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Toward a Theory of Episodic Memory: The Frontal Lobes and Autonoetic Consciousness

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Adult humans are capable of remembering prior events by mentally traveling back in time to re-experience those events. In this review, the authors discuss this and other related capabilities, considering evidence from such diverse sources as brain imaging, neuropsychological experiments, clinical observations, and developmental psychology. The evidence supports a preliminary theory of episodic remembering, which holds that the prefrontal cortex plays a critical, supervisory role in empowering healthy adults with autonoetic consciousness—the capacity to mentally represent and become aware of subjective experiences in the past, present, and future. When a rememberer mentally travels back in subjective time to re-experience his or her personal past, the result is an act of retrieval from episodic memory.

One of the most fascinating achievements of the human mind is the ability to mentally travel through time. It is somehow possible for a person to relive experiences by thinking back to previous situations and happenings in the past and to mentally project oneself into the anticipated future through imagination, daydreams, and fantasies. In the everyday world, the most common manifestation of this ability can be referred to as "remembering past happenings." Everyone knows what this phrase means and what it is like to reflect on personal experiences, past or future, that are not part of the present.

Although mental time travel is clearly related to memory, it is interesting that in very few of the countless articles, chapters, and books that have been written on the topic of memory have researchers paid attention to the conscious act of remembering personal experiences. Of course, there have been some notable exceptions to this claim. In general, most models and theories of memory focus on the structures or processes by which information is encoded, stored, or retrieved, with little interest to the actual experience of remembering.

We propose that the ability to mentally travel through time is an expression of the episodic memory system of the brain and that this ability is not shared by other systems of memory. In what follows, we intend to show that episodic memory, and therefore the act of remembering through mental time travel, is a special kind of mind–brain achievement that bears only a superficial resemblance to other things that can be classified under the rubric of memory and that it can be studied on its own and in its interaction with other mental faculties.

The theory of episodic memory that we eventually propose here would not have been possible, or at least could not have been readily defended, a few years ago. The timing of the proposal is rendered more reasonable now, largely because of recent findings in psychology and cognitive neuroscience, especially those provided by the functional neuroimaging of remembering. In the last several years, researchers have shown an increasing amount of evidence that links the operations of episodic memory to the frontal lobes of the brain (Schacter, 1987; Tulving, 1985). Squire (1987) associated frontal pathology with a loss of "personal familiarity and connectedness" to recent events. More recently, in a series of articles on findings from positron emission tomography (PET) studies, Tulving, Kapur, Craik, Moscovitch, and Houle (1994) linked the left prefrontal cortex with episodic encoding and the right prefrontal cortex with episodic retrieval. Since then, the overall pattern has been further corroborated in a number of PET studies (reviewed by Nyberg, Cabeza, & Tulving, 1996), suggesting that, despite early skepticism (Roskies, 1994), this relation between episodic memory and the frontal lobes represents a reliable fact of the neuroanatomy of remembering.

The PET findings were the prime inspiration for this review in which we consider research from other scientific approaches that bear on the neuroanatomical correlates of episodic remembering and on the cognitive and behavioral abilities subserved by the frontal lobes. The research has resulted in a preliminary theory of episodic memory. The theory holds that the frontal lobes underlie a special kind of consciousness called *autonoetic* consciousness, which allows healthy human adults to both mentally represent and become aware of their subjective experiences in the past, present, and future. Autonoetic consciousness is important for many of the most complex abilities, including the ability to perform mental time travel in the personal, subjective way that is the hallmark of retrieval from episodic memory. It

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is autonoetic awareness, driven by the frontal lobes, that makes recollective experience what it is.

The general purpose of this review is to relate what is known about episodic memory, autonoetic consciousness, and the frontal lobes into a coherent account of the relation between purely mental happenings, such as the remembering of a personal episode, and structural components of the central nervous system, such as the frontal lobes. Because the three concepts have not typically been considered together, this review spans several lines of evidence, with each part contributing a different piece of the overall story. As an example, much research from cognitive neuropsychology and neuroimaging has implications for the connection between the frontal lobes and episodic memory, yet issues pertaining to consciousness and autonoetic consciousness have not typically been discussed within these domains. Also, findings from developmental psychology imply a relation between the emergence of both autonoetic consciousness and episodic memory, although the frontal lobes can be implicated only indirectly. Finally, there is a clinical literature that describes the consequences of frontal pathology, with many of the effects corresponding to a loss of autonoetic consciousness, although remembering has not generally been a focus of the clinical case reports.

The first sections of this review serve to introduce and define each of the three concepts, before turning to the evidence that relates them. In the course of our discussion, we raise, and attempt to answer, the following questions. What is episodic memory? How has the concept changed since its introduction in 1972? Why is it related to mental time travel and remembering? What is autonoetic consciousness? How does it relate to other forms of consciousness? How does it relate to episodic memory? What are the facts concerning the frontal lobes and memory? Given that the frontal lobes contribute to memory processes, what are these contributions? How should psychologists think about PET data, in light of what is known about the frontal lobes? Given that the frontal lobes are involved in a large number of cognitive and behavioral expressions of the brain, in addition to remembering, is there at least a common theme that unifies these expressions at some higher level of analysis? We conclude by bringing the various lines of evidence together into a theory of episodic memory. Because many of the pertinent facts are of recent origin and many earlier beliefs about episodic memory are no longer valid, our review may also serve as a refresher course on these topics, even if our theoretical mission falls short of its goal.

Concepts and Definitions

Episodic Memory

The term *episodic memory* is commonly used in two different ways. One has to do with a system of memory that is different from the other major systems of human memory; the other concerns a particular kind of memory task or memory performance. To minimize problems of communication, it is essential that these meanings be differentiated and the meaning used in a particular context be made clear. In this article, we use the term consistently in the sense of a particular kind of capability and achievement of the brain. It is the kind of memory that renders possible conscious recollection of personal happenings and events from one's personal past and mental projection of anticipated events into one's subjective future. As such, it is the memory system that mediates mental time travel. We assume that it is subserved by a distinct neurocognitive system that has evolved specifically for that purpose.

A second, different sense of episodic memory is that of a type of memory task and of performance on the task. Episodic memory in this sense refers to the acquisition of propositional (or declarative, cognitive, or symbolically representable) information on a particular occasion and its reproduction on a subsequent occasion. The prototypical laboratory list-learning task in which participants are exposed to a collection of verbal (or verbalizable) items and then tested for what they have learned—by recall, recognition, or some kind of memory judgment—is often classified as an episodic memory test.

In 1972, the connection between the episodic memory system and putative episodic memory tests seemed simple: An intact episodic system was a sufficient and necessary condition of successful test completion. In the intervening years, it has become clear that this idea, even if appealingly obvious, is incomplete. Today, it is known that the situation is much more complex and that many verbal learning tasks are only minimally episodic in nature. Although the two types of episodic memory—kind of memory system and kind of memory task or performance—are related, they cannot be equated. A participant's performance on a so-called episodic memory task, such as recall or recognition of words encountered in a studied list, depends not only on episodic memory but also on other kinds of memory, such as semantic memory. A number of experiments demonstrate that participants do not only consciously recollect words from a studied list, relying on episodic memory, but can also simply "know" that some words occurred in the list, even if they are unable to have conscious recollection of the event of having studied the word (Gardiner, 1988; Tulving, 1985). Differently stated, it is possible for a person to know about events from the past, even the recent past, without mentally traveling back to re-experience the retrieved event. Furthermore, it has been shown that even patients with dense amnesia, who cannot bring to mind any recollections of learning episodes and in that sense lack functioning episodic memory, can nevertheless recall words from studied lists in response to relevant cues (Hamann & Squire, 1995; Hayman, Macdonald, & Tulving, 1993; Tulving, Hayman, & Macdonald, 1991). If nonepisodic memory processes are sufficient to allow such patients to perform more or less successfully on what nominally are episodic memory tasks, it means that the episodic memory system is not necessary for so-called episodic memory tasks (i.e., item recognition and recall). If so, the same should be true of healthy people. This point is important. It is central to the discussion later in this article of patients with frontal lesions who are capable of completing nominally episodic tasks by relying on memory systems outside of the episodic system. Again, in both our discussion and subsequent theory, episodic memory is discussed as a *neurocognitive system,* which renders possible the conscious recollection of events as they were previously experienced, although evidence from putatively episodic memory tasks is occasionally relevant.

Like any other scientific concept, episodic memory derives its meaning not only from what it is—the description of its properties, rules of operations, and neural substrates—but also from what it is not. Episodic memory was initially defined (Tulving, 1972) in terms of its distinction from semantic memory, and even today the similarities and differences between the two kinds of memory are useful to explicate the nature of episodic memory.

Episodic and semantic memory have many features in common. Both represent large and complex systems, essentially unlimited in their capacity to hold information. They are unlike, for example, working memory, which has a limited capacity, and the perceptual representation systems, which deal only with information in a particular modality. Both are cognitive (representational, declarative) systems, whose contents can be described in terms of objects and relations, and both model the world in the sense that a person can map their contents and make true–false judgments about individual propositions based on these contents. In this sense, episodic and semantic memory are unlike procedural memory, whose contents are nonpropositional and lacking in truth value. (An individual's learned skill of balancing on a bicycle—one of the myriad achievements of the procedural memory system—cannot be expressed propositionally, and it is neither true nor false.)

The manner in which information is registered in the episodic and semantic systems is highly similar—there is no known method of readily encoding information into an adult's semantic memory without putting corresponding information in episodic memory or vice versa. Both episodic and semantic memory enable individuals to acquire factual information through different sensory modalities; in both, such acquisition can occur very rapidly, sometimes as a consequence of a single glimpse or sound of a relevant input. Both episodic and semantic memory can register and hold information about various states of the world, including the internal states of the individual; information stored in both forms of memory is flexibly accessible, being elicitable by a variety of queries, prompts, and cues. Despite this flexibility, not possessed by procedural memory, both episodic and semantic memory obey the principles of encoding specificity and transfer appropriate processing: The effectiveness of given retrieval cues is determined not only by the nominal identity of target information in the memory store but also by its episodically and semantically encoded context. Finally, the results of acts of retrieval from either memory system can be expressed symbolically, albeit often imperfectly, through language or graphic representations. This long, and by no means exhaustive, list of commonalties and similarities between episodic and semantic memory has made the thought of their essential identity highly attractive to generations of memory and other researchers. It has also encouraged researchers to attribute whatever differences that may exist between episodic and semantic memory to particular nonessential features, such as differences in the kinds of information on which the two forms of memory operate. As a result of the commonalties, the two have been collectively referred to as *declarative* memory or "remembering that" and dealt with as a unity, distinguishable from *procedural* memory or "remembering how."

For many purposes, such leveling is quite reasonable and does not violate any rules of logic or science. Particularly in everyday life, it matters little to individuals whether they know something because they recollect a particular episode in which the contemplated bit of knowledge was gained or because they "just know it." Living organisms, human beings included, rely on their memory capabilities primarily as a source of guidance for their ongoing behavior and future actions. Possible differences between episodic and semantic memory are of little relevance to the practicing learner and rememberer. What matters to people is that these things work.

From the perspective of science, however, any differences between episodic memory and semantic memory are important, and it is necessary to study and try to understand them. These differences have to do with the specific functions that different memory systems serve, especially the functions that are unique to a given system, not shared by others. They also concern matters such as the development of memory in children and breakdown of memory in old age. They have to do with, for example, memory processes that have been impaired by an accident or disease. They have to do with questions, such as "What is the relation between memory for the past and intentions for the future?" and "Is recall a conscious activity?" The way one studies these matters, or attempts to answer these questions, depends critically on what one believes or knows about the relation between episodic and semantic memory, whether they are basically the same or basically different.

Our hypothesis is that, despite the many similarities, they are basically different. In this article, we consider in some detail the major distinguishing characteristic of episodic memory—its dependence on a special kind of awareness that all healthy human adults can identify. It is the type of awareness experienced when one thinks back to a specific moment in one's personal past and consciously recollects some prior episode or state as it was previously experienced. The general concept has been recognized for at least 100 years; William James referred to such awareness as *remembering*. According to James (1890), "remembrance is like a direct feeling; its object is suffused with a warmth and intimacy to which no object of mere conception ever attains" (p. 239). Episodic recollection is well described, with reference to that personal feeling experienced when a rememberer reflects on some moment in the past. It is a unique mental experience, not confusable with the awareness of an "object of mere conception," which corresponds to something simply known. This latter type of knowledge does not possess any personal *veridicality* or pastness and represents retrieval from semantic memory. Living organisms may know many things, even facts about things that have happened to them, that are not infused with a conscious recollection of the past. We label the types of awareness associated with episodic and semantic retrieval as autonoetic (self-knowing) and *noetic* (knowing) awareness, respectively. Thus, episodic and semantic memory represent not only two hypothetical systems of memory but also two varieties of conscious awareness. Because episodic memory is defined, at least partly, by the type of awareness that accompanies retrieval, it is not equivalent to other forms of memory, such as event memory or autobiographical memory which are defined by the content of the material they operate on; although episodic memory is clearly related to these varieties of memory, they should not be equated.

The Frontal Lobes

The frontal lobes constitute approximately one third of the entire mass of the human brain. Because much of it has no known sensory or motor function, it stands to reason that this large area of the brain plays an important role in higher order cognitive functioning. The concept of *frontal lobe functions* has evolved to identify the behaviors that are presumed to depend on the frontal lobes, although the term has been used in diverse ways. Despite the anatomical nomenclature, many references to frontal processes have described a set of abilities that are purely behavioral, with no immediate reference to the anatomical region of the frontal lobes (Goldberg & Bilder, 1987; Stuss & Gow, 1992). We adopt a more limited definition: The term frontal lobe functions specifically refers to those processes related to the brain region defined as the frontal lobes.

The frontal lobes may be globally defined as the brain region anterior to the central sulcus, although many researchers restrict their interest to include only the areas anterior to the motor and premotor areas. This latter region is commonly known as the *prefrontal cortex;* our interest is primarily in that prefrontal area anterior to the premotor cortex, and we use the terms frontal lobes and prefrontal cortex interchangeably.

The functional importance of the frontal lobes derives from its reciprocal interconnections with virtually every part of the nervous system (Fuster, 1989; Nauta, 1973; Pandya & Barnes, 1987; Stuss & Benson, 1986). The anatomical basis of many frontal functions should actually be considered as frontal systems and their reciprocal connections (Alexander, DeLong, & Strick, 1986; Cummings, 1993). Although behavioral similarities clearly exist after lesions occur in the frontal lobes and certain connected regions (e.g., Stuss et al., 1994), researchers have only sporadically investigated the possible associations and dissociations among these connected regions. In this article, we continue to emphasize the defined region of the prefrontal cortex, while realizing that the functions of this area are represented in its connections with more posterior brain regions.

The size of the prefrontal cortex allows for further subdivision, and there is increasing evidence of more specific architectonic differentiation (Barbas & Pandya, 1991; Pandya & Barnes, 1987; Petrides & Pandya, 1994). Researchers, however, have only infrequently mentioned the specific regions of the frontal lobes in relation to memory. Indeed, in lesion studies, patients with frontal lesions have often been combined into a single frontal group, despite the presence of a wide range of etiologies and locations for their lesions. This practice is at least partly attributable to the rarity of patients with focal lesions restricted to the frontal lobes. Therefore, despite the possibility that lesions in different regions of prefrontal cortex produce different symptoms, much of the available evidence has been drawn from the behavior of patients with relatively large lesions of the prefrontal cortex.

Based on clinical and neuroanatomical evidence, the functions of the frontal lobes can be broadly subdivided into three levels (Stuss & Benson, 1986). Functions at each level serve a supervisory role over other functions and domains that are localized more posteriorly (i.e., language, attention, motor control). Frontal lobes regulate overall brain functioning by establishing, maintaining, and monitoring neurocognitive programs (Luria, 1973), depending on the level.

The first level is comprised of those processes that interact directly with the posterior functional domains. Functions include the ability to organize and maintain information in a fixed sequence and to integrate diverse types of information into a meaningful representation. These abilities are most likely mediated by lateral regions. Within this same level, medial frontal structures affect motivation and drive, including the ability to initiate cognitive and motor activities. These seemingly diverse functions comprise a single level of frontal functions because they affect posterior cortical and subcortical domains directly, although they serve a type of superordinate role (Stuss & Benson, 1986).

A second independent level is equivalent to a class of operations often labeled as *executive functions* (sometimes called "supervisory" or "working-with-memory" functions). These functions represent a higher order than those at the first level because they provide conscious control and direction for the integrated behavior of total brain operations and are especially important during nonroutine situations that require novel solutions (Norman & Shallice, 1980). Behavioral characteristics have been described at length elsewhere and comprise those processes that consciously direct, or temporally structure, the low-level systems toward a selected goal, including anticipation, goal selection, plan formulation, behavior monitoring, inhibitory control, and feedback use (Baddeley & Wilson, 1988; Fuster, 1989; Moscovitch, 1992; Shallice, 1988; Shimamura, 1995). The executive functions, like the first level of frontal functions, are mediated by the reciprocal connections of the frontal lobes with more posterior, multimodal and limbic structures (Nauta, 1971; Pandya & Barnes, 1987).

The second level has received most of the attention from cognitive neuroscientists, and the wide use of neuropsychological tests purporting to measure frontal lobe functions reflects this bias. The most widely used test of psychologically frontal functioning, the Wisconsin Card Sorting Test, is assumed to measure abilities manifested largely at this level because the test uses a novel and complex task that requires goal selection and hypothesis testing, along with cognitive flexibility and inhibition of salient responses. Operations at this level also correspond with the central executive component in models of working memory (Baddeley, 1992).

A third proposed level of prefrontal function consists of what is commonly called *self-awareness,* the ability to introspect on one's own thoughts and to realize the relation of self to one's social environment (Stuss & Benson, 1986). The abilities are intimately related to autonoetic consciousness (as discussed later), and it is the awareness of self, largely dependent on the frontal lobes, that serves as a foundation for this unique capacity of human consciousness. Only through the sophisticated representation of self can an individual autonoetically recollect personal events from the past and mentally project one's existence into the subjective future. It is not known which regions of the frontal lobes are especially critical for self-awareness, but the most anterior regions are good candidates. It would be appropriate that this—the most recently evolved area of the brain—subserves autonoetic consciousness, arguably the most clearly human form of consciousness.

Although there is good evidence for the dependence of these capabilities on the prefrontal cortex, there is as yet little known about the dissociability of the levels—although later we describe one patient with symptoms consistent with a selective loss of self-awareness and autonoetic consciousness. Their relations may be best described as interactive, especially the two highest levels. Another possibility is that self-awareness requires executive functioning for its operations. The executive functions coordinate complex operations such as anticipation, planning, monitoring, and structuring behavior toward future goals (Shallice, 1988), and many of these abilities imply at least some primitive form of self-awareness. Indeed, it is difficult to imagine that an individual could mentally prepare oneself for any kind of future undertaking without some representation of self as a stable entity that endures over time. Similarly, by coordinating and monitoring one's mental operations, an organism attends to self and, in doing so, demonstrates a defining characteristic of self-awareness.

During the subsequent discussion of data, it is necessary at times to interpret the available evidence in terms of either self-awareness–autonoetic consciousness or the executive functions to the seeming exclusion of the other. We do so, although we realize that the two concepts are routinely interchangeable and perhaps interdependent. However, researchers relating the frontal lobes to remembering have placed relatively too much emphasis on the class of processes, broadly described as executive functions, and too little on the manifestations of self-awareness and autonoetic consciousness. One of our central arguments is that it is this highest form of consciousness that makes episodic memory possible.

Consciousness and Autonoetic Consciousness

The concepts of autonoetic consciousness and autonoetic awareness play important roles in the discussion of episodic memory. The distinction between autonoetic consciousness and autonoetic awareness parallels the distinction between consciousness and awareness in general (Tulving, 1993). Although the two terms have often been considered synonyms ("I am conscious of something" or "I am aware of something"), we take a more restrictive definition. Here, *consciousness* is a general capacity that an individual possesses for particular kinds of mental representations and subjective experiences. *Awareness* refers to a particular manifestation or expression of this general capacity. Consciousness, like other capacities of living systems, has no object; it is not directed at anything. It is like a stage that allows some actions, but not others, to take place on it, but it does not prescribe the action. Awareness always has an object; it is always of something. Thus, awareness presumes consciousness, but consciousness does not imply awareness: Consciousness is a necessary but not sufficient condition of awareness.

The relation between consciousness and awareness is analogous to the relation between the sense of sight and seeing; the sense of sight allows its possessor to see things, but this sense alone cannot determine what an individual sees. Consciousness too allows an individual to become aware of things without exactly determining what the individual becomes aware of. Awareness is determined jointly by one's general state of consciousness and the particular stimulation from external and internal sources. Further discussion of the relation between consciousness and awareness can be found elsewhere (Tulving, 1993). Autonoetic consciousness is the capacity that allows adult humans to mentally represent and to become aware of their protracted existence across subjective time. When autonoetically aware, an individual can focus attention directly on his or her own subjective experiences. We distinguish this form of awareness from *noetic awareness,* which is experienced when one thinks objectively about something that one knows. Note that is also possible to be noetically aware of one's self, including body position in space, traits and characteristics, and even autobiographical facts that are not accompanied by a feeling of re-experiencing or reliving the past.

To describe autonoetic consciousness with regards to episodic memory, there is a natural bias to cast the discussion in terms of awareness of the past. Autonoetic consciousness is not limited to the past, however; it encompasses the capacity to represent the self's experiences in the past, present, and future. When one is autonoetically aware of one's experiences in the past, one recollects the past and, therefore, retrieves information from episodic memory. But also dependent on autonoetic consciousness and, we argue, closely related to episodic memory is the ability to be aware of the self's present. Healthy adults can introspect and have on-line experiences of their current thoughts, perceptions, and feelings; this capability goes beyond the simpler ability of reporting the outputs of one's thoughts and behaviors (i.e., "I am happy now").

Just as the episodic memory system allows individuals to recollect their personal past, it also mediates the awareness of their personal future. Again, we attribute to autonoetic consciousness the capacity to project one's own existence into the future and to reflect about what one's experiences might be like at a later time. Tulving (1985) has described a male patient with profound amnesia who, in addition to an inability to consciously recollect even a single episode from his past, was incapable of imagining his future. When the patient attempted to either think back to a prior episode or think forward toward later personal events, he described his state of mind as a kind of "blankness." Although the patient was noetically conscious and could become noetically aware, the capacity for autonoetic awareness had been disrupted, leaving his mental state in the permanent present and himself incapable of mental time travel.

In summary, autonoetic consciousness affords individuals the possibility to apprehend their subjective experiences throughout time and to perceive the present moment as both a continuation of their past and as a prelude to their future. We consider this the most highly evolved form of consciousness and think of it as the Jamesian "stream of consciousness," which provides a fluid link from the individual's past, through the present, to the future, and back again. Because autonoetic consciousness is related to both the frontal lobes and episodic memory, the goal is not only to demonstrate how such a capacity interacts with these other concepts but also to make the case that autonoetic consciousness represents an important concept in its own right and is worthy of more psychological attention than it has received in the past.

Episodic Memory and the Frontal Lobes

Lesion Studies

Until most recently, almost all of the knowledge about the relation between brain and behavior was gleaned from patients with circumscribed brain damage. The logic of most studies (sometimes called the logic of single dissociation) is straightforward: If damage to a brain area produces an impairment on a cognitive Test A, then that area should be considered a critical region in the performance of Test A. Similarly, if localized pathology does not result in a deficit on Test B, then the area is probably not an important area in the observable performance of the test. In this section, we provide a summary of experiments in which patients with damage restricted to the frontal lobes have been compared with other populations on tests that likely involve the episodic memory system. Comparison groups are typically either healthy controls or patients with more posterior lesions that do not encroach directly on the frontal lobes.

Recall and recognition tests. In many experiments, researchers have assessed the role of frontal damage with the three tests most commonly used to test episodic memory: free recall, cued recall, and recognition. As already mentioned, however, some reasonable level of performance on these tests can potentially be achieved without the participation of the episodic memory system (see *Episodic Memory*). For example, a participant might know that an item has appeared in a prior study list without autonoetically remembering the item's presentation. Thus, we assume that the semantic memory system can support the recognition and recall of information concerning recent experiences in a participant's past. For this reason, it is difficult to draw strong conclusions about the relation between the frontal lobes and episodic memory system solely from recognition and recall tests. Nevertheless, because these tests represent the most common forms of memory assessment, it is important to understand how frontal damage affects performance. What follows is a chronological overview of how the perceived relation between the frontal lobes and memory has developed throughout the last decade, as measured by tests of recognition, cued recall, and free recall.

For many years, it has been known that dorsolateral prefrontal lesions do not result in a full-blown amnesic syndrome (Milner, 1964), and it was assumed that patients with pathology restricted to the prefrontal cortex had no deficits in recall or recognition. These facts complemented the widely accepted view that organic amnesia, especially anterograde amnesia, is associated with damage to the structures in the medial temporal lobe and diencephalon. Also, it is now known that patients with lesions restricted to the prefrontal cortex demonstrate a different profile than do patients with amnesia on a wide variety of memory tests (Shimamura, Janowsky, & Squire, 1990).

Two reviews from the middle of the 1980s reaffirm that there is little evidence for frontal involvement in the most common tests of memory, such as recall and recognition, which are commonly impaired in patients with amnesia (Squire, 1987; Stuss & Benson, 1986). Around the same time, however, individual studies began to appear, reporting findings of significantly impaired free recall following damage to the prefrontal cortex. To keep with the memory-free thinking about the frontal lobes, theoretical explanations attribute the deficits to complex strategies, which healthy controls adopt to enhance their performance, rather than to basic processes of encoding, storage, or retrieval. At first, such explanations were made post hoc in an attempt to justify the (then) unexpected deficit. It was suggested that patients with frontal lobe damage may have difficulty carrying out the complex operations required to encode items effectively (Incisa della Rocchetta, 1986; Smith & Milner, 1984). Jetter, Poser, Freeman, and Markowitsch (1986) related the free-recall deficit to a disturbance of attention and drive, combined with a reduced ability to generate appropriate retrieval cues.

Since that time, in a number of other studies, researchers have replicated the finding of impaired free recall following frontal damage, and theoretical explanations have been generally consistent with a working-with-memory hypothesis (Moscovitch, 1992). That is, frontal lobes are important for goal-directed activity, such as organization of information of both encoding and retrieval, and for response monitoring. Working-with-memory processes are mnemonic strategies that can be brought under a participant's control to mediate performance and are closely related to the executive functions (Baddeley & Wilson, 1988) and to the second level of frontal functions proposed by Stuss and Benson (1986). In a working-with-memory hypothesis, performance on an episodic memory test is affected by frontal damage only to the extent that strategic factors augment test performance. Both Hirst and Volpe (1988) and Gershberg and Shimamura (1995) noted that their patients with frontal lobe damage would not spontaneously categorize a word list or use other top-down organizational strategies as required for subjective organization, despite that such a strategy would have clearly aided subsequent retrieval (Eslinger & Grattan, 1994; Stuss et al., 1994). When the patients were induced to organize the list, recall significantly improved, although not quite to regular levels. Another suggestion has been that recall deficits are worse following left- rather than right-sided frontal damage because effortful strategies typically involve verbal mediation (Incisa della Rocchetta & Milner, 1993).

The common element of all of these ideas is that the frontal lobes are associated with the selection and implementation of controllable mental operations. Therefore, recognition performance should be unaffected, or relatively unaffected, because the recognition judgment is typically fast and not dependent on participant-initiated organization. In only one study have researchers explicitly documented a statistically significant recognition impairment (Stuss et al., 1994) following frontal pathology, and follow-up analyses hinted at the cause of the deficit. All patients with a recognition deficit fell into one of two categories: (a) a lesion extending into the septal region or posterior extent of the anterior cingulate or (b) a mild language impairment resulting from left frontal pathology. Damage to the septum and anterior cingulate may produce a mild form of amnesia, and, indeed, the regions are often viewed as the most anterior portion of the limbic circuitry of memory. Although none of the patients had a significant aphasia, some patients with left-hemisphere damage performed poorly on the Boston Naming Test, and scores on this test were strongly correlated with recognition performance, implying that the recognition deficit for this subpopulation of patients was secondary to the subpopulation with anomia. Findings demonstrate that some areas within the frontal lobes can be associated with even the most primary processes of remembering, such as those involved in recognition, and that researchers of the role of the frontal lobes in remembering must ultimately consider regional differences in processing. Findings are possibly consistent with much of the previous literature because patients with basal forebrain damage or language impairment may have been excluded from certain lesion studies.

In an empirical review, Wheeler, Stuss, and Tulving (1995) summarized all of the lesion work since 1984 in which researchers assessed the relation between frontal damage and performance on tests of free recall, cued recall, and recognition. They examined all relevant experiments in which patients with authenticated frontal damage were compared with healthy controls.

The first of the two main findings has to do with recognition. In the great majority of comparisons of recognition performance (18 out of 21 or 86%), control participants performed numerically better than the patient group, implying that frontal injury impairs even simple recognition. One possible explanation for this relatively unexpected finding is that frontal functions, such as organization, monitoring, and autonoetic awareness, might enhance performance, even on mostly nonstrategic tests with strong retrieval cues. Another possibility is some patients having mild amnesia with basal forebrain or septal lesions or patients with language impairments may have been unwittingly included in some of the patient groups. Because the frontal-related recognition effects reported in the individual articles were small and usually not statistically significant, it is difficult to draw strong conclusions other than to note the consistency of the effect.

A second major finding (Wheeler et al., 1995) is that participants showed greater sensitivity to frontal damage through their scores on recall tests as compared with those on recognition tests. The latter finding fits into the general framework proposed by Stuss and Benson (1986) and supports existing theories of frontal lobe functioning. Through its extensive reciprocal connections, the prefrontal cortex exerts a superordinate influence over the more posterior, lower level systems, and frontal participation is critical for any situation in which an individual has to initiate or sequence cognitive processes (first level) or consciously select goals and implement strategies (second or executive level). Maximal performance on recall tests requires many of these frontal functions, especially the use of encoding and retrieval strategies, but the same is not true, at least not to the same extent, for tests of recognition. Therefore, it is appropriate to attribute part of the relative recall deficit to executive functions.

The explanation that we favor is that frontal lobe damage impairs memory performance, to the extent that such performance benefits from autonoetic awareness. Tulving (1985) and Perner and Ruffman (1995) found that free recall is correlated with the ability to remember, whereas performance on tests requiring stronger retrieval cues (cued recall and recognition) could be supported to a larger extent by semantic memory processes, as reflected in known responses. This explanation helps to account for some of the difference in recognition and recall in patients with frontal pathology: Because of the failure of autonoetic awareness, patients cannot mentally travel back to previous personal experiences.

Other measures of episodic memory. Recall and recognition tests represent the most common laboratory measures of memory assessment, but the most ideal tests of the episodic system take place in situations in which rememberers must think back to a specific moment in the subjective past to consciously recollect a personally experienced episode. It is such mental time travel that, based on our theory, cannot be accomplished by any other memory system. In practice, it is difficult to design a task that can be performed only through conscious recollection, although some lesion studies have used tests that come close. One useful approach is to assess dimensions of the learning episode that were not central to the target information at encoding (e.g., contextual information). Because typical encoding instructions motivate participants to attend to the identity of items, identity is often encoded into the semantic memory system. Rather than knowledge of the identity of study items, an episodic test might assess some aspect of each items' presentation that is recoverable only through a conscious recollection of the study episode.

An example of a dissociation between item identity and episodic recollection is known as *source amnesia* (Schacter, Harbluk, & McLachlan, 1984). Source amnesia is said to occur when a rememberer shows retention of a fact but cannot recollect where or how the information was learned. During source amnesia, there is an inability to recollect a salient dimension of the study's episode. When an individual attempts to mentally re-experience or re-create earlier events, the recollection often includes knowledge about the source from which prior semantic information was learned. It has long been recognized that source identification and item recognition can be experimentally dissociated (Johnson & Raye, 1981) and that correlations between the two measures vary widely, depending on task demands (Craik, 1989). A lack of consistency is not surprising because the efficacy of both item identification (recall and recognition) and memory for source is powerfully affected by the manipulation of variables during encoding. For example, a deeper level of processing strongly increases the probability of subsequent identification of an item, although the same process might not affect, or even adversely affect, the ability to recollect that item's source (Johnson, Raye, Foley, & Foley, 1981). Given the vast number of potential processing manipulations, one cannot expect to find the same relation between source memory and item memory within each relevant comparison.

Lesions restricted to the frontal lobes have been associated with source amnesia. Perhaps more important, the impairment is often disproportionately higher than decrements in item recall or recognition (Janowsky, Shimamura, & Squire, 1989b). When tested with general information facts as stimulus materials, patients with frontal pathology were more likely than healthy controls to make two kinds of source errors: (a) claiming that a fact learned in the study phase had been learned from an outside source, prior to the experiment, or (b) reporting that a fact had been learned in the experiment when it had not. These errors represent prime examples of source amnesia because patients were impaired in their ability to assign the source of their recollection to an experimental or pre-experimental situation. Source amnesia has been related to the frontal lobes after researchers studied other populations as well, and these relations are typically shown in correlational measures. Schacter et al. (1984) demonstrated that the ability of patients with amnesia to remember the source of facts was highly correlated with performance on tests that traditionally measure the frontal psychological functions (i.e., Wisconsin Card Sorting Task), providing another link between autonoetic awareness and executive functions. A similar correlation exists with healthy older persons (Craik, Morris, Morris, & Loewen, 1990; Glisky, Polster, & Routhieaux, 1995).

Recollection of the source is but one aspect of episodic remembering. Other tests require rememberers to bind their retrieved knowledge to a subjectively experienced episode. P. Corsi (cited in Milner, 1971) presented patients having frontal lobe damage with lists of verbal or nonverbal stimuli, occasionally requiring them to make forced-choice judgments between pairs of stimuli and to decide which item had been presented most recently. The presence of frontal lesions impaired recency judgments as compared with that of controls, whereas the groups showed similar performance in tests of item recognition (Milner, Corsi, & Leonard, 1991). Although patients could identify those items they had previously encountered at regular levels, they were often unable to monitor the temporal dimension of events in their past. There are various possible explanations for the deficit (Milner et al., 1991; Moscovitch, 1992), with one prime candidate involving autonoetic awareness. Recency judgments can be considered measures of autonoetic awareness of the past because the conscious recollection of prior events is one important component of successful performance (e.g., individuals can evaluate recency by traveling back in personal time).

Judgments of source and recency do not necessarily tap episodic memory. Virtually any category of information can be, in principle, represented in, and its retrieval mediated by, semantic memory, including knowledge of source and contextual information. For example, it is possible to know that one has learned a certain fact from a college professor, without consciously recollecting the learning episode. To tap into autonoetic consciousness, a test must require a rememberer to contemplate some past personal event directly as it was subjectively experienced. We propose that the experimental situations described above largely fulfill this requirement.

There are other memory and memory-related tasks that show impairments following frontal damage, but they are more difficult to interpret in terms of autonoetic awareness. For example, patients with frontal lobe damage are impaired when they attempt to reproduce the order of a recently presented word list (Shimamura et al., 1990). Although the temporal ordering involves recollection of the prior presentation, it could also be considered a novel or nonroutine task, requiring patients to select and implement cognitive strategies to estimate item order. Therefore, the deficit can be reasonably construed as a failure of either episodic memory, executive functioning, or both. The latter interpretation is logical because the same patient group could also not reproduce the chronological order of a series of historical events, which they could not consciously recollect from their personal past. Impairments in complex tasks can arise from any number of factors.

As another example, patients with prefrontal damage are impaired at a variety of metamemory functions, with *metamemory* defined as the capacity to make judgments and predictions about one's memory abilities (Metcalfe & Shimamura, 1994). Many experiments on this topic have involved feeling-of-knowing judgments, in which rememberers estimate the likelihood that they will subsequently recognize an item given that they did not recall it. Under some conditions, patients with circumscribed frontal lobe lesions do exhibit less accurate feeling-of-knowing ratings relative to healthy controls and patients with amnesia (Janowsky, Shimamura, & Squire, 1989a; Shimamura & Squire, 1986). Again, it is not a simple matter to explain the findings. Deficits may be related to the novelty and difficulty of the task or to the fact that patients must respond by providing estimates because this group has been associated with an inability to estimate both the costs of objects (Smith & Milner, 1984) and the solutions to problems (Shallice & Evans, 1978). Conversely, the test may tap participants' abilities to consciously recollect some information pertaining to the original learning episode. To the extent that this latter possibility is so, it is an episodic memory task. As the safest conclusion, it is difficult to know what much of the memory-related research with patients having frontal damage means because task requirements do not lend themselves to easy interpretation.

To summarize, patients with brain pathology confined to the prefrontal cortex have been directly compared with healthy controls on a variety of tasks that, to varying degrees, engage the episodic memory system. Although the patients were at least mildly impaired on all of the measures, there was probably some relation between level of impairment and extent to which each test required autonoetic awareness of the study episode. As an example, recall performance suffers more than recognition, and recall tests are more highly correlated with conscious recollection (Perner & Ruffman, 1995; Tulving, 1985). Similarly, source amnesia is more likely a result of frontal damage than impaired recognition (Janowsky et al., 1989b; Schacter, 1987; Schacter et al., 1984). Therefore, the overall pattern of results is broadly consistent with the hypothesis that damage localized to the prefrontal cortex causes a selective loss in the episodic memory system, but it also lends itself to other reasonable interpretations. The most obvious of the alternative explanations is that the frontal lobes play a critical role in the ability to select and execute complex mental operations. Such operations may be especially important when a rememberer seeks to capture the details of the past, such as individual items appearing in a list, through mental re-creation of the overall episode in which the details appeared, such as the situation in which the list was learned (Moscovitch & Winocur, 1992).

PET Studies

What is PET? Although the lesion study approach remains the dominant means of knowledge acquisition within cognitive neuroscience, the field is being rapidly transformed by neuroimaging. The growth of brain imaging has been driven largely by technological advances. At first, imaging techniques were applied mostly to the localization and diagnosis of brain damage or brain change in patient populations. What began as a clinical tool soon proved valuable to researchers as well; by comparing the images of a patient's brain with his or her cognitive and behavioral profile, neuroscientists could begin to associate pathology in specific brain regions with impairments in specific classes of tests.

More recently, it has become possible to study the functional neuroanatomy of the healthy human brain during task performance. The ability to record and measure neural activity in healthy adults alleviates some concerns that have been raised about the lesion study approach. By studying damaged brains, some researchers believed that it was difficult to draw strong conclusions about healthy brains. Functional neuroimaging overcomes this problem, although the approach comes with its own set of complexities and concerns, as we discuss later. Another advantage of neuroimaging, specific to memory research, is its potential to separate encoding and retrieval processes so that they can be studied in isolation. A typical episodic memory experiment, for example, includes stages of encoding, storage, and retrieval, and this requirement presents interpretative difficulties for the lesion approach. If a brain-damaged population shows impairment on a memory test, it is difficult to know the extent to which the disruption is related to impoverished encoding, storage, or retrieval processes. With PET, the neural correlates of encoding can be measured independently of retrieval and retrieval processes separately from encoding.

PET takes advantage of the fact that mental and behavioral tasks are accompanied by neuronal activity in the brain, which is, in turn, accompanied by changes in blood flow (Posner & Raichle, 1994). Before each PET scan, a radio-labeled isotope (usually $H_2{}^{15}O$) is injected into the participant's bloodstream; following the injection, a concentration of the isotope can be detected in the regional cerebral blood flow (rCBF) by PET for about 1 min. The resulting image depicts the rCBF in each area of the brain during that minute.

The interpretation of PET data is not straightforward, and it is not possible simply to measure brain activity during performance of a single task and then draw meaningful conclusions about the neural underpinnings of that task based on the resulting brain image. Such a procedure does not specify those components of the image that were produced from the task instructions and those that were already present. Therefore, experiments are typically performed using a "subtraction method." At least two cognitive tasks are required of each participant in a PET comparison; ideally, the tasks are identical except for a single component. The pixel-by-pixel levels of blood flow from one of the two tasks (the reference task) are subtracted from the corresponding levels during the target task. The challenge for PET researchers is to design two tasks that differ by only one meaningful component. After subtraction, the resulting image shows the pattern of activation that is assumed to represent the localized blood flow associated with the different component between the two tasks. The logic of PET implies that, if a brain region is shown to have a higher blood flow on Task A than Task B, then that region is more active in Task A than Task B. The resulting brain map is only as meaningful as the analysis of the cognitive ingredients of the compared tasks. The manipulation of mental operations of participants within the PET scanner represents another means to investigate the relation between cognition and neurophysiology. (For more detailed analyses of the methods and limitations of PET studies, see Buckner & Tulving, 1995; Posner & Raichle, 1994; and Raichle, 1987.)

In this section, we describe the PET experiments from which conclusions can be drawn about the neuroanatomical correlates of episodic memory. Although memory processes are known to involve many distributed regions of the brain, our summary, in the context of this article, concentrates on the frontal lobes.

Episodic retrieval. When a rememberer recollects some personal experience from the past, the recollection comprises retrieval from both episodic and semantic memory. First, the recollection represents the re-experience of a prior subjective event (i.e., the original experience of seeing a word on a study list), which is handled by the episodic system. Within that re-experience, there exist factual contents about the retrieved event (i.e., knowledge of the word's meaning and of the word's presentation occurring within the context of other list items).

With PET, researchers have attempted to isolate the components of episodic retrieval that are purely episodic. Through the subtraction method, the goal is to remove those retrieval components that reflect extra-episodic influences, such as semantic memory operations. The appropriate comparison includes two conditions—one requiring retrieval from both the episodic and semantic systems (target condition) and the other, from only the semantic system (reference condition). After the subtraction of the reference condition, the remaining activation is assumed to reflect that neural activity specifically associated with the retrieval of information from a specific moment in the past (e.g., mental time travel).

To study the episodic component of recall with PET, one must compare an episodic recall test (and its underlying semantic retrieval component) with a condition in which items are recalled from semantic memory rather than from a particular study event. Results of studies conforming to this arrangement have been consistent: Episodic retrieval is associated with increased blood flow in the right prefrontal cortex, usually in the absence of similar activation in the left prefrontal cortex (Nyberg et al., 1996).

In two studies (Buckner et al., 1995; Squire et al., 1992), participants were scanned while completing three-letter word stems. The test was either episodic (stems completed with words from a previously studied list) or semantic (stems completed with the first word that comes to mind; these words could not be completed with words from the study list). Similarly, Shallice et al. (1994) conducted an experiment in which study materials were paired associates that conformed to a category–exemplar relation (i.e., poet, Browning). On the test, participants recalled the appropriate exemplars for each category (episodic task) or generated exemplars to new categories (semantic reference task). In all relevant comparisons, retrieval of the studied items showed an additional activation in right frontal areas, without similar left frontal activity. Note that, in these studies, the two recall tasks (episodic–target and semantic–reference) were alike in several ways. Both the baseline and reference tasks required participants to generate an item in response to a retrieval cue, and both the retrieval cues and subsequent responses assumed similar forms. Episodic and semantic tasks differ primarily by the source of the retrieved information; target tests encourage participants to think back to a specific moment in their past, whereas reference tests require the recall of information from general knowledge. Thus, it is safe to conclude that the target task involves the episodic memory system to a larger extent than the reference task. The remaining activation in the right prefrontal cortex, by our interpretation, reflects the cognitive activity that results from the attempt to retrieve information from a specific study episode—although later we discuss the hazards involved in drawing this kind of conclusion.

Recognition experiments, with both verbal and nonverbal materials, have replicated the basic relation between right prefrontal activation and episodic retrieval, with different tasks and procedures. Using drawings of common objects as stimulus materials, Moscovitch, Kohler, and Houle (1995) reported that right prefrontal activation was preferentially involved in the episodic recognition tests both for the identity and the spatial location of objects. Similarly, Haxby et al. (1993, 1996) reported right prefrontal cortical activation during a forced-choice recognition test for faces that had been studied a few minutes before. Several other researchers have obtained similar results with both auditorily (Tulving, Kapur, Markowitsch, et al., 1994) and visually presented verbal materials (Andreasen et al., 1995; Cabeza et al., in press; S. Kapur et al., 1995; Nyberg et al., 1995). The right prefrontal activation in all these experiments signifies an episodic component of retrieval because the reference tasks in these studies involved the perceptual presentation of comparably new items.

The general findings regarding the right prefrontal cortex are impressively consistent. A review by Nyberg et al. (1996) summarizes results of those comparisons in which the PET image corresponding to a semantic reference task was subtracted from an episodic target task. In 25 of the 26 relevant subtractions, the right prefrontal cortex was preferentially involved in the episodic task. In addition to the studies already mentioned, the various tasks include the cued recall of words from word stems (Backman et al., 1997; Buckner et al., 1995; Schacter, Alpert, Savage, Rauch, & Albert, 1996), category cues (Fletcher, Frith, Grasby, et al., 1995), and paired associates (Cabeza et al., in press), as well as the recognition of words (Nyberg et al., 1995), faces (Grady et al., 1995; cf. N. Kapur, Friston, Young, Frith, & Frackowiak, 1995), pictures of landscapes (Tulving, Markowitsch, Kapur, Habib, & Houle, 1994; Tulving, Markowitsch, Craik, Habib, & Houle, 1996), visual patterns (Roland, Kawashima, Gulyas, & O'Sullivan, 1995), and odors (Jones-Gottman, Zatorre, Evans, & Meyer, 1993).

The consistency leads to the more difficult question, What is the role of the right frontal involvement? One possible explanation is that personal memories are somehow represented in the right frontal lobes, and with PET researchers have discovered the reactivation of those memory traces. This interpretation implies that the increased blood flow represents *ecphory,* the process by which the stored memory trace interacts with the retrieval cue to produce the contents of retrieval (Tulving, 1983). More recent research is inconsistent with this idea, suggesting instead that the right prefrontal involvement signifies retrieval attempt, or retrieval mode (Tulving, 1983), rather than successful retrieval (ecphory). The data show that the right prefrontal cortex is more active than the left prefrontal cortex when participants try to recognize presented test items, whether they succeed or not. S. Kapur et al. (1995), using two episodic retrieval conditions, replicated previous findings, showing that both tasks led to increased right prefrontal activation when they were compared with a common baseline condition of semantic retrieval. The episodic tests differed with respect to retrieval success. In one case, retrieval was relatively successful because 85% of the words were old and participants could recognize the words. The other retrieval condition was designed to be relatively unsuccessful, with only 15% of the words old. The subtraction technique revealed no differences in frontal blood flow related to success or ecphory. In a similar experiment, Nyberg et al. (1995) confirmed and extended the findings of S. Kapur et al. (1995); comparable results have been reported by Schacter et al., (1996), providing good support to the hypothesis that the role of the frontal lobes in episodic retrieval corresponds to episodic retrieval attempt or retrieval mode rather than, or perhaps in addition to, ecphory (Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1996). Ecphory is associated with differential activation of posterior cortical regions, including cuneus and precuneus (Nyberg et al., 1995; S. Kapur et al., 1995)—regions that have been found to be activated in episodic retrieval in other PET studies (i.e., Shallice et al., 1994), especially retrieval involving visual imagery (Fletcher, Frith, Baker, et al., 1995).

Thus, the evidence implies that one role of the frontal lobes in remembering, especially in the right hemisphere, is to create and maintain an episodic retrieval mode (Tulving, 1983), an autonoetically aware state or set in which incoming information is treated as possible reminders of what has happened in the past or as guides to mental time travel. At present, it does not look as if frontal lobes represent storage sites of episodic information (cf. Rugg et al., 1996).

Episodic encoding. It is more difficult to disentangle the neural correlates of episodic and semantic encoding because there is no obvious way to present materials to participants in such a way that it is selectively encoded into only one of the two systems. Therefore, the logic behind PET studies of episodic encoding is different than of episodic retrieval. Two study conditions are needed, and the conditions must differ with respect to the efficacy of the encoding for a subsequent episodic memory test. From cognitive psychology, it is known that certain study manipulations lead to better retention of information, as measured by recall and recognition tests. For example, subsequent recall performance is higher if items are processed based on their meaning rather than a purely orthographic or phonemic attribute (Craik & Lockhart, 1972). S. Kapur et al. (1994) have applied this knowledge to a PET study, which required participants to process items under either shallow (whether the noun contained the letter *a*) or deep (if the noun represents a living thing) instructions. By the subtraction of the level of blood flow associated with the former task from that of the latter, the resulting pattern reveals the activation associated with more efficient episodic encoding conditions. After subtraction, the deep encoding task was associated with increased activation in the left prefrontal cortex. Basic results have been replicated many times with both verbal (Fletcher, Frith, Grasby, et al., 1995; Shallice et al., 1994) and nonverbal (Grady et al., 1995; Haxby et al., 1996) stimulus materials.

Episodic encoding is also more effective when rememberers actively generate items rather than simply read them (Slamecka & Graf, 1978). When the PET image corresponding to a verb-reading task is subtracted from that of a verb-generation task, remaining blood flow is again localized in the left prefrontal cortex (Petersen, Fox, Posner, Mintum, & Raichle, 1988, 1989; Raichle et al., 1994; Wise et al., 1991; see also Frith, Friston, Liddle, & Frackowiak, 1991a, 1991b). In their review of episodic encoding studies, Nyberg et al. (1996) found that, in 18 out of 20 relevant comparisons, the more effective encoding tasks differentially activated left frontal regions when compared with the less effective encoding tasks. Therefore, episodic encoding, like episodic retrieval, has consistently been associated with a region of the frontal lobes, in this case, the left prefrontal cortex. The pattern of findings is referred to as HERA (Hemispheric Encoding/Retrieval Asymmetry) of the frontal lobes in episodic memory processes. (For more on HERA, see Buckner, 1996; Nyberg et al., 1996; and Tulving, Kapur, Markowitsch, et al., 1994.)

PET caveats. The biggest strength of PET derives from its ability to provide an image of the healthy brain during task performance. The technique is accompanied by a host of complexities, however, which constrain the types of conclusions that can be drawn. Probably the single biggest concern comes from the validity of the subtraction method. The method assumes that the two tasks, target and reference, differ by only one meaningful component; subtraction will cleanly isolate the component; and the component can be meaningfully associated with specific brain regions. In practice, it is difficult for PET researchers to justify that they have satisfactorily addressed these assumptions. Cognitive psychologists often reasonably disagree about the various processing components that comprise a given task or set of tasks, making the interpretation of PET data a theoretical exercise as well as a descriptive one.

The PET studies that have been described in this review can be criticized along these grounds. Consider the episodic retrieval studies. Target and reference tasks in these experiments were designed to differ along one primary component: the extent to which the tasks involved the episodic memory system. If each study is looked at individually, it would be unreasonable to claim that the various target and reference tasks could not have differed along any other dimensions. In the Buckner et al. (1995) experiment, for example, participants completed word stems under either episodic (target) or semantic (reference) instructions. There were probably a number of subtle cognitive operations that differed between the two tasks, perhaps involving the mental set, expectations, and strategies that were brought to bear on the two approaches for stem completion. Similar criticisms could be made about any of the PET experiments discussed above.

Because of this type of potential problem, the results of a single PET study are often not very informative. The evidence linking the right prefrontal cortex to episodic retrieval does not come from any one comparison but from the remarkable consistency across many different studies. Again, Nyberg et al. (1996) discovered 25 out of the 26 relevant comparisons that demonstrate preferential right prefrontal cortical involvement in episodic retrieval conditions, and the target tasks included both recognition and recall tests, for both verbal and nonverbal materials, across various levels of task difficulty and retrieval success. Similarly, a large majority of relevant subtractions link episodic encoding of the left prefrontal cortex with the types of encoding operations and stimulus materials varying widely from experiment to experiment. The criticisms that can be raised, quite fairly, with respect to the application of the subtraction technique to individual studies are much less troublesome when different experimental procedures converge on a common area associated with a hypothesized cognitive component. Still, the interpretation of PET data is often difficult, and researchers must proceed with caution; in the eventual construction of a theory of the frontal lobes and episodic memory, evidence from neuroimaging will only play one part.

Relation between lesion work and PET. Findings from the two research approaches that we have considered thus far, lesion experiments and PET studies, support the general idea that the frontal lobes play some critical role in the episodic system. One may, however, wonder about an apparent discrepancy between the approaches. Damage to the prefrontal cortex produces a different degree of impairment on these two supposedly episodic tests—there is a relatively large effect on recall performance (cued and free) when compared with the smaller effect on tests of recognition. Data from neuroimaging do not imply any such difference: There was a consistent role for the right frontal lobes in both kinds of tests, and, in a direct comparison (Cabeza et al., in press), there was no detectable difference in the amount of frontal blood flow between recognition and (cued) recall. If the prefrontal cortex is similarly involved in both test forms, as suggested by PET, why does pathology lead to varying effects? This paradox speaks to the larger issue of the relation between lesion studies and neuroimaging (Buckner & Tulving, 1995).

Researchers of lesion and PET studies do not measure the same things, and one should not expect a perfect concordance between the two approaches. That a particular brain region can be associated with a cognitive or behavioral task by PET need not imply that damage to that area will noticeably disrupt performance of the task. It only suggests that activity in the brain region typically accompanies target task performance. Similarly, that a lesion in a particular area produces severe impairment in certain kinds of memory tasks need not imply that the area could be identified by PET. Lesions are most likely to affect memory processes when they involve bottleneck structures that transmit information to and from associative cortical areas, which serve as the sites of stored information (Markowitsch, 1995) that may be difficult to detect by PET. As a simple example, consider the fornix. A lesion in the fornix, even in the absence of other brain damage, can result in a severe impairment of remembering (Araki, Kawamura, Shiota, Kasahata, & Sugita, 1994; D. Gaffan, 1985; E. A. Gaffan, Gaffan, & Hodges, 1991). Yet, because the fornix is a fiber tract (white matter), it is highly unlikely to reveal changes in the blood flow that could be measured by PET. Whenever a meaningful relation between lesion data and PET findings does occur, the converging findings provide additional reassurance that the brain regions in question have an important role in the behavior of interest. Nevertheless, there are no reasons to always expect or even look for such concordance.

With a return to the frontal lobes and episodic memory, PET data have shown that the frontal lobes are active during episodic recognition tests, despite the fact that frontal damage, with the exceptions noted, barely affects performance. Given such evidence, the challenge is to interpret the role of the frontal lobes in this type, and other types, of episodic memory tests.

The right frontal blood flow, uncovered by PET, is most closely associated with task instructions, more specifically the requirement to think back to some specific, previous personal episode. The level of activity is not modulated by the degree of retrieval success (S. Kapur et al., 1995) or of retrieval difficulty (Nyberg et al., 1995); the form of the test, cued recall or recognition (Cabeza et al., in press); or the properties of the stimulus materials, verbal or nonverbal (Tulving, Kapur, Markowitsch, et al., 1994). We interpret the blood flow in the right prefrontal cortex as signifying neural correlates of the intent to become autonoetically aware of a previous experience but not as a correlate of the ultimate result of the retrieval attempt as such. The prefrontal cortex, especially the right side, plays a crucial, supervisory role by establishing this retrieval set. It is within this retrieval set that rememberers can become autonoetically aware and thereby retrieve information from episodic memory. PET only demonstrates how healthy people typically respond to the target task instructions; it cannot specify the most basic structures and networks that are necessary for simple yes–no recognition performance.

Neuropsychological studies show that frontal lesions disrupt conscious recollection of a study episode more than the ability to recognize items that were presented in that same episode. The neuroimaging and behavioral approaches are not in conflict; they converge to suggest both an important memory-related role for the prefrontal cortex (the capacity for autonoetic awareness) and those memory tasks that can (recognition) and cannot (recall and memory of source) be relatively successfully completed without this highest form of consciousness. Frontal lobes typically set the stage for episodic retrieval and autonoetic awareness, but this brain region is not necessary whenever putatively episodic tests can be mediated by other systems of memory. Patients with damage restricted to the frontal cortex are impaired when required to mentally re-experience a study episode in sufficient detail to recollect contextual information about that episode, even though they can often report about the factual contents of the same episode.

Hemispheric asymmetry. The discovery of the consistent pattern of asymmetrical activation of the frontal lobes in episodic encoding and episodic retrieval, captured by the HERA model (Tulving, Kapur, Craik, et al., 1994), is surprising. There is essentially nothing in the previous literature that suggested that encoding operations should preferentially engage the left side more than the right and that retrieval processes should engage the right side more than the left and do so for a wide variety of materials and tasks (Nyberg et al., 1996). Hemispheric asymmetry of cognitive and behavioral functions has been widely discussed, and a number of relevant facts have been generally accepted, but the idea of an asymmetrical brain organization with respect to encoding and retrieval had never been publicly contemplated before 1994. Indeed, the finding that HERA—left encoding and right retrieval—holds for both verbal items (S. Kapur et al., 1994; Squire et al., 1992; Tulving, Kapur, Markowitsch, et al., 1994) and visual objects (Moscovitch et al., 1995) and faces (Grady et al., 1995; Haxby et al., 1996) does not seem to fit in well with the conventional wisdom that the left hemisphere is critical for verbal processes, whereas the right one mediates processing of visual and spatial information.

The lesion studies described above cannot help much in the evaluation of HERA. Because neuropsychological experiments involve stages of both encoding and retrieval, the difficulties of remembering in patients with frontal lobe damage cannot be isolated to either stage. There is some evidence that the right frontal lobes may play a slightly larger role in episodic retrieval than the left ones, but persuasive neuropsychological evidence for the complete prefrontal dominance of the right, rather than the left, in episodic retrieval does not exist, and neither does the dominance of the left hemisphere in episodic encoding. What has been discovered is that damage or change restricted to the right prefrontal cortex has been related to both a transient memory disorder and reduced self-monitoring, a process that can be considered as a supervisory operation in the retrieval of episodic information.

One piece of evidence comes from a case study by Baron et al. (1994). A 56-year-old woman with previous hypertension experienced a sudden episode of transient global amnesia, an isolated and temporary anterograde amnesia, with no precipitating event. During the episode, she was unaware of the origin of a carpet she had purchased 6 months before and could not identify the doctor who had been in charge of her over the last 4 months. The amnesia was not accompanied by sensory or motor impairments or any disturbances of consciousness or language, although the patient was disoriented to time. A PET scan taken in the early recovery phase revealed a reduction in blood flow and oxygen across the entire right dorsolateral frontal cortex, with smaller changes around the right thalamus. There was a notable lack of any medial temporal (hippocampal) involvement, and Baron et al. suggested that the prefrontal cortex plays an important role in the retrieval of "memory traces." For our purposes, the most interesting aspect is the neuroanatomical localization (right prefrontal cortex) that was selectively impaired in a syndrome commonly associated with the medial temporal or diencephalic regions.

Another bit of evidence comes from a study by Stuss et al. (1994). They tested patients with damage to the right, left, or bilateral frontal regions on a word-list learning task and found an association between right-side damage and a selective impairment designated as "retrieval monitoring." Although the overall recognition and recall performance of the right frontal group was in many ways comparable with healthy controls', these patients showed a tendency to perseverate by repeating words that had already been successfully recalled from the study list. Patients with left-sided lesions also demonstrated some detectable perseveration, but there was a clear asymmetry in performance, suggesting that the right prefrontal cortex plays some role in the monitoring of performance. The patients with right prefrontal damage were also the only group significantly inconsistent in their retrieval performance from trial to trial. Together, the data suggest some role of the right frontal region in retrieval monitoring and retrieval set, a finding compatible with the PET data.

Our self-monitoring interpretation is complicated because the phenomenon sometimes extends to complex retrieval from semantic memory. Moscovitch (1995a) identified a number of confabulating patients with a combination of prefrontal damage and mild-to-moderate amnesic syndrome that was produced by hippocampal or diencephalic pathology. Confabulation, or "honest lying," is a syndrome in which patients report information that is mostly correct yet many details have been modified or combined and are often attributed to inappropriate sources. Moscovitch reported equal amounts of confabulated responses for both episodic (personal) and semantic (historical and factual) retrieval conditions and concluded that frontal damage does not differentially affect the two memory systems (cf. Baddeley & Wilson, 1988; Dalla Barba, Cipolotti, & Denes, 1990). The syndrome is interpreted as a failure of strategic retrieval, along with a failure of output monitoring. To keep with the general pattern, however, there was a stronger effect following right- rather than left-side damage.

Findings from confabulating patients reinforce the relation between those frontal processes characterized as executive and those of self-awareness or autonoetic consciousness. The reporting of complex material, mediated by either the episodic or semantic system, involves the coordination and execution of a number of subgoals, including the effortful retrieval of information, ability to sequence knowledge into a coherent story, and monitoring of output. Previous researchers have discovered a correlation between autobiographical memory retrieval and executive functioning in a number of populations, including patients with amnesia and those with focal frontal damage (della Sala, Laiacona, Spinnler, & Trivelli, 1992). If Moscovitch's (1995a) recall tasks are considered tests of the executive functions, it follows that both complex episodic and semantic retrieval would be impaired. As to the hemispheric asymmetry, the right prefrontal cortex may be a crucial area underlying the monitoring of complex goal-directed activity, including recollection of one's personal past. A co-existing possibility is that the act of monitoring one's own responses, especially difficult, unrehearsed responses, requires a form of self-awareness in the focusing of attention to one's own behavior. The impairment of output monitoring reported by Moscovitch may be related to the level of self-awareness proposed by Stuss and Benson (1986), even though some of the responses could not have been consciously recollected through the episodic system. PET data also associate episodic encoding with the left prefrontal cortex. Encoding into the episodic system is probably not driven solely by one hemisphere, but the consistency of relevant findings suggests an important relative contribution by this hemisphere.

The brain areas activated in the left prefrontal cortex may be a part of the neural substrate involved in the association of factual knowledge of one's environment with a personal, subjectively experienced milieu. From PET studies, we know that this same brain region is involved in working memory (Buckner & Tulving, 1995), with working memory defined as the processes by which information is transitorily accessed or activated, so it can be manipulated and integrated with other information. One possibility is that the left prefrontal cortex underlies the integration of ongoing perceptual experience with a self-referential perspective; that is, the consciously attended information is placed into a subjective context, which includes both external (environmental) and internal (mental) events that temporally coincide with the target event. This idea is consistent with Kihlstrom's (1987) suggestion that individuals are consciously aware only of the events whose mental representation is linked to the mental representation of self as the agent or experiencer. Taking the argument a step further, the link may be subserved by the left prefrontal cortex, whereas recollection of the event as experienced (Perner & Ruffman, 1995) is subserved by networks in which right prefrontal regions play a critical role.

In summary, the body of PET data consistent with HERA has grown to such a critical mass that hemispheric asymmetry in blood flow with respect to episodic encoding and retrieval can now be considered a reasonably secure fact. The behavioral data linking the frontal lobes to autonoetic awareness and episodic memory offer barely a hint of the hemispheric differences uncovered by PET. The best hope for a satisfactory explanation for HERA lies in future neuropsychological, technological, and theoretical advances.

Episodic Memory and Autonoetic Consciousness

In many ways, the relation between autonoetic consciousness and episodic memory can be thought of as much a matter of definition as a matter of empirical facts; we have defined episodic memory in terms of its dependence on autonoetic awareness. Given such an assumption, it is impossible for us to critically evaluate the relation between the two concepts simply by looking at measures that are thought to tap the episodic system. It is possible, however, to look at the development of episodic memory, especially as it parallels the development of a concept that is closely related to autonoetic consciousness: self-awareness. Through clever experimentation and analysis, self-awareness at different stages of development can be measured and associated with both the ability to remember facts and episodes and the types of conscious experiences that accompany memory retrieval.

What follows is a summary of research findings relevant to the relation of autonoetic awareness and episodic memory, as revealed by the progression of both self-awareness and memory in the developing human infant. We acknowledge at the outset that some of these issues are controversial, and many empirical findings have been subjected to different interpretations. What follows is our reading of the literature of the development of memory and self. Findings are broadly consistent with the idea that, as children become fully autonoetically conscious, they experience a qualitative shift in the ability to both represent and recollect information, with gradual progression toward the operation of the episodic memory system. Of course, cognitive development is a complex, dynamic process in which many intellectual functions are organized and fine tuned. Our discussion focuses on episodic memory, with the realization that this system of memory develops along with, and is perhaps related to, the emergence of other complex abilities, such as language and narrative skills, reasoning, and problem solving.

Development of Memory and Self-Awareness

Conclusions about self-awareness in the very young are often derived from observations of infants' behaviors when they are given the opportunity to recognize themselves in mirrors (see Lewis & Brooks-Gunn, 1979). Exposure to a mirror encourages healthy adults to focus attention on themselves, especially their thoughts, feelings, and attitudes (Carver & Scheier, 1978). Individuals can only show these same effects to the extent that they possess the capacity of autonoetic consciousness.

Although it is difficult to assess self-awareness in the first few months of life, there is some agreement that infants below about Age 4 months are probably unaware of their separateness from the environment (for a discussion, see Howe, Courage, & Peterson, 1994). By the fourth month, babies become attentive to mirrors and demonstrate mirror-directed behaviors, meaning that attention is directed to the mirror image. Babies can reach and crawl toward their image, yet there is no evidence that they can identify themselves as the object of reflection. At this stage, attention is controlled largely by the environment; although infants can show some evidence of a primitive representation of perceptually absent stimuli (Meltzoff, Kuhl, & Moore, 1991; Swain, Zelazo, & Clifton, 1993), use of the representation is stimulus driven. Such learning can be thought to reflect the operations of a procedural memory system (Schacter & Tulving, 1994). The infant's behavior is governed by reflexes, habituation, and simple learned associations, and learning is based on conditioning and stimulus–response strengthening (Fischer, 1980; Lewis, 1991).

A later phase of development comprises the acquisition of semantic memory or representational knowledge (Fischer, 1980). Because the procedural memory system is stimulus driven and requires environmental support, organisms can demonstrate procedural learning only when the appropriate stimulus cues and behavioral supports are present in the environment. When semantic memory emerges, the infant becomes capable of mentally representing and operating on the part of the world that exists beyond immediate perception. Semantic knowledge coexists with and does not replace the procedural memory system.

Piaget (1954) foreshadowed the concept of semantic memory with his discovery of object permanence in infants: At about Age 8 months, babies can think and make simple decisions about objects that are not available to their immediate sensory experiences (see also Baillargeon, 1986, 1987; and Diamond, 1985). Evidence for the operation of semantic memory at this age has come from other paradigms as well. In a line of research on deferred imitation, Meltzoff (1988a, 1988b) found that children as young as Age 9 months could repeat a series of actions that they had witnessed on a previous day. Retention could not have been mediated solely by a procedural memory system because the study episode did not allow the infants to have any kind of physical practice with the target objects. Learning, in this case, required the formation of cognitive representations of acts, followed by the appropriate retrieval and deployment of these representations. It looks as if successful deferred imitation involves mental representations of functional uses of objects ("What does one do with it?"), which are activated by the appropriate environmental cues. With the functioning of the semantic memory system, the child can think about things that are not physically present and begin to build a knowledge base. Such infants possess, at a minimum, noetic consciousness.

Young children at this stage (from about Age 8 to 18 months) do not yet possess a fully developed autonoetic consciousness, although their growing knowledge base allows them to acquire information about their bodies and physical capabilities. When an infant is exposed to a mirror, he or she shows knowledge that the mirror represents a reflection of objects placed in front of the mirror and realizes that his or her movements correspond to the movements of the reflection; the child can then use this correspondence during play (Howe et al., 1994). Children have some self-knowledge—they know that their bodies are discrete objects in the world, and then can begin to acquire propositional knowledge about their appearance. Most children younger than Age 18 months, however, cannot demonstrate self-directed behavior. That is, although they can attend to their reflected image, they cannot use the mirror as a tool to direct attention to themselves.

The identification of self-directed behavior has been formalized through a dye-identification task introduced by Gallup (1970). The power in the task is derived from its ability to discriminate between mirror- and self-directed behaviors. Without the participant's knowledge, an odorless dye is applied to a point on the face. When the participant is re-exposed to a mirror, self-directed behavior is demonstrated when he or she uses information from the reflected image to attend directly to his or her face, usually by touching the affected facial area. The behavior confirms that the participant has some mental representation of his or her appearance and can use information from the environment as a stimulus to direct attention away from the environment and to himself or herself directly. The self-directed behaviors, which appear at around Age 18 months, involve an awareness of one's physical appearance and the constancy of that appearance throughout time and space. All of these abilities are crucial for autonoetic consciousness. The type of self-awareness necessary for successful performance on the dye-identification task is not identical to autonoetic consciousness, but these abilities are necessary for its conditions.

Although children know propositional facts and can think about things that are not physically present (e.g., have semantic memory), it is difficult if not impossible to determine whether they can consciously recollect the past in a way that engages a developed episodic system. Much recent research has been directed at the issue of just what infants at the second year of life do know and can remember. The second and third years represent a crucial transition period for children, with respect to remembering and self-awareness.

Experiments have shown that children can demonstrate event recall as early as their 13th month. Babies ranging in age from 13 to 20 months at encoding later showed verbal and nonverbal recall of event sequences that they had witnessed at delays of up to 12 months (Bauer & Wewerka, 1995). Verbal recall was related to the ability to verbally describe the events at encoding and was also enhanced by variables, such as retrieval cues, repeated encoding opportunities, and active participation in the event sequences, as opposed to mere observation (Bauer, Hertsgaard, & Wewerka, 1995). Findings suggest that the capacity for event memory in 1- to 2-year-olds not only exists but also is, in at least some meaningful ways, similar to that of older children and adults (Bauer & Wewerka, 1995).

The findings above demonstrate that children younger than Age 18 months can recall information about specific events in their lives. In this sense, they can be said to possess event memory. The difficult question concerns the extent to which event–memory recall represents episodic remembering. Although a young child's verbal account of a particular event seems compelling evidence of such remembering, appearances may be deceiving. We do not believe that event memory necessarily implies episodic or autonoetic remembering because evidence suggests that, for a period of at least several months, young children are without the capacity of autonoetic consciousness that would allow them to recollect the past in that rich, personal way that accompanies episodic recollection.

Several pieces of evidence support our belief. When children retrieve information that was encoded before Age 18 months, responses are often, but not always, expressed nonverbally or limited to single words (Howe & Courage, 1993) and reports do not conform to a well-developed narrative style (Nelson, 1993). Rather, the infants' recall typically consists of words and short phrases that were identical or highly similar to those used at the time of study (Bauer & Wewerka, 1995). A case study highlights what is often remembered and often not remembered from episodes occurring during the second year (Howe et al., 1994). An 18-month-old had a fish bone lodged in her throat, a situation that required emergency medical attention. Seven months later, when the child had some language skills, she demonstrated memory for the traumatic event that was semantic (she correctly identified the photograph of the physician that removed the bone) and associative (she became upset when she saw a tongue depressor). She could not relate any details of the event verbally, although she did have language skills and many aspects of the event had clearly been retained. Howe et al. concluded that, at the time of the traumatic episode, the child could not integrate any events into her autobiographical or personal memory. From our closely related interpretation, because the child was noetically but not autonoetically aware of the incident, she could only retain propositional fragments of the original episode. That is, the event was represented within memory systems other than episodic.

We think it is unlikely that children below about Age 2 are autonoetically aware of their past, partly because our definition of autonoetic consciousness encompasses the ability to reflect on one's self in the past, present, and future. When babies do not engage in self-directed behavior in the dye-identification task, it represents one piece of evidence that babies do not attend to themselves until about Age 18 months. At about this same time, babies begin to demonstrate other self-conscious behaviors (shy smiling, gaze aversion, and self-touching) while gazing in a mirror and, a few months later, are able both to identify themselves by name and to use pronouns such as *I* and *me* (Howe et al., 1994; Miller, Potts, Fung, Hoogstra, & Mintz, 1990). These capabilities seem like reasonable requirements for the operation of a memory system that represents the self's experiences.

Another revealing anecdote suggests that children cannot consciously recollect their past experiences before about the third year, despite the ability to recall the experiences. In a case study, Nelson (1984) obtained tapes of a 2-year-old who regularly talked to herself before falling asleep. Because the content of her monologues often included significant personal events, it was possible to assess changes in her ability to both remember and report those events. Although from the outset (at 21 months), the child could recall material that was related to specific episodes, these were interpreted by Nelson as belonging to a general knowledge base, undifferentiated with respect to subjective time. We would interpret this as noetic awareness. The example converges nicely with the proposal that participants can often retrieve facts about personal experiences without consciously recollecting them through the episodic system. Also, the child's (still at Age 21 months) verb forms did not obviously refer to either a past or a present. Over the next few months, the style of the monologue changed. Around Age 23 months, the child began to use temporal markers for the past and was able to anticipate future activities on the basis of past experiences. Nelson described the changes as conveying a "greater intentionality with respect to reminiscing, anticipating, explaining, and planning" (p. 125), thereby foreshadowing many of the key concepts of this review. Similarly, Howe and Courage (1993) claimed that, between Ages 2 and 3, children begin to talk about their personal past much more elaboratively and with respect to place and time. Together, findings reinforce the relation between autonoetic awareness, or awareness of the self in subjective time, and episodic remembering, as well as a tentative link between episodic memory and some functions traditionally considered to be subserved by frontal lobes such as anticipation and planning.

The development of autonoetic consciousness and the episodic system, like that of many other brain–mind systems, continues to mature throughout childhood. There is no point in a child's life that can be identified with the beginning or the completion of such development. Indeed, there is no single, foolproof test that assesses the presence or absence of autonoetic consciousness. Therefore, although we could say that newborn infants have no episodic memory but it becomes fully functional by Ages 2, 3, or 4, it would be difficult to argue that no further development of episodic memory occurs after the given milepost. It is more reasonable to hypothesize that the development of episodic memory parallels the gradual growth of autonoetic consciousness and that both mature slowly over time.

Data in support of this idea come from experiments by Wimmer, Hogrefe, and Perner (1988). During a study phase, 3- and 4-year-olds were given information about items in a box, and the information came in one of two forms. Some items were placed in the box by the researcher as the children watched; for other items, each child was simply told what was in the box. Although all children showed excellent retention of the contents of the box, few 3-year-olds, but almost all of the 4-year-olds, could report the basis of their knowledge. The younger children were incapable of distinguishing between those objects that they had seen placed in the box and those that they had only been told about. Similarly, on a recognition test for sentences, Lindsay, Johnson, and Kwon (1991) found a substantial improvement between Ages 4 and 6 at recollecting which of two speakers had made the statement, despite only minor improvements in statement recognition. These examples represent studies of source amnesia. Like the patients with damage restricted to the frontal lobes, the younger children had knowledge of the propositional contents of the study episode but could not recollect one of the most salient aspects of the episode on which the knowledge was based. The inability to recall source information in these cases may represent a failure to mentally travel back to or consciously recollect the study episode, implying a selective failure of episodic memory.

Based on the mirror-identification studies and that children can talk elaboratively about their personal past by Age 2 or 3, it is likely that some important component of self has been realized by that time. There is a gap of 2 or 3 more years, however, before most children can demonstrate autonoetic awareness of a previous personal event on a source memory task. One possibility is that autonoetic consciousness has been achieved by around Age 3 but it represents only a necessary, but not a sufficient, condition for episodic encoding and retrieval and that other neurocognitive factors are involved in the regular operations of the adult episodic memory system. As a co-existing explanation, mirror studies may not tap into the most sophisticated level of self-awareness; therefore, the self-knowing necessary for episodic remembering is not reached until around Age 4 or later.

Childhood Amnesia

Issues raised in our discussion of the development of self and memory have implications for the well-known phenomenon of *childhood amnesia* (sometimes called "infantile amnesia"), defined as the inability of adults to remember experiences from their first few years of life. Most adults cannot recall events which occurred before their third birthday (Loftus, 1993; Rubin, 1982; Winograd & Killinger, 1983; cf. Usher & Neisser, 1993), although the number of remembered events increases dramatically for Ages 3–6. At face value, childhood amnesia is surprising because clearly many important things are learned before Age 3.

It is now clear that, whatever the cause for the paucity of early childhood memories, the phenomenon is poorly named. Young children are not amnesic. They can recognize and recall general knowledge about the world and particular knowledge about single episodes. Several theories have been proposed to account for the phenomenon (see Drumney & Newcombe, 1995; Howe & Courage, 1993; Neisser, 1962); many of them suggest that childhood memories do not transfer from infancy to early childhood because some cognitive or neurocognitive transformation makes previously encoded memory traces nonretrievable (Bower, 1981; Neisser, 1962). It is more difficult to endorse such a position now because there is no obvious period in the early lifespan across which the recognition and recall of events is lost. Indeed, children ranging from Ages 14 to 16 months have demonstrated successful deferred imitation for completely novel, witnessed acts at delays of 4 months (Meltzoff, 1995). Similarly, Bauer (1996) documented that children as young as Age 13 months could encode and subsequently recall aspects of novel events at delays as long as 1 year (see also Fivush, Gray, & Fromhoff, 1987). It is also not the case that the retention of general knowledge is lost between the first few years of later childhood and adulthood. Examples of such preserved knowledge include the identity and significance of words, concepts, and people and the relations and regularities of the world. Given that children are not amnesic and much information is retained throughout childhood and into adulthood, infantile amnesia can be seen as an issue of episodic remembering. The failure to recollect events from early life is a specific deficit of autonoetic memory, not of semantic knowing. Adults cannot mentally transport themselves back in time to recollect events from early childhood, and, we suggest, neither could they do so when they were children. Childhood amnesia does not implicate the semantic memory system, which develops before the episodic system.

Our approach is in basic agreement with a proposal by Howe and Courage (1993). They suggested that the offset of childhood amnesia occurs along with the emergence of children's self-concept and self-awareness near the end of Year 2. The newly discovered self is thought to provide an organizational structure into which events and experiences can be integrated to produce personally coded autobiographical memories. Because they define autobiographical memory as "memory for information and events pertaining to the self" (p. 306), it is reasonable to expect that an increasingly sophisticated realization of self could bolster such a capacity.

We take a similar position with respect to the importance of an emerging self-awareness or autonoetic consciousness. By our interpretation, however, the cognitive changes in childhood provide more than a schemalike organizational structure; rather they lead to a more advanced form of thought which comprises the ability to reflect on the self's experiences in the past, present, and future. Perner and Ruffman (1995) have advanced this type of approach to childhood amnesia and suggested that, before about Age 4, children are not capable of episodic encoding. Although children younger than this age can both attend to and encode events, they cannot encode the events as they were personally experienced.

The difference between encoding (and recalling) personally experienced events, on the one hand, and encoding (and remembering) events as experienced, on the other, is subtle; but along with Perner and Ruffman (1995), we see it as fundamental. It lies at the heart of the distinction between noetic and autonoetic awareness, hence episodic and semantic memory. A 2-year-old can be aware, for example, that "a dog is in the yard" and may be able to recognize the dog later as the one that was in the yard. The same child could not, however, encode an entire episode, such as "I am now watching (experiencing) a dog in the yard," in the personal way that the event was actually experienced. The former instance could later be recalled or recognized through the semantic memory system, but the latter could not. Semantic memory handles propositional facts and not personal experiences represented as such because these belong to the domain of episodic memory. To recollect or episodically remember a prior happening, the episode must have been originally encoded as a subjective experience and integrated into the personal perspective of the rememberer. Of course, this idea does not mean that adults must actually think to themselves that, for example, "I am now experiencing a word on a study list," to have an episodic recollection of the event later. Rather, the capacity to have subjective experiences is a common, yet integral part of the healthy adult human's conscious awareness. During episodic recollection, the rememberer does not simply retrieve a fact; instead, mnemonic recovery is of the original episode as it was experienced and of the aspects that have been retained. In agreement with Perner and Ruffman's (1995) theory and the findings about source amnesia then, our interpretation of childhood amnesia is that the phenomenon results from a lack of autonoetic awareness in early childhood. As this capacity becomes more sophisticated throughout the first several years, a child can become autonoetically aware of an increasing number of episodes. Adults are only amnesic of their early childhood in that they cannot mentally travel back in time to recollect happenings from the first few years of life as personally experienced events because in one sense the events were never personally experienced.

Frontal Lobes and Autonoetic Consciousness

So far in this review, we have portrayed autonoetic consciousness as a critical defining feature of the episodic memory system. The capacity to consider self in the past, present, and future, however, comprises more than memory. The possessor of autonoetic consciousness is capable of considering the past in relation to the future and making up action plans and ambitions for the anticipated future based on past experiences. At a more fundamental level, autonoetic consciousness allows for the mental representation of such subjective experiences, even those of which a rememberer is not consciously aware. Indeed, the adult's conscious state has been characterized as the result of the brain's ability to access, somehow simultaneously, information concerning the personal past, present, and future (Ingvar, 1985), and this access is not necessarily at a level of awareness. Again, the brain possesses a general level of consciousness; from within that level, specific events and perceptions can come into awareness.

This section includes a summary of clinical findings regarding patients with lesions largely restricted to the frontal lobes as they relate to issues of awareness of the personal present and future. Such issues are not easily addressed by neuropsychological experiments. We do not propose to survey the numerous other clinical findings relevant to frontal lobe pathology; comprehensive reviews can be found elsewhere (Fuster, 1989; Luria, 1969; Stuss & Benson, 1986).

Findings support the idea that frontal lobe damage leads to a disruption in the way that people think about themselves and that the disturbance manifests itself in a wide variety of situations. There is sufficient evidence from both experimental and clinical reports of patients with frontal damage to conclude that they demonstrate deficits in the recollection of the past and the introspection of the present, as well as foresight and anticipation of the future.

After reviewing a number of case studies, Luria (1969; Luria & Homskya, 1964) concluded that most patients with large prefrontal lesions had a disturbed critical attitude toward themselves and were unable or unwilling to identify and address their deficits adequately. The same patients could notice those identical deficits in someone else if they were led to believe that the mistakes were committed by another person (Luria, Pribram, & Homskaya, 1964). There was no obvious disruption of semantic memory, and patients could accept the knowledge of their deficits if informed by someone else. Missing was that sense of self-interest and the ability to respond with appropriate concern to the knowledge of their impairments. Other observations imply that affected patients had difficulty relating information to themselves. Ackerley and Benton (1947) noticed that their patients with frontal damage seemed unable to self-reflect and lacked the ability or desire to daydream or to engage in introspection. Some psychosurgery patients accepted the existence of their cognitive deficits yet did not appear concerned or resentful about their problems and often discussed their situation as if they were a casual observer (Robinson & Freeman, 1954).

We interpret these conditions as disruptions in the fully developed autonoetic consciousness, which manifest themselves as a lack of awareness of the personal present. Affected patients cannot reflect about themselves and, similarly, cannot reflect on the knowledge that pertains to themselves in a meaningful way. Such disruptions tend to be associated with frontal lobe damage.

There are several neurological syndromes that result in *anosognosia,* a loss of knowledge of the disorder. Significantly, the syndromes commonly follow brain damage in predominantly posterior regions. Lesions to the left parietal–temporal cortex can result in Wernicke's aphasia, a language disturbance in which affected patients lack comprehension and are impaired of the ability to speak in meaningful sentences, despite fluent speech production. There is often a lack of knowledge accompanying the disturbance, and patients are typically unaware of their impairment, even as they speak inappropriately (Hecaen & Albert, 1978; Heilman, 1991). Similarly, patients with circumscribed right posterior lesions often have perceptual–cognitive deficits (left hemianopia, prosopagnosia, or hemiattention), rendering them unable to attend to or identify objects in space. In prosopagnosia, for example, damage to the occipito–temporal cortex precludes patients from recognizing faces, even the familiar faces of relatives and friends (Damasio, 1985). Again, the syndrome is frequently accompanied by anosognosia.

The lack of awareness in these examples exists at the level of representational knowledge or semantic memory. Affected patients are unable to mentally represent the very existence of their syndromes. Although it is possible to think of anosognosia as a disturbance in the knowledge about the self as reflecting deficient self-awareness, note that patients with anosognosia do not know or are not aware of something about themselves that others do know. They lack the noetic awareness of the facts of the world (e.g., "This patient does not see things in the left visual field"), knowledge that can be shared by outside observers. There are two additional important points about these examples: (a) They accompany pathology that is localized posteriorly in the brain rather than frontally, and (b) the deficits are domain specific (Schacter, 1990; Stuss, 1991a)—the loss is restricted to a single area of semantic knowledge and does not extend to all types of knowledge that had been acquired before the brain lesion.

The comparison of patients with posterior deficits and those with frontal damage can be instructive. Because the knowledge base is intact, patients with frontal damage can often mentally represent and discuss the facts of their situation, at least at a shallow, impersonal level. Unlike patients with Wernicke's aphasia or prosopagnosia, they have knowledge of their behavior and of the output of their behavioral and mental processes. A patient with large, bilateral frontal lesions cannot, however, consider the information in the emotional, personal way that characterizes a typical expression of self-concern following physical or cognitive injury. After observing a number of patients following frontal lobotomies, Stengel (1952) remarked that the patients could recognize their shortcomings but seemed uninterested and unconcerned. In one 19th century case study, DeNobele (1835, as cited in Blumer & Benson, 1975) described a patient with, among other things, both mesial–orbital frontal damage and blindness, as a result of a gunshot wound. The patient understood his blindness yet was completely unconcerned about it. The general pattern, then, is that posterior and frontal lesions typically produce different types of deficits with respect to awareness. Posterior pathology can create a loss of simple awareness of the deficit, whereas frontal damage leads to a loss of the self-importance of the dysfunction.

Possible exceptions to this general pattern arise in Korsakoff's syndrome and, similarly, in patients having amnesia with additional frontal lobe pathology (McGlynn & Schacter, 1989; Schacter, 1990). Such patients typically have poor awareness of the existence of their memory deficits, and this lack of awareness has been related to the frontal dysfunction (Jarho, 1973; Vilkki, 1985) rather than the hippocampal–diencephalic damage commonly associated with the amnesic syndrome (Shimamura & Squire, 1986). Anosognosia, in these cases, might be interpreted as a lack of knowledge of the deficit rather than a lack of general personal concern. Although the patients may have an inability to represent knowledge of the impairment, it is not clear that the knowledge failure is domain specific. Patients with Korsakoff's syndrome also do not notice other physical disabilities (Zangwill, 1966), and these patients may suffer from a general inability to monitor their performance. A specific anosognosia related to remembering would imply that frontal damage differentially affects remembering more than other faculties (i.e., attention, planning, language), and this possibility is at odds with the generally accepted idea that the prefrontal cortex plays a similar, supervisory role over all posterior domains. For this reason, we are not inclined to interpret the anosognosia exhibited by Korsakoff's patients as a domain-specific failure of awareness, although the issue is not settled.

With these possible exceptions, frontal deficits leave noetic consciousness largely or completely untouched; patients know about things that have happened to them and are aware of their behavior and of the output of their mental processes. What is lacking is the personal significance of the knowledge and, often, the ability to use the knowledge. For an analogy, consider the performance of infants between Ages 8 and 18 months on the dye-identification task. Most realize that it is their physical image that is represented in the mirror because they know the relation between their body and the image. When infants see the red dye, however, they inspect the mirror image rather than their own face. It is not until about Age 18 months that an infant can apply information from the environment to his or her own situation; such an ability requires an organism to direct attention to himself or herself (i.e., become autonoetically aware). Similarly, adult patients with frontal pathology have knowledge about their impairments but do not direct that knowledge to themselves. In one important respect, symptoms resemble those of 8- to 18-month-olds; they do not have autonoetic consciousness and cannot self-reflect and evaluate themselves.

One case study emphasizes the striking dissociation between knowledge about one's physical self and the ability to attend to oneself directly and highlights another way that disturbances of autonoetic awareness affect behavior. Stuss (1991a, 1991b) described the behavior of a highly intelligent professional after the removal of a tumor in the right prefrontal cortex. (For sake of confidentiality, the personal details of the patient have been altered in different versions.) Neuropsychological testing revealed only minor difficulties, including left-side motor slowing, mild distractibility, and some perseveration of responses on a word-recall task. More noteworthy was that the patient's performance was excellent on many of those clinical tests that are assumed to measure the executive functions.

Although the patient could perform virtually any single task (whether it be work related or a neuropsychological test), the overall productivity in his daily life was quite low. When questioned, he blamed his difficulties on the work environment. The patient would neither attribute the poor performance to his own shortcomings nor accept any relation between the surgery and diminished productivity. Despite 18 months of rehabilitation and therapy, which directly focused on the enhancement of his awareness of his situation and betterment of his work habits, the patient showed little improvement, and he was recommended for partial disability. The patient did not accept that solution and insisted that he should return to work.

At this stage, the patient participated in a role-playing exercise, designed to force him to consider his situation from a different perspective. When playing the role of his supervisor and analyzing his own situation (as the employee), he was able to analyze the situation clearly. Recommendations when he perceived himself as an objective other were appropriate and included a disability pension and the cessation of full-time employment. When the patient considered this same information in relation to himself, however, he reverted to his previous state and refused to agree with the recommendations that he himself had made when playing the role of the supervisor. A similar case was reported by Schacter, Glisky, and McGlynn (1990).

This example represents a disruption of what one thinks of as the highest level of self-awareness; despite an impressive amount of knowledge, the patient could not use the knowledge to behave appropriately in the present or to make the appropriate plans for the future. That he was capable of imparting correct information to others implies that there was no general impairment of critical thinking or decision making. Neither was the patient obviously impaired at the executive or control processes. The deficit was specific and dramatic: The individual could not internalize his knowledge at a self-reflective or personal level. When discussing himself as an unbiased observer might, clearly he knew what should be done. Similarly, when confronted with a concrete task, either during clinical testing or at work, he knew how to complete the task. Neither of these types of knowledge, however, were manifested in this conduct. The whole picture is one of a dissociation between knowledge and the realization of personal relevance of that knowledge. Eslinger and Damasio (1985) have described a patient with a similar profile; following bilateral orbital and lower mesial frontal pathology, predominantly on the right, their patient seemed unable to use his knowledge about the world. Again, the patient could solve abstract problems and demonstrated a superior psychometric IQ and solid performance on tests of executive functions, but he acted in a manner described by the researchers as "goal-less" and seemingly without regard to the long-term consequences of his behavior.

The case studies above reflect not only a disturbed awareness of self in the present but also an inability to appropriately address the personal future. Indeed, one of the most often-noted characteristics of persons with frontal pathology is a disrupted ability to structure goal-directed behaviors to achieve short- and long-term objectives. Damage is thought to reduce one's concern for the future, especially plans and ambitions (Shakow, 1967). Based on a number of case reports, Ingvar (1985) attributed to the frontal lobes an inadequacy in ambition, foresight, and initiative. Fuster (1989) has convincingly argued that this area underlies the temporal integration of behavior. By this explanation, it is only with the participation of the frontal lobes that an organism can bridge temporal discontinuities; frontal operations are predicated on the anticipation of future events, with preparation for the future dependent on both past experiences and current goals.

The difficulties of patients with frontal pathology have not typically been cast in terms of consciousness or awareness. A more common approach has been to relate such deficits to executive or supervisory functions (i.e., planning, goal formation, etc.) because there is overwhelming evidence that such patients are impaired at tasks requiring these functions. Thus, although the prefrontal cortex is critically involved in the mechanical, regulatory functions, such as directing, structuring, and monitoring complex cognitive and behavioral repertoires, we agree with other researchers, such as Fuster (1989) and Ingvar (1985), that the situation can be conceptualized more broadly. This brain area plays a critical role in the ability to mentally represent and operate on information from the personal past and present to generate and execute action plans for the personal future. Intimately related is the ability to become aware of the self's experiences across time, but the awareness alone does not adequately define the importance of frontal lobes. The prefrontal cortex, through autonoetic consciousness, allows for the flexible use of the self's experiences to prepare for the short- and long-term future, even when such preparation is not accompanied by an awareness of the personal past or future.

General Discussion

The concept of episodic memory has changed since its introduction in 1972. What was at that time defined largely as memory for temporally dated events is now a distinct, neurocognitive memory system, whose uniqueness lies in the capacity to experience the world autonoetically. Reasons for the transformation of the concept of episodic memory are multiple and complex, but they have been motivated primarily by facts about memory and the brain that have become known over the intervening years.

The first major distinction between episodic and semantic memory is no longer best described in terms of the type of information they work with. The distinction is now made in terms of the nature of subjective experience that accompanies the operations of the systems at encoding and retrieval. The differences in subjective experience are supported by findings in experimental and clinical neuropsychology, developmental psychology, and neuroimaging studies of memory processes in healthy people.

We now believe that semantic memory can handle any propositional fact about the world, including facts that directly involve the rememberer, even if some of this system's operations are sluggish in the absence of support from episodic memory. Thus, it is possible for a learner to know that he or she personally witnessed an event, such as the appearance of a word in a studied list, without consciously recollecting the event. A rapidly increasing literature attests to the reality of such a dissociation—one that in 1972 seemed distinctly impossible (Gardiner, 1988; Gardiner & Java, 1993; Rajaram, 1993). The kind of knowledge that retrieval from semantic memory provides is that from the point of view of an observer of the world rather than that of a participant. Even when it concerns autobiographical facts, it is objective, impersonal, and tied to the present moment—it is carried by noetic consciousness. Episodic memory need not play any role in the actualization of this kind of knowledge and, for these purposes, need not exist.

Recollection of episodic information, by contrast, is not merely an objective account of what is, what has happened, or what one has seen, heard, and thought. It involves remembering by re-experiencing and mentally traveling back in time. Its essence lies in the subjective feeling that, in the present experience, one is re-experiencing something that has happened before in one's life. It is rooted in autonoetic awareness and in the belief that the self doing the experiencing now is the same self that did it originally.

Recall of an event—a brain–mind feat of which young children and nonverbal animals are quite capable—provides knowledge that can be used as any other kind of knowledge, such as semantic-memory knowledge or knowledge about the world and the things in it. Recollection of an event as experienced, however, goes beyond such semantic event memory. It too allows the rememberer to make use of past experiences, but in addition it makes possible awareness of facts and events that are personal, subjective, and fused with the self's past and that provide guidance to the self's future. This knowledge about subjectively experienced events is carried by autonoetic consciousness. Semantic knowledge is highly relevant to episodic memory but in itself is not capable of producing it.

The second major distinction between episodic and semantic memory, unknown in earlier times, has to do with the neural correlates underlying the two systems. Both neuroimaging and lesion studies have already yielded evidence that the prefrontal cortex plays an important role in episodic memory, above and beyond any role it has in semantic memory. The consistent findings of HERA have provided a foundation on which we can build further knowledge about the similarities and differences in the brain maps of episodic and other forms of memory. Because neuroimaging is still in its formative stages, there is every reason to believe that this kind of knowledge will grow and expand greatly in the future.

In the construction of a theory about episodic memory, these two concepts, the psychological construct of autonoetic consciousness and the neuroanatomical region demarcated as the prefrontal cortex, assume prominent roles. It is autonoetic consciousness, as mediated by the human frontal lobes, that makes episodic memory what it is.

A Preliminary Theory of Episodic Memory

In this section, we describe a preliminary theory of frontal involvement in episodic memory. The goal of this exercise is to explain the findings from various lines of research reviewed here, while we build on what is already known about both the functions of the frontal lobes and the episodic memory system.

A basic tenet of this theory is that episodic recollection, infused with the autonoetic awareness of one's existence in subjective time, is closely related to other mental capabilities and achievements that are essentially, uniquely human. In two important respects, episodic memory resembles those classes of behaviors, such as complex problem solving, that are often classified as supervisory or executive functions: It requires a higher level of control that can be adapted to situational demands, and it depends on widely distributed cortical and subcortical networks of which the prefrontal cortex is a central part. Autonoetic consciousness is a capacity. By this capacity, adults are empowered with the ability to mentally represent and become aware of their experiences in subjective time. Like other frontal phenomena, autonoetic consciousness itself is contentless; contents are represented in the posterior cortex and can be permeated by autonoetic awareness at ecphory. Episodic memory, then, can be thought to bear a closer family resemblance to some other higher order mental achievements and capabilities (the frontal functions) than it does to other forms of memory (i.e., procedural and semantic) that are shared by other species.

As a frontal capacity, autonoetic consciousness is similar to other brain–mind capabilities whose expression has been found to depend on the integrity of the frontal lobes. One such capability is the establishment, maintenance, and shifting of neurocognitive sets necessary for the accomplishment of complex mental tasks (Baddeley & Wilson, 1988; Moscovitch, 1992; Shallice, 1988). Most theories implicating frontal functioning accept the regulatory, monitoring activity of this brain area, including the inhibition of unnecessary or competing operations (Shimamura, 1995). The well-known tendency of patients with frontal lesions to perseverate on learned categories of the Wisconsin Card Sorting Task provides a salient example of these functions. In autonoetic consciousness, the prefrontal cortex regulates and directs the characteristics of the awareness experienced by an individual at any given time, in conjunction with stimulation from internal and external sources, much as the selection of actions and schemata depends on this brain area and the situational task demands (Pribram, 1973; Shallice, 1988).

Because our theory holds that the episodic memory system is closely linked to self in a way that other systems of memory are not, it follows that any organisms not possessing this most sophisticated form of self-awareness are not capable of having episodic recollections. They may know many things about the world, including the personal past, but they cannot consciously recollect the experiences on which their knowledge is based. Recent research in developmental psychology has produced some relevant evidence, but because of the enormous complexity of the human brain–mind, it will take a long time to definitely settle this issue, along with others that can be seen to emerge from this theory.

Our ideas depart from the writings of other researchers primarily in the attempt to integrate the facts already known under the umbrella of episodic memory and autonoetic consciousness. We suggest that the prefrontal cortex, in conjunction with its reciprocal connections with other cortical and subcortical structures, empowers healthy human adults with the capacity to consider the self's extended existence throughout time. The most complete expression of this capacity, autonoetic awareness, occurs whenever one consciously recollects or re-experiences a happening from a specific time in the past, attends directly to one's present or on-line experience, or contemplates one's existence and conduct at a time in the future. Autonoetic awareness of the subjective past constitutes episodic retrieval. It represents the major defining difference between episodic and semantic memory.

Our concentration on the frontal cortical regions does not mean, of course, that there are no other brain areas that play a role in memory. Massive evidence exists that implicates many other regions, notably the medial temporal (hippocampal) and diencephalic regions (Markowitsch, 1995; Markowitsch & Pritzel, 1985; Squire, 1987; Squire & Cohen, 1984). The exact role of these regions to episodic memory processes is not known, and we can only speculate about their relative contributions to episodic versus semantic memory and their association with autonoetic versus noetic consciousness.

Patients with medial temporal damage often have amnesia and are grossly impaired as they attempt to bring to mind recent life episodes or learn new semantic facts, although they commonly show healthy levels of implicit learning and memory. We share the belief that the integrity of the medial temporal lobes is crucial for the ability to become consciously aware (in our terminology, noetically aware) of recent events (Moscovitch, 1995b). Again, it is not yet known to what extent the activity of medial temporal and diencephalic structures is directly involved in autonoetic awareness.

Perhaps the most important new issue raised in this review is the link between the prefrontal cortex and autonoetic consciousness. This highest level of consciousness makes possible many of our most sophisticated thoughts and behaviors, with episodic memory representing only one example. In 1985, Tulving proposed that "autonoetic consciousness is a necessary correlate of episodic memory" (p. 5). By our theory, the statement is still correct, but the emphasis should be changed. It is autonoetic consciousness—perhaps the ultimate achievement of the human brain–mind—that is expressible in many forms of higher cognition, including episodic remembering.

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