point is made by Donald (1991), who wrote that an ape's behavior, "complex as it is, seems unreflective, concrete, and situation-bound" (p. 199). Conversely, Stebbins (1982) and Eccles (1989) refer to "time-binding," meaning simultaneous access to past and future, as uniquely human.

### *The Bischof-Kohler Hypothesis*

Bischof (1978, 1985) and Bischof-Kohler (1985), based on Kohler's writings, suggest a more explicit limit on the extent to which animals can represent the future. Their hypothesis is that animals other than humans cannot anticipate future needs or drive states and are therefore bound to a present that is defined by their current motivational state. We shall refer to this as the Bischof-Kohler hypothesis, noting that the name acknowledges all three of its proponents, namely, Wolfgang Kohler, Norbert Bischof, and Doris Bischof-Kohler.

The hypothesis still retains a measure of ambiguity, since there is no clear definition of drive or need. It relies instead on commonsense notions. Bischof (1985) illustrated with the example of a homeostatic drive, thirst. When an animal is thirsty, it tries to find drink: Perception is focused on key stimuli, memory is searched, perhaps a plan of action is worked out. To begin these procedures, however, the animal must in fact be thirsty. Humans, by contrast, plan the future regardless of present need; a full-bellied lion is no threat to nearby zebras,

but a full-bellied human may be. We humans anticipate future needs in multifarious ways, as when we buy food or other provisions, install burglar alarms, or manufacture or purchase tools. Business is to a great extent dependent on anticipation of our own and others' future needs.

The Bischof-Kohler hypothesis is consistent with the idea, developed earlier, that nonhuman species may be unable to *dissociate* another mental state from their present one. Future need anticipation therefore might be only a special case of animals' general problem with simultaneously representing conflicting mental states. Like 3-year-old children, they may be unable to imagine an earlier belief (or state of knowledge, or drive, etc.) that is different from a present one or to understand that another individual holds a belief different from their own. This may apply to future states as well as to past ones. That is, a satiated animal may be unable to understand that it may later be hungry, and therefore may be unable to take steps to ensure that this future hunger will be satisfied.

Griffin (1978) pointed to the importance of studying animals' sense of a remote future or, in terms of the Bischof-Kohler hypothesis, to a future beyond the present drive state, but as yet little has been published on the topic. The evidence that exists is anecdotal. Goodall (1986), for example, recorded the case of a chimpanzee, Satan, who followed a female in estrus, then slept close beside her. This suggests an activity designed for sexual gratification the next morning. Even if Satan planned this, one can still argue that he was acting according to his present sexual drive; that is, his plan did not extend into the "future" in Kohler's sense.

Bischof (1985) suggested that, in the course of evolution, there was a progressively increasing gap between drive and action. Great apes display quite extensive gaps; they can postpone the immediate enactment of their current drive and make plans to receive gratification at a later time. De Waal (1982), for example, reported an incident in the Arnhem Zoo in which the researchers hid grapefruit in the chimpanzee enclosure by burying them in the sand. The chimpanzees searched enthusiastically but apparently unsuccessfully, although several, including Dandy, passed over the spot. Later in the afternoon, unnoticed by the others, Dandy went straight to the spot, dug up the grapefruit, and enjoyed them without competition from the others. Similar examples of tactical deception have been recorded by Byrne and Whiten (1990). Such cases may demonstrate an impressive delay of gratification to achieve greater gain, but they do not necessarily reflect mental travel beyond the present drive state.

Chimpanzees carry stones over long distances to open nuts at a place where no suitable stones can be found (Boesch & Boesch, 1984), but even this fairly extreme example of forethought may still be controlled by a single drive state. "What is imagined is the resonance of current needs in a future environment" (translated from Bischof, 1985, p. 541).

Another anecdote that suggests an awareness of the future was recounted by Byrne and Byrne (1988). A group of chimpanzees surrounded a cave in which a leopard and its infant had hidden, and amid much excitement, and after several unsuccessful attempts, one old male lunged into the cave and emerged with a very small leopard cub. The group inspected the cub, bit it, and eventually killed it. However they did not eat it, and some of them (not the killers) groomed its body. One interpretation of this behavior is that the chimpanzees had acted to eliminate a future predator. But is this what they had in mind when they began their siege? We do not really know.

An anecdote recounted by de Waal (1982) is perhaps more compelling:

It is November and the days are becoming colder. On this particular morning Franje collects all the straw from her cage (subgoal) and takes it with her under her arm so that she can make a nice warm nest for herself outside (goal). Franje does not do this in reaction to the cold, but before she can have actually felt how cold it is outside. (p. 192)

However, no further details are provided, and taken by itself it scarcely provides a convincing refutation of the Bischof-Kohler hypothesis.

The widespread use of anecdotes in the 19th century led to wildly exaggerated accounts of the mental capacities of nonhuman animals. Lindsay (1880), for example, concluded that animals engage in criminal activities and commit suicide. There was also the infamous case of Clever Hans, the horse that appeared to be able to perform prodigious feats of arithmetic by tapping out the answers to questions put to him by his owner. It transpired that the owner, unbeknownst even to himself, was giving subtle signals to the horse that indicated when to stop tapping (Pfungst, 1911/1965).

Claims about animal intelligence came to be mistrusted, and a more skeptical attitude was enshrined in Lloyd Morgan's canon and the principle of parsimony. However, the pendulum may have swung too far, making it virtually impossible to obtain evidence of mental time travel. We may now be entering a phase of more balanced enquiry. The anecdotal method has been successfully introduced for studying primate deception (Byrne & Whiten, 1985, 1990, 1992; Whiten & Byrne, 1988), and a similar survey of anecdotes relating to mental time travel into the future has also been instigated (Suddendorf, 1994). This has yet to reveal convincing evidence of mental travel into the future by nonhuman primates.

Of the 73 leading primatologists, comparative psychologists, and representatives of the ape-language projects initially surveyed, only 5 contributed observations they thought might contradict the Bischof-Kohler hypothesis. None of these observations described clear cases of future-need anticipation such as refinement or continued carrying of tools after a need has been satisfied or, in the case of the ape-language studies, the acquisition and appropriate use of words referring to the remote future. Only 2 respondents, Tutin (see below) and Savage-Rumbaugh, stated that they believed apes to be capable of anticipating the future beyond the current state of needs/drives. Savage-Rumbaugh, however, appears to have changed her view, for she has recently stressed the importance of the encoupling of current and future needs in hominid evolution (Savage-Rumbaugh, 1994a).

Although this survey confirms that the Bischof-Kohler hypothesis is consistent with our current data, it still remains difficult to distinguish mental time travel from instinctive behavior that may give the appearance of forethought. As de Waal (1982) pointed out, for example, adolescent humans often provoke and challenge their parents in displays of independence, but are generally unaware of the true motive for their actions, which are based on instinct rather than explicit mental constructions of the future. De Waal suggested a similar explanation for the apparent strategic intelligence displayed at the Arnhem chimpanzee colony by an ex-alpha male, called Yeroen. After losing his alpha status to Luit, Yeroen formed an alliance with a third male, Nikkie, a strategy that eventually brought him back to power. The strategy was at first unsuccessful and took months to pay off. Although noting that alternative explanations are possible, de Waal suggests that the strategy may not have been formulated with the future goal in mind. Even so; such anecdotes clearly raise the possibility that chimpanzees have a greater capacity for forward planning than we are yet willing to grant them.

Similar arguments may apply to the acquisition of mental maps for future use. Chimpanzees and gorillas seem to acquire an extensive knowledge of territory, allowing them later to take the shortest route to trees when they contain fruit or to stones for opening nuts (C. E. G. Tutin, Record #14 in Suddendorf, 1994; Boesch & Boesch, 1984). Whether this knowledge is acquired intentionally, having in mind its usefulness for future needs, is questionable. Spatial knowledge seems to be acquired implicitly rather than explicitly, and may be a general adaptive mechanism that requires no explicit reference to the future.

## Evolutionary Considerations

There must be some question as to why it might be adaptive to travel mentally into the past when phylogenetically older forms of memory already allow for learning from a single event. Part of the answer may lie in the nature of the information extracted. Sherry and Schacter (1987) argued that the older form of memory (procedural) is essentially concerned with extracting *invariances* from stimulus events, as in pattern recognition, whereas the newer form is concerned with preserving the *individuality* of events. Because these characteristics are mutually incompatible, the later form of memory evolved as a separate system.

This distinction may capture the difference between nondeclarative and declarative memories, but it does not seem to capture that between the two varieties of declarative memory, namely, semantic and episodic. Semantic memories themselves may vary considerably in individuality; knowing that Canberra is the capital of Australia, for example, is more specific than knowing what a capital is. Even more individual, however, is remembering precisely when and how we learned that Canberra is the capital of Australia. (Some readers may have learned it just now.)

The ability to travel mentally back in time may confer the added advantage of allowing events to be repeated, mentally if not physically, so that we can reflect on them, draw more general or abstract conclusions from them, and so on. In that sense, episodic memory may contribute to the elaboration of semantic memory. On these grounds, some have argued that episodic memory may have preceded semantic memory in hominid evolution (e.g., Donald, 1991; Seamon, 1984). However, because other species seem to be capable of at least a primitive form of semantic memory, we agree with Tulving (1983, 1984, 1985) that episodic memory emerged later, but then allowed the semantic memory system to develop more fully. Kinsbourne and Wood (1975) showed that the absence of episodic memory slows the acquisition of new knowledge.

This relationship is also observed in human development, and we suggest that again semantic memory precedes episodic memory. Taylor et al. (1994) showed that children between 4 and 5 years of age begin to remember learning events and in so doing gradually overcome so-called source amnesia. This age period can therefore be viewed as containing the onset of semantic learning based on episodic memory. That is, only by this age can children travel mentally back to the source of their knowledge and, for example, assess the accuracy and reliability of the source or whether there might be other things to be learned from the event. With mental access to the learning event, children can truly become generative in Corballis' s (1991) sense, because knowledge can be flexibly transferred across different domains. This is supported by the recent finding that when false-belief tasks are passed, and thus dissociation is evident, children generate significantly more, and more diverse, answers to simple problems (Suddendorf & Fletcher-Flinn, in press).

Although the ability to build up semantic memory increases the fitness of the organism, we doubt that this fully explains the evolution of mental time travel. Rather, the precursors of mental time travel, such as the ability to attribute mental states to others, may have evolved as a result of the pressures of an increasingly complex social structure. This underlies the theory of so-called Machiavellian intelligence (Byrne & Whiten, 1988; Humphrey, 1976, 1986; Jolly, 1966); at some point in primate evolution, there was a selective pressure for the ability to read the minds of other individuals, because this allowed for better planning, cooperation, imitation, and teaching-and, no doubt, deception. Humphrey (1986) argued that the human desire for varied experience emerged because it allowed individuals to understand others; in a sense, psychology was born. Self-knowledge might then have been an adaptation derived from the ability to know others. As support for this, it has been noted that chimpanzees reared in social isolation seem unable to recognize themselves in a mirror (Gallup, McClure, Hill, & Bundy, 1971).

These considerations suggest that the real importance of mental time travel applies to travel into the future rather than into the past; that is, we predominantly stand in the present facing the future rather than looking back at the past. This assertion is supported by the finding that "children can judge the forward order of parts of the day, days of the week, and months of the year at earlier ages than they can mentally move backwards through the sequences" (Friedman, 1992, p. 173).

This finding may help explain why we are in fact such poor witnesses. That is, the constructive element in episodic recall is adaptive in that it underlies our ability to imagine *possible* scenarios rather than actual ones, but it may be rather maladaptive with respect to reconstruction of the actual past. If it were important to remember the past in faithful detail, then we might have expected a more efficient system to have evolved. Instead, we bolster our faulty memories with external storage systems, such as drawings, books, tapes, films, and computer disks, leaving our minds ever freer to create scenarios for the future (not to mention fantasies about the past).

The ability to represent possible future events has clear advantages over the older systems for generating anticipatory behavior, namely, instinct and learning. The flexibility of the newer system allows one to consider different options, whereas inherited instincts or insight-free acquisition of response patterns are effectively fixed by the motivational state of the organism and by environmental contingencies. Through the combining of different options, we can generate scenarios that are highly specific and that are novel; we can plan to do things we have never done before. The future exerts so obvious an influence over our thoughts and actions and, indeed, over the shaping of society itself, that it needs no further elaboration here.

In recent years motivation theorists have come to appreciate that human behavior is not governed merely by internal drives, habits, and external stimuli, but depends very largely on anticipatory cognition. Bandura (1991) writes that "even in the so-called biological motivators, human behavior is extensively activated and regulated by anticipatory and generative cognitive mechanisms rather than simply impelled by biological urges" (p. 70). This is not to say that humans have overcome their biological needs; rather, they have the capacity to integrate the enactment of present and future drives in a complex set of action plans directed at a variety of goals. Only through considering the cognitive component (and the importance of mental time travel) can we begin to explain the evolution of human volition, including such biologically paradoxical phenomena as celibacy or hunger strikes.

The self-regulation required for the management of our motivation appears to begin with the emergence of mental time travel, that is, at around age 4 (Perner, 1991). Because of the limited scope of this article, we refer the reader to the work of Kuhl (e.g., Kuhl & Kraska 1989) for an excellent analysis of the development of meta-volition and to Frankfurt (1988) for a philosophical discussion of the logic behind this issue. That meta-motivation is vital for human culture, however, should be clear without further elaboration.

### *When Did Mental Time Travel Evolve?*

We suggested earlier that a critical ingredient of mental time travel is dissociation, or the ability to maintain different mental states simultaneously. Savage-Rumbaugh (1994a) proposed the intriguing hypothesis that this may have arisen as a consequence of bipedal locomotion and the ensuing problem of transporting infants. The precursors of the hominoids moved primarily by brachiation swinging from branch to branch-as gibbons and seaman's do today. Infants were transported simply by clinging, and the mother could assist by simply raising her hind legs to provide extra support. With deforestation during the Miocene, it was necessary to develop alternative methods of locomotion across the savanna, between forest patches. Chimpanzees and gorillas solved this problem by knuckle-walking, which allowed the infant to cling to the mother's back.<sup>2</sup>

---

<sup>2</sup> It is usually assumed that the common ancestor of chimpanzee, gorilla, and human was also a knuckle walker. Controversially, Savage-Rumbaugh (1994a) suggests that the common ancestor depended primarily on brachiation, and that gorillas and chimpanzees evolved knuckle walking independently-a case of convergent evolution.

However, the hominids, for whatever reason, adopted a bipedal mode of locomotion, which posed a problem in the transportation of infants. It was no longer sufficient to assume that the infant would simply cling, and greater demands were placed on the mother-and perhaps the father as well-to ensure that the infant was supported and monitored. Infants would be put down while sleeping, but it would be important to remember them and pick them up before moving on. Human infants are held in front of the parent, allowing a more direct monitoring of their expressions, direction of gaze, and attention fixations. In short, it may have proved adaptive for the parent to be able to take the perspective of the infant, mentally as well as physically.

The requirement to monitor the presence and needs of an infant may have led to an expansion of the ability to keep several things in mind. Savage-Rumbaugh suggested that this also enabled hominids to carry tools and weapons that were related not to current needs, but to contingencies that might arise, such as unexpected attacks, or terrains unlike those encountered before. It may well have been such considerations that eventually permitted the migration of *Homo erectus* from Africa to various parts of the Old World. This is generally considered to have begun about 1.6 million years ago, although recent dating of fossils from Java suggests that some migration may have occurred some 1.8 million years ago, before there was any known evidence of bifacial tools (Swisher, Curtis, Jacob, Getty, Suprijo, & Widiasmoro, 1994).

These migrations took *H. erectus* into diverse environments with differing climates, suggesting a facility for rapid adaptation. Instead of slow morphological adaptations, such as changes in size or the growth of fur, these early hominids must have been able to construct ecological niches in conditions that originally could not have met human requirements. So began the human propensity to shape virtually any terrestrial environment to our own ends.

It is sometimes suggested that the stone tools of the so-called Oldowan culture, dating from some 1.6 to 2.4 million years ago, provide the earliest evidence for deliberate planning for the future. These tools are generally associated with *Homo habilis*, regarded as the first hominid to show an increase in cranial size beyond that of an ape. Although there has been considerable emphasis in the past on the importance of tools in early hominid evolution, recent evidence has suggested a reappraisal. For example, the creation of simple Oldowan tools appears to be within the competence of modern chimpanzees (Toth et al., 1993; Wynn & McGrew, 1989), and it has been claimed that the tool culture of Tai chimpanzees, although not involving the making of stone tools, represents a comparable stage of development (Boesch & Boesch, 1984). Moreover, although the production of an Oldowan tool may require some advance mental picture of the finished product and the use to which it will be put, it is not convincing evidence for mental time travel according to the Bischof-Kohler hypothesis. Like Tai chimpanzees, *H. habilis* may have manufactured primitive stone tools simply to satisfy a current need.

The more sophisticated Acheulian culture associated with *H. erectus* around 1.6 million years ago may provide more convincing evidence. For example, the bifacial hand ax involved symmetrical removal of flakes from a stone core to produce a tool that was sharper and more pointed than the primitive Oldowan scrapers. This more costly and time-consuming procedure suggests that these tools were not intended for one-time use only, but were kept for future use. This implies that the manufacturer was able to anticipate future needs, possibly extending beyond the present drive state (Suddendorf, 1994). As Savage-Rumbaugh (1994a) put it, the Acheulian hand ax provides the first evidence of the "uncoupling" of present and future needs. We might regard this as representing an intermediate stage of mental time travel, perhaps roughly that of a 4-year-old human child, in which the simulation of past and future episodes was possible, but there was little development of abstract semantic concepts and theories about the future.

With *Homo sapiens neandertalensis*, between 100,000 and 35,000 years ago, we find the first evidence of burial and associated rituals. This finding perhaps signals a final step in the freeing of mental time travel, to the point that it outstrips bodily time travel, giving rise to that singularly unwelcome concept death. Consequently, personal identity through time must have existed in Neanderthals. Here, too, we see evidence of the generative nature of time travel, in which scenarios are created for the possibility of life after death. Religion was born.

As we have already intimated, the emergence of mental time travel may have depended on increased encephalization, beginning with *H. habilis* and reaching its peak some 300,000 years ago with *Homo sapiens*. Not every part of the brain enlarged at the same rate, however. The limbic system, a prominent structure in most mammalian brains, was significantly reduced in relative size. Given its role in basic motivation (drives, needs, and emotions), this might be taken as evidence that other parts of the brain became increasingly important in driving behavior. This is not to say that emotions are no longer an important part of the human condition (the limbic system did increase in absolute size).

With mental time travel, "cognition" challenged "impulse" for the driver's seat, as it were. The neurological correlate appears to be the disproportionate development of the prefrontal lobe, which is reciprocally connected to the limbic region and to sensory association areas (Fuster, 1989). The prefrontal

---

cortex plays a vital role in subjective self-awareness (Freeman & Watts, 1942), temporal organization of action (Fuster, 1989; Ingvar, 1985), and episodic memory (Shimamura et al., 1990). Lesions to the prefrontal area may also lead to impaired goal-directed behavior, lack of ambition, apathy, unawareness of behavioral consequences, or what Ingvar (1985) referred to as a "lack of future:"

### *Relation to Language*

One characteristic of mental time travel that distinguishes it from instinct and associative learning is its flexibility. That is, given a basic vocabulary of actors, objects, and events, we can reconstruct unique episodes in the past and create scenarios to deal with unique contingencies in the future. This ability to generate an infinite variety of combinations from a finite vocabulary is also what characterizes human language and sets it apart from the communication systems of all other species (Chomsky, 1988). Generativity may not be unique to language, but it may be an aspect of thought that arose as a means of rapid adaptation to complex physical and social environments.

Again, it may have been the emergence of multiple monitoring that led to the development of language from a relatively crude associative device that may be within the competence of both chimpanzee and 2-year-old child, to the sophisticated generative, recursive system that every human over the age of about 4 seems effortlessly to have acquired. The ability to create a sentence with an embedded clause, such as this one, requires that one keep track of the overall structure while the embedded clause is generated. That is, even at the level of word production, multiple monitoring (and short-term memory) is required. But one must also keep track of meaning-what it is one is trying to say.

True language may also require a dissociation between one's own thoughts and the thoughts of those to whom we speak. Premack and Premack (1994) emphasized that human language requires a theory of mind; through language, we aim not merely to change the behaviors of others but to change their beliefs. This of course requires that we have a theory of what others believe; that is, a theory of others' minds. We attribute mental states to the people we talk to, but dissociate those states from our own. We speak differently to an ignorant audience than to a knowledgeable one, to an angry person than to a happy one. We have argued in this article that this ability to dissociate is also involved in mental time travel.

Recursion itself depends on dissociation. For example, social behavior may be governed by the knowledge that Individual A knows something, or that A knows that B knows something. Mental time travel may involve similar propositions: I am not hungry now, but I know that I will be hungry soon; I am here today, but last week I was in Wellington and went to the opera. These kinds of propositions are characteristic of the sorts of things that we use language to express. Premack and Premack (1994) suggested that the attributions involved in language may involve as many as four levels of meta-representation: "A speaker believes that his listener believes that he will tell the truth; further that the listener believes he believes that the listener believes that he will tell the truth" (p. 105).

These considerations need not imply that mental time travel is dependent on language. Intuitively, at least, we seem to be able to create or recreate scenarios that rely on imagery rather than on language, and indeed it is not always easy to express in words something that we have seen. This suggests that language and mental time travel both exploit more general attributional, dissociative, and generative abilities. Even so, language is in many ways ideally crafted to recount episodes and sequence them into narratives (Corballis, 1994; Pinker & Bloom, 1990). Episodes are often about who did what to whom, and when, and where, and why, and what happened next. Although mental time travel and language may well have co-evolved to some extent, we suggest that the true priority lay with mental time travel; that is, the ability to generate mental experience probably preceded the ability to communicate it.

It is worth noting, however, that recent research on counting in chimpanzees (e.g., Boysen & Berntson, 1995) demonstrated how symbolic systems can foster the detachment from immediate impulses. Selection of one of two arrays with different amounts of candy resulted in the other, nonselected array, being received. Thus, choosing the smaller array results in more obtained candy. The chimpanzees seemed not to comprehend this simple, yet counterintuitive, rule and tended to choose the larger array. But when the actual candy was replaced by Arabic numerals, the chimpanzees reliably selected the smaller number to obtain the larger reward. Apparently, the symbolic system helped the chimpanzees to override their natural impulse, or evaluative disposition (to select the larger amount of candy), and created the space for applying what cognitively was well understood. These results suggest that symbolic representation might have paved the way for effective meta-motivation, that is, the practical application of forethought to behavior. Language clearly was important for the evolution of the fully fledged mental time travel capacity.

### **Conclusions**



We have argued that the ability to travel mentally in time constitutes a discontinuity between humans and other animals. Current empirical data and theoretical analyses from a wide range of research areas have been brought together to support our argument. We recognize, however, that the ideas we have developed in this article might at times be no more than "just so" stories, in which it is assumed that things simply had to be the way they are. Moreover, we have relied fairly extensively on comparisons between apes and humans, on the grounds that chimpanzees, in particular, are closest to humans in genetic makeup (e.g., Miyamoto, Slightom, & Goodman, 1987). The most recent common ancestor of humans and chimpanzees probably existed some 5-7 million years ago, however, so considerable divergence can be expected. Our hominid ancestors lived in very different environments and were subjected to very different selective pressures. Inevitably, then, there is a good deal of pure speculation in any attempt to bridge the gap between ape and human, and there may be important respects in which comparisons with other species may be more relevant.

However, it is important to conduct meta-analyses that integrate up-to-date data from diverse and fast-paced fields. This is particularly critical if the analysis can shed new light on the data by providing a novel perspective. We believe that the obviously important, yet largely overlooked, human ability to travel mentally in time constitutes such a perspective. Our analysis challenges experimenters to provide evidence for mental time travel in other species and to study its development in children (a more promising area of research).

Anecdotes, too, should be subjected to careful scrutiny to ensure that they meet appropriate criteria. Demonstrations of putative time travel must not merely reflect habits, or instinctive behaviors, or behaviors based on semantic knowledge or generalized rules. The essence of mental time travel lies in its particularity, and this in turn implies the ability to generate unique representations from combinations of elements. We believe that the importance of mental time travel as a prime mover in human cognitive evolution has not been adequately recognized. It may hold the key to the evolution of such characteristically human phenomena as agriculture, morality, philosophy, science, technology, and trade.

## REFERENCES

- Amsterdam, B. K. (1972). Mirror self-image reactions before age two. *Developmental Psychobiology*, 5, 297-305.
- Anderson, J. R. (1986). Mirror mediated finding of hidden food by monkeys (*Macaca tonkeana* and *M. fascicularis*). *Journal of Comparative Psychology*, 100, 237-242.
- Ashmead, D. H., & Perlmutter, M. (1980). Infant memory in everyday life. In M. Perlmutter (Ed.), *New directions for child development* (Vol. 10). San Francisco: JosseyBass.
- Astington, J. W., Harris, P. L., & Olson, D. R. (Eds.). (1988). *Developing theories of mind*. London: Cambridge University Press.
- Bandura, A. (1991). Self-regulation of motivation through anticipatory and self-reactive mechanism. In R. A. Dienstbier (Ed.), *Perspectives on motivation: Nebraska Symposium on Motivation* (pp. 69-164). Lincoln: University of Nebraska Press.
- Baron-Cohen, S. (1989). Are autistic children behaviorists? An examination of their mental-physical and appearance-reality distinctions. *Journal of Autism and Developmental Disorders*, 19, 579-600.
- Baron-Cohen, S. (1995). *Mindblindness*. Cambridge, MA: MIT Press.
- Baron-Cohen, S., & Goodhart, F. (1994). The "seeing leads to knowing" deficit in autism. The Pratt and Bryant probe. *British Journal of Developmental Psychology*, 12, 397-402.
- Baron-Cohen, S., Leslie, A., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, 21, 37-46.
- Bartlett, F. C. (1932). *Remembering*. London: Cambridge University Press.
- Bauer, P. J., Hertsgaard, L. A., & Dow, G. A. (1995). After 8 months have passed: Long-term recall of events by 1- to 2-year-old children. *Memory*, 2, 353-382.
- Beck, B. B. (1980). *Animal tool behavior: The use and manufacture of tools by animals*. New York: Garland STPM Press.
- Bickerton, D. (1986). More than nature needs? A reply to Premack. *Cognition*, 23, 73-79.
- Bischof, N. (1978). On the phylogeny of human morality. In G. Stent (Ed.), *Morality as a biological phenomenon* (pp. 53-74). Berlin: Abakon.
- Bischof, N. (1985). *Das Ritzel Odipus* [The Oedipus riddle]. Munich: Piper.
- Bischof-Kohler, D. (1985). Zur Phylogenese menschlicher Motivation [On the phylogeny of human motivation]. In L. H. Eckensberger & E. D. Lantermann (Eds.), *Emotion und Reflexivität* (pp. 3-47). Vienna: Urban & Schwarzenberg.
- Bloom, P. (1994). Generativity within language and other cognitive domains. *Cognition*, 51, 177-189.
- Boesch, C. (1991). Teaching wild chimpanzees. *Animal Behavior*, 41, 530-532.
- Boesch, C. (1992). New elements of a theory of mind in wild chimpanzees. *Behavioral and Brain Sciences*, 15, 149-150.
- Boesch, C., & Boesch, H. (1984). Mental map in wild chimpanzees: An analysis of hammer transports for nut cracking. *Primates*, 25, 160-170.

- Boucher, J., & Lewis, V. (1989). Memory impairments and communications in relatively able autistic children. *Journal of Child Psychology and Psychiatry*, 30, 99-122. Boucher, J., & Warrington, E. K. (1976). Memory deficits in early infantile autism: Some similarities to the amnesic syndrome. *British Journal of Psychology*, 67, 73-87.
- Bowers, K. S., & Hilgard, E. (1986). Some complexities in understanding memory. In H. M. Pettinadi (Ed.), *Hypnosis and memory* (pp. 3-18). New York: Guilford Press. Boysen, S. T., & Berntson, G. G. (1995). Responses to quantity: Perceptual versus cognitive mechanisms in chimpanzees (*Pan Troglodytes*). *Journal of Experimental Psychology: Animal Behavior Processes*, 21, 82-86.
- Byrne, R. W. (1994). The evolution of intelligence. In P. J. B. Slater & T. R. Halliday (Eds.), *Behavior and evolution* (pp. 223-265). London: Cambridge University Press. Byrne, R. W., & Byrne, J. M. (1988). Leopard killers of Mahale. *Natural History*, 3, 22-26.
- Byrne, R. W., & Whiten, A. (1985). Tactical deception of familiar individuals in baboons (*Papio ursinus*). *Animal Behavior*, 33, 669-673.
- Byrne, R. W., & Whiten, A. (Eds.). (1988). *Machiavellian intelligence*. Oxford: Clarendon Press.
- Byrne, R. W., & Whiten, A. (1990). Tactical deception in primates: The 1990 database. *Primate Report*, 27, 1-101.
- Byrne, R. W., & Whiten, A. (1992). Cognitive evolution in primates. *Man*, 27, 609-627. Cheney, D. L., & Seyfarth, R. M. (1990). *How monkeys see the world*. Chicago: University of Chicago Press.
- Chomsky, N. (1988). *Language and the problem of knowledge: The Managua lectures*. Cambridge, MA: MIT Press.
- Corballis, M. C. (1991). *The lopsided ape*. New York: Oxford University Press. Corballis, M. C. (1992). On the evolution of language and generativity. *Cognition*, 44, 197-226.
- Corballis, M. C. (1994). The generation of generativity: A response to Bloom. *Cognition*, 51, 191-198.
- Daechler, M., Bukatko, D., Benson, K., & Myers, N. (1976). The effects of size and color cues on the delayed response of very young children. *Bulletin of the Psychonomic Society*, 7, 65-68.
- Dawson, G., & McKissick, F. C. (1984). Self-recognition in autistic children. *Journal of Autism and Developmental Disorders*, 14, 383-394.
- de Waal, F. (1982). *Chimpanzee politics*. London: Jonathan Cape.
- de Waal, F. (1989). *Peacemaking among primates*. Cambridge, MA: Harvard University Press.
- Deacon, T. W. (1990). Brain-language coevolution. In J. A. Hawkins & M. Gelman (Eds.), *The evolution of human languages. SFI studies in the sciences of complexity, proceedings* (Vol. 10). Reading, MA: Addison-Wesley.
- DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mother's voices. *Science*, 208, 1174-1176.
- DeCasper, A. J., & Spence, M. J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. *Infant Behavior and Development*, 9, 133-150. Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. *Child Development*, 56, 868-883.
- Doht, F. (1970). Zielorientiertes Verhalten beim Schimpansen [Goal-directed behavior in chimpanzees]. *Naturwissenschaft und Medizin*, 34, 43-57.
- Donald, M. (1991). *Origins of the modern mind*. London: Harvard University Press. Dretske, T. (1982). The informational character of representations. *Behavioral and Brain Sciences*, 5, 376-377.
- Eccles, J. C. (1989). *Evolution of the brain: Creation of the self*. London: Routledge. Fivush, R., Gray, J. T., & Fromhoff, F. A. (1987). Two-year-olds talk about the past. *Cognitive Development*, 2, 396-409.
- Fivush, R., & Hamond, N. R. (1990). Autobiographical memory across the preschool years: Toward reconceptualizing childhood amnesia. In R. Fivush & J. A. Hudson (Eds.), *Knowing and remembering in young children* (pp. 223-248). New York: Cambridge University Press.
- Flavell, J. H. (1993). The development of children's understanding of false belief and the appearance-reality distinction. *International Journal of Psychology*, 28, 595-604. Fouts, R. S., Fouts, D. H., & van Cantfort, T. (1989). The infant Loulis learns signs from cross-fostered chimpanzees. In R. A. Gardner, B. T. Gardner, & T. E. van Cantfort (Eds.), *Teaching sign language to chimpanzees* (pp. 280-292). New York: State University of New York Press.
- Frankfurt, H. G. (1988). *The importance of what we care about*. New York: Cambridge University Press.
- Freeman, W., & Watts, J. (1942). *Psychosurgery: Intelligence, emotion, and social behavior following prefrontal lobotomy for mental disorder*. Springfield, IL: Charles C. Thomas.
- Freud, S. (1966). Project for a scientific psychology. In J. Strachey (Ed. and Trans.), *The standard edition of the complete works of Sigmund Freud* (Vol. 1). London: Hogarth Press. (Original work published 1895)
- Friedman, S. (1972). Newborn visual attention to repeated exposure of redundant vs. "novel" targets. *Perception & Psychophysics*, 12, 291-294.
- Friedman, W. J. (1991). The development of children's memory for the time of past events. *Child Development*, 67, 139-155.
- Friedman, W. J. (1992). Children's time memory: The development of a differentiated past. *Cognitive Development*, 7, 171-187.
- Friedman, W. J. (1993). Memory for the time of past events. *Psychological Bulletin*, 113, 44-66.
- Frith, U. (1989). *Autism: Explaining an enigma*. Oxford: Basil Blackwell. Fuster, J. M. (1989). *The prefrontal cortex*. New York: Raven Press. Gagliardi, J. L., Kirkpatrick-Steger, K. K., Thomas, J., Allen, G. J., & Blumberg, M. S. (1995). Seeing and knowing: Knowledge attribution versus stimulus control in adult humans (*homo sapiens*). *Journal of Comparative Psychology*, 109, 107-114.
- Gallup, G. G., Jr. (1970). Chimpanzees: Self recognition. *Science*, 167, 86-87.
- Gallup, G. G., Jr. (1983). Toward a comparative psychology of mind. In R. L. Mellgren (Ed.), *Animal cognition and behavior* (pp. 473-510). New York: North-Holland. Gallup, G. G., Jr. (1994). Self-recognition: Research

- strategies and experimental design. In S. T. Parker, R. W. Mitchell, & M. L. Boccia (Eds.), *Self-awareness in animals and humans* (pp. 35-50). Cambridge: Cambridge University Press.
- Gallup, G. G., Jr., McClure, M. K., Hill, S. D., & Bundy, R. A. (1971). Capacity for self-recognition in differentially reared chimpanzees. *Psychological Record*, *21*, 69-74.
- Gardiner, J., & Java, R. I. (1990). Recollective experience in word and nonword recognition. *Memory and Cognition*, *18*, 23-30.
- Gibson, K. R. (1990). New perspectives on instincts and intelligence: Brain size and the emergence of hierarchical mental construction skills. In S. T. Parker & K. R. Gibson (Eds.), *"Language" and intelligence in monkeys and apes* (pp. 97-128). Cambridge: Cambridge University Press.
- Gibson, K. R. (1993). General introduction: Animal minds, human minds. In K. R. Gibson & T. Ingold (Eds.), *Tools, language and cognition in human evolution*. Cambridge: Cambridge University Press.
- Goodall, J. (1986). *The chimpanzees of Gombe: Patterns of behavior*. Cambridge, MA: Harvard University Press.
- Gopnik, A. (1993). How we know our own minds: The illusion of first-person knowledge of intentionality. *Behavioral and Brain Sciences*, *16*, 1-14.
- Gopnik, A., & Astington, J. W. (1988). Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Development*, *59*, 26-37.
- Gopnik, A., & Graf, P. (1988). Knowing how you know: Young children's ability to identify and remember the source of their belief. *Child Development*, *59*, 1366-1371.
- Gopnik, A., & Slaughter, V. (1991). Young children's understanding of changes in their mental states. *Child Development*, *62*, 98-110.
- Gordon, R. M. (1986). Folk psychology as simulation. *Mind and Language*, *1*, 158-171.
- Greenfield, P. M., & Savage-Rumbaugh, E. S. (1990). Grammatical combination in *Pan paniscus*: Processes of learning and invention in the evolution and development of language. In S. T. Parker & K. R. Gibson (Eds.), *"Language" and intelligence in monkeys and apes* (pp. 540-578). Cambridge: Cambridge University Press.
- Griffin, D. R. (1978). Prospects for a cognitive ethology. *Behavioral and Brain Sciences*, *1*, 527-538.
- Harris, P. L. (1991). The work of imagination. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development, and simulation of everyday mindreading* (pp. 283-304). Oxford: Basil Blackwell.
- Hart, D., & Fegley, S. (1994). Social imitation and the emergence of a mental model of self. In S. T. Parker, R. W. Mitchell, & M. L. Boccia (Eds.), *Self-awareness in animals and humans* (pp. 149-165). Cambridge: Cambridge University Press.
- Hayes, C. (1951). *The ape in our house*. New York: Harper & Brothers.
- Heyes, C. M. (1993). Anecdotes, training, trapping, and triangulation: Do animals attribute mental states? *Animal Behavior*, *46*, 177-188.
- Howe, M. L., & Courage, M. L. (1993). On resolving the enigma of infantile amnesia. *Psychological Bulletin*, *113*, 305-326.
- Hughes, C., & Russel, J. (1993). Autistic children's difficulty with mental disengagement from an object: Its implications for theories of autism. *Developmental Psychology*, *3*, 498-510.
- Hughes, C., Russel, J., & Robbins, T. W. (1994). Evidence for executive dysfunction in autism. *Neuropsychologia*, *32*, 477-492.
- Humphrey, N. K. (1976). The social function of intellect. In P. P. G. Bateson & R. A. Hinde (Eds.), *Growing points in ethology* (pp. 303-317). Cambridge: Cambridge University Press.
- Humphrey, N. K. (1986). *The inner eye*. London: Faber & Faber.
- Ingvar, D. H. (1985). "Memory of the future." An essay on the temporal organization of conscious awareness. *Human Neurobiology*, *4*, 127-136.
- Jacoby, L. L., Kelley, C. M., & Dywan, J. (1989). Memory attributions. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 391-422). Hillsdale, NJ: Erlbaum.
- Jarrold, C., Carruthers, P., Smith, P. K., & Boucher, J. (1994). Pretend play: Is it meta-representational? *Mind & Language*, *9*, 445-468.
- Johnson, C. N. (1988). Theory of mind and the structure of conscious experience. In J. W. Astington, P. L. Harris, & D. R. Olson (Eds.), *Developing theories of mind* (pp. 47-63). Cambridge: Cambridge University Press.
- Jolly, A. (1966). Lemur social behavior and primate intelligence. *Science*, *153*, 501-506.
- Kendrick, D. F., Rilling, M. E., & Denny, M. R. (1986). *Theories of animal memory*. Hillsdale, NJ: Erlbaum.
- Kinsbourne, M. (1989). The boundaries of episodic remembering. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 179-191). Hillsdale, NJ: Erlbaum.
- Kinsbourne, M., & Wood, F. (1975). Short-term memory processes and the amnesic syndrome. In D. Deutsch & J. A. Deutsch (Eds.), *Short-term memory* (pp. 258-293). San Diego: Academic Press.
- Kohler, W. (1927). *The mentality of apes* (E. Winter, Trans.). London: Routledge & Kegan Paul. (Original work published 1917)
- Kuhl, J., & Kraska, K. (1989). Self-regulation and meta-motivation: Computational mechanisms, development, and assessment. In R. Kaufer, P. L. Ackerman, & R. Cudeck (Eds.), *The Minnesota Symposium on Learning and Individual Differences* (pp. 343-374). Hillsdale, NJ: LEA.
- Leslie, A. (1987). Pretense and representation in infancy: The origin of "theory of mind." *Psychological Review*, *94*, 412-426.
- Leslie, A., & Frith, U. (1988). Autistic children's understanding of seeing, knowing, and believing. *British Journal of Developmental Psychology*, *6*, 315-329.
- Lindsay, W. L. (1880). *Mind in the lower animals*. New York: D. Appleton.

- Loftus, E. F. (1993). Desperately seeking memories of the first few years of childhood: The reality of early memories. *Journal of Experimental Psychology: General*, *122*, 274-277.
- Lyon, D. L., & Flavell, J. H. (1994). Young children's understanding of "remember" and "forget." *Child Development*, *65*, 1357-1371.
- Marshall, J. C. (1982). A la representation du temps perdu. *Behavioral and Brain Sciences*, *5*, 382-383.
- Meador, D. M., Rumbaugh, D. M., Pate, J. L., & Bard, K. A. (1987). Learning, problem solving, cognition, and intelligence. In J. Erwin (Ed.), *Comparative primate biology: Vol. 2B* (pp. 17-83). New York: Alan R. Liss.
- Mental simulation: Philosophical and psychological essays. (1992). *Mind and Language*, *7*, 1&2.
- Menzel, E. W. (1974). A group of young chimpanzees in a one-acre field. In A. Schrier & F. Stollnitz (Eds.), *Behavior of non-human primates*, Vol. 5 (pp. 83-153). San Diego: Academic Press.
- Mitchell, R. W. (1994). Multiplicities of self. In S. T. Parker, R. W. Mitchell, & M. L. Boccia (Eds.), *Self-awareness in animals and humans* (pp. 81-107). Cambridge: Cambridge University Press.
- Miyamoto, M., Slightom, J. L., & Goodman, M. (1987). Phylogenetic relations of humans and African apes from DNA sequences in the psi-nu-globin region. *Science*, *230*, 369-373.
- Nelson, K. (1992). Emergence of autobiographical memory at age 4. *Human Development*, *35*, 172-177.
- Ogden, J. A., & Corkin, S. (1991). Memories of H. M. In W. C. Abraham, M. C. Corballis, & K. G. White (Eds.), *Memory mechanisms: A tribute to G. V. Goddard* (pp. 195-215). Hillsdale, NJ: Erlbaum.
- Olton, D. R. (1984). Comparative analysis of episodic memory. *Behavioral and Brain Sciences*, *7*, 250-251.
- O'Neill, D. K., & Gopnik, A. (1991). Young children's ability to identify the sources of their beliefs. *Developmental Psychology*, *27*, 390-397.
- Ozonoff, S., Pennington, B. F., & Rogers, S. (1991). Executive function deficits in high-functioning autistic children: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry*, *32*, 1081-1105.
- Parker, S. T., & Gibson, K. R. (1979). A developmental model for the evolution of language and intelligence in early hominids. *Behavioral and Brain Sciences*, *2*, 367-408. Parker, S. T., Mitchell, R. W., & Boccia M. L. (Eds.). (1994). *Self-awareness in animals and humans*. Cambridge: Cambridge University Press.
- Passingham, R. E. (1982). *The human primate*. San Francisco: W. H. Freeman.
- Patterson, F. (1991). Self-awareness in the gorilla Koko. *Gorilla*, *14*, 2-5.
- Pepperberg, I. M., Garcia, S. E., Jackson, E. C., & Marconi, S. (1995). Mirror use by African grey parrots. *Journal of Comparative Psychology* *109*, 182-195.
- Perner, J. (1991). *Understanding the representational mind*. Cambridge, MA: MIT Press.
- Perner, J., Frith, U., Leslie, A., & Leekam, S. (1989). Exploration of the autistic child's theory of mind. *Child Development*, *60*, 689-700.
- Perner, J., & Ruffman, T. (1995). Episodic memory and autogenetic consciousness: Developmental evidence and a theory of childhood amnesia. *Journal of Experimental Child Psychology*, *59*, 516-548.
- Pfungst, O. (1965). *Clever Hans, the horse of Mr. Von Osten* (C. L. Rahn, Trans.). New York: Holt, Rinehart & Winston. (Original work published 1911)
- Piaget, J. (1954). *The construction of reality in the child*. New York: Basic Books.
- Pillemer, D. B., & White, S. H. (1989). Childhood events recalled by children and adults. *Advances in Child Development and Behavior*, *21*, 297-340.
- Pinker, S. (1994). *The language instinct*. New York: William Morrow.
- Pinker, S., & Bloom, P. (1990). Natural language and natural selection. *Behavioral and Brain Sciences*, *13*, 707-784.
- Povinelli, D. J. (1989). Failure to find self-recognition in Asian elephants (*Elephas maximus*) in contrast to their use of mirror cues to discover hidden food. *Journal of Comparative Psychology*, *103*, 122-131.
- Povinelli, D. J. (1993). Reconstructing the evolution of mind. *American Psychologist*, *48*, 493-509.
- Povinelli, D. J. (1995). The unduplicated self. In P. Rochat (Ed.), *The self in early infancy* (pp. 162-192). Amsterdam: North-Holland-Elsevier.
- Povinelli, D. J., Nelson, K. E., & Boysen, S. T. (1990). Inferences about guessing and knowing by chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, *104*, 203-210.
- Povinelli, D. J., Nelson, K. E., & Boysen, S. T. (1992). Comprehension of social role reversal by chimpanzees: Evidence for empathy? *Animal Behavior*, *43*, 633-640.
- Povinelli, D. J., Parks, K. A., & Novak, M. A. (1991). Do rhesus monkeys (*Macaca mulatta*) attribute knowledge and ignorance to others? *Journal of Comparative Psychology*, *105*, 318-325.
- Povinelli, D. J., Parks, K. A., & Novak, M. A. (1992). Role reversal by rhesus monkeys, but no evidence of empathy. *Animal Behavior*, *44*, 269-281.
- Powell, S. D., & Jordan, R. R. (1993). Being subjective about autistic thinking and learning to learn. *Educational Psychology*, *13*, 359-370.
- Premack, D. (1988). "Does the chimpanzee have a theory of mind?" revisited. In R. W. Byrne & A. Whiten (Eds.), *Machiavellian intelligence* (pp. 160-179). Oxford: Clarendon Press.
- Premack, D., & Dasser, V. (1991). Perceptual origins and conceptual evidence for theory of mind in apes and children. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development and simulation of everyday mindreading* (pp. 253-266). Oxford: Basil Blackwell.
- Premack, D., & Premack, A. J. (1994). How "theory of mind" constrains language and communication. *Discussions in Neuroscience*, *10*, 93-105.
- Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral & Brain Sciences*, *4*, 515-526.
- Roitblat, H. L. (1982). The meaning of representation in animal memory. *Behavioral & Brain Sciences*, *5*, 353-406.

- Ross, L. D., Green, D., & House, P. (1977). The false consensus bias in self-perception and social perception process. *Journal of Experimental Social Psychology*, 13, 279-301.
- Rovee-Collier, C. K., Sullivan, M. W., Enright, M., Lucas, D., & Fagen, J. (1980). Reactivation of infant memory. *Science*, 208, 1159-1161.
- Russel, J., Jarrold, C., & Potel, D. (1994). Executive factors in preschoolers' strategic deception. *British Journal of Developmental Psychology*, 12, 301-314.
- Savage-Rumbaugh, E. S. (1986). *Ape language: From conditioned response to symbol*. New York: Columbia University Press.
- Savage-Rumbaugh, E. S. (1994a). Hominid evolution: Looking to modern apes for clues. In D. Quiatt & J. Itani (Eds.), *Hominid culture in primate perspective* (pp. 7-49). Niwot: University Press of Colorado.
- Savage-Rumbaugh, E. S. (1994b). *Kanzi: The ape at the brink of the human mind*. New York: Wiley.
- Savage-Rumbaugh, E. S., & McDonald, K. (1988). Deception and social manipulation in symbol-using apes. In R. W. Byrne & A. Whiten (Eds.), *Machiavellian intelligence* (pp. 224-237). Oxford: Clarendon Press.
- Seamon, J. G. (1984). The ontogeny of episodic and semantic memory. *Behavioral and Brain Sciences*, 7, 254.
- Sheingold, K., & Tenny, Y. J. (1982). Memory for a salient childhood event. In U. Neisser (Ed.), *Memory observed* (pp. 201-212). New York: Freeman.
- Sherry, D. F., & Schacter, D. L. (1987). The evolution of multiple memory systems. *Psychological Review*, 94, 439-454.
- Shimamura, A. P., Janowsky, J. J., & Squire, L. R. (1990). Memory for the temporal order of events in patients with frontal lobe lesions and amnesic patients. *Neuropsychologia*, 28, 803-813.
- Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review*, 99, 195-231.
- Stebbins, G. L. (1982). *Darwin to DNA, molecules to humanity*. New York: Freeman.
- Suarez, S. D., & Gallup, G. G., Jr. (1981). Self-recognition in chimpanzees and orangutans, but not gorillas. *Journal of Human Evolution*, 10, 175-188.
- Suddendorf, T. (1994). *Discovery of the fourth dimension: Mental time travel and human evolution*. Master's thesis, University of Waikato, Hamilton, New Zealand.
- Suddendorf, T., & Fletcher-Flinn, C. (1996). Some correlates of the emerging theory of mind. *Australian Journal of Psychology*, 48, (Sup.), 26-27.
- Suddendorf, T., & Fletcher-Flinn, C. (in press). Theory of mind and the origins of divergent thinking. *Journal of Creative Behavior*.
- Swartz, K. B., & Evans, S. (1991). Not all chimpanzees (*Pan troglodytes*) show self-recognition. *Primates*, 32, 483-496.
- Swisher, C. C., III, Curtis, G. H., Jacob, A. G., Getty, A. G., Suprijo, A., & Widiasmoro. (1994). Age of the earliest known hominids in Java, Indonesia. *Science*, 263, 1118-1121.
- Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence for a cognitive deficit. *British Journal of Developmental Psychology*, 9, 417-430.
- Taylor, T., Esbensen, B. M., & Bennett, R. T. (1994). Children's understanding of knowledge acquisition: The tendency for children to report that they have always known what they have just learned. *Child Development*, 65, 1581-1604.
- Terrace, H. S., & McGonigle, B. (1994). Memory and representation of serial order by children, monkeys, and pigeons. *Current Directions in Psychological Science*, 3, 1-6.
- Toth, N., Schick, K. D., Savage-Rumbaugh, S., Sevcik, R. A., & Rumbaugh, D. M. (1993). Pan the toolmaker: Investigations into stone tool-making and tool-using capabilities of a bonobo (*Pan paniscus*). *Journal of Archeological Science*, 20, 81-91.
- Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381-403). San Diego: Academic Press.
- Tulving, E. (1983). *Elements of episodic memory*. London: Oxford University Press.
- Tulving, E. (1984). Precipitous elements of episodic memory. *Behavioral and Brain Sciences*, 7, 223-268.
- Tulving, E. (1985). How many memory systems are there? *American Psychologist*, 40, 385-398.
- Tulving, E. (1993). What is episodic memory? *Current Directions in Psychological Science*, 2, 67-70.
- Wellman, H. M. (1991). From desires to beliefs: Acquisition of a theory of mind. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development, and simulation of everyday mindreading* (pp. 19-38). Oxford: Blackwell.
- Westergaard, G. C., & Suomi, S. J. (1994). The use and modification of bone tools by Capuchin monkeys. *Current Anthropology*, 35, 75-77.
- Whiten, A. (1991). *Natural theories of mind: Evolution, development, and simulation of everyday mindreading*. Oxford: Blackwell.
- Whiten, A., & Byrne, R. W. (1988). Tactical deception in primates. *Behavioral & Brain Sciences*, 11, 233-273.
- Whiten, A., & Byrne, R. W. (1991). The emergence of meta-representation in human ontogeny and primate phylogeny. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development, and simulation of everyday mindreading* (pp. 267-281). Oxford: Blackwell.
- Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, 13, 103-128.
- Wimmer, H., Hogrefe, G. J., & Perner, J. (1988). Children's understanding of informational access as source of knowledge. *Child Development*, 59, 386-396.
- Wynn, T., & McGrew, W. C. (1989). An ape's view of the Oldowan. *Man*, 24, 383-398.

Received July 17, 1996