

Where in the Brain Is the Awareness of One's Past?

7

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When a layperson ponders memory, what it is and what it does, that individual usually thinks that memory refers to the kind of mental capacity that makes possible learning or experiencing something now, then later remembering what it was that one learned or experienced. How it is accomplished usually does not concern the user of memory; it is a problem gladly left for the amusement of scientists. Indeed, for over a hundred years now, scientists in a variety of disciplines have tried to understand how memory works. Although they have made tremendous advances on many fronts, the main “discovery” to date has been that memory is extraordinarily complicated.

With the complications, however, have come some exciting prospects. One of these has to do with an aspect of memory that laypeople have always taken for granted and that scientists studying memory have managed to neglect—namely, the subjective element of the mental experience of remembering. To remember an event means to be consciously aware now of an experience that happened on an earlier occasion. It follows that remembering a past event as such is a conscious experience. For most of the long history of memory research, psychologists and others have assumed that the subjective and conscious recollective experience that accompanies memory performance was not amenable to scientific scrutiny. It was believed that there were no valid ways of directly getting at the subjective side of memory, at “remembering as conscious awareness.” Brain imaging techniques, such as PET (positron emission tomography), fMRI (func-

tional magnetic resonance imaging) and ERP (event-related potentials), have provided memory researchers with a new strategy to further the understanding of memory and awareness. With these recently developed techniques it has become possible to study the brain-mind correlates of remembering and to specifically examine the brain activity associated with different forms of memory and different types of subjective awareness that accompany recollection.

This chapter shares some of the excitement of memory research today with readers outside the field. The first part of the chapter stresses that there are many forms of memory, from habituation and simple classical conditioning to the loftiest thoughts that one can have based on what one has learned. Interestingly, most of these forms of memory, contrary to the public consensus, have nothing to do with the past. Instead, most forms of memory and learning studied in many areas of the life sciences have to do with the present and the future, not with the past. The single exception is episodic memory. It, and it alone, is very much concerned with the past.

The second part of the chapter describes episodic memory, which deals with a person's experienced past and makes possible "mental time travel" through subjective time. A special form of conscious awareness is required—otherwise we would not know whether we are just thinking about something or remembering. Evolution has seen fit to provide for that, too, with "autonoetic" awareness, which encompasses both the personal past and the personal future of an individual.

In the third portion of the chapter we present some material on subjective awareness and memory research using the techniques of brain imaging, research that is beginning to answer the question posed in the chapter's title: where in the brain is the awareness of one's past? Some of this research has been directed at distinguishing between the processes of encoding (getting information in) and retrieval (getting information out). A surprising finding is that the two hemispheres of the brain seem to be engaged in a kind of division of labor in which the left is doing more for encoding, whereas the right seems to be more interested in retrieval. Further exploration of this pattern, referred to as hemispheric encoding/retrieval asymmetry, or HERA, suggests that an important contribution of the right frontal lobe to

episodic memory retrieval is the establishment and maintenance of a particular neurocognitive state, referred to as the episodic retrieval mode. It is this retrieval mode, supported by the prefrontal (especially right) cortex and its connectivity with other brain regions (especially in the medial temporal lobes), that we suggest gives rise to the highly subjective, auto-noetic awareness of one's past. The hypothesis is supported by additional data, from both clinical cases of brain damage and studies of normal individuals' awareness of the past, that employ the technique of electrophysiological recording.

Our main theme is the subjective side of memory, the aspect that has to do with conscious awareness of not only space but time. This subjective side, specific to episodic memory and absent from all other forms of memory, has been difficult to pinpoint using the rules of science. New techniques of measuring and imaging the activity of the living brain have opened a window through which we are beginning to "see" the outlines of conscious awareness in memory in a way that was beyond the pale of science only a few years ago.

Memory and Time

Many organisms, including human beings, begin life with a host of biologically useful behavior patterns, or with the potential for postnatal maturation of such patterns that are released in appropriate situations. These instincts, effective ways of behaving in one's environment, have evolved over long periods and do not depend much on individual experience. For example, as shown by Eleanor Gibson many years ago; human infants, like the very young of other species, do not crawl off a "visual cliff" when given an opportunity to do so, but cling to the safe side of the divide, even during the very first test (Gibson, 1969).

Learning is another effective source of information that is useful for survival. It comes into play in situations that evolution does not know much about. Thus, the same young child, who knows without learning that mommies are to be approached and cliffs are to be avoided, must learn (through actual experience or vicariously) about the desirability of M&Ms and the danger of hot stoves. Despite the differences in origin, acquired knowledge can be as effective as innate knowledge in helping an organism to reach reproductive age and perhaps beyond.

All of the many different forms of memory, with a single exception, serve the same purpose as do the "instincts": they provide organisms with the means of behaving more effectively than would have been possible in the absence of the relevant acquired knowledge or skill. The experience at Time 1 allows the organism to respond more adaptively at Time 2, and this holds all the way from very simple forms of learning, such as habituation, to the most complex forms of acquired knowledge, such as the knowledge that all humans are mortal.

Another feature common to the vast majority of different forms of learning and memory is that none requires a conscious awareness of where or when or how the skill or knowledge used at the present moment was acquired. Remembering the particular occasion on which one learned about the mortality of living beings, or knowing how or why one knows something, is as irrelevant as the infant's lack of insight into the origin of her wisdom in refusing to crawl to mommy on the other side of what looks like empty space. Whether we think about a trout, a canary, our pet cat, or ourselves, survival clearly does not require conscious awareness of the past; it requires current skills and knowledge. This is why almost all evolved forms of learning and memory are oriented toward the present and the future, rather than the past. We designate these forms of memory collectively as "proscopic" (forward-looking) memory.¹

Episodic Memory

The singular exception to the ubiquity and evolutionary significance of proscopic memory that serves the future without bothering about the past is episodic memory. It does exactly what the other forms of memory do not and cannot do; it enables the individual to mentally travel back into the personal past. A child remembers what happened at a friend's birthday party the day before, a young lover remembers the expression on his beloved's face in the moonlight, the scientist remembers the first time when a speaker at a conference mentioned her work, and so on. They all are happy possessors of this latest arrival on the evolutionary scene, episodic memory.

Figure 7.1 represents episodic and all other forms of memory as differences between the temporal relations among memory episodes. The

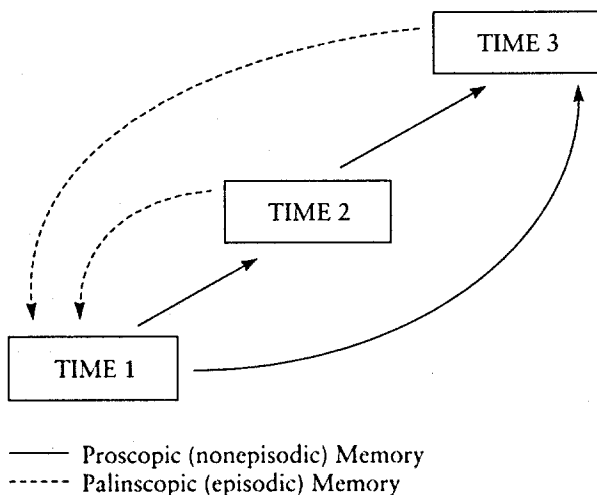


Figure 7.1 Schematic of time's arrows of proscopic (forward-looking) and palinscopic (backward-looking) memory.

time's arrow of nonepisodic memory is straight and points to the future. Episodic memory's time is not an arrow, but rather a loop from Time 2 to Time 1. The influence of Time 1 at Time 2 expresses itself in a mental return to the past: the individual has a conscious awareness of reexperiencing here and now something of the experience of the earlier time. Because it allows us to mentally visit and "see" the past, we can refer to episodic memory as "palinscopic" (backward-looking) memory.² Thus, episodic memory makes possible one of the impossible dreams of the science fiction writer—time travel (see also Suddendorf and Corballis, 1997).

As with all familiar objects, we take our episodic memory for granted and do not spend even a minute marveling at the astounding evolutionary feat it represents. Nor do we marvel at what is an even more astounding feat of evolution: the looping arrow of episodic memory can loop once more at remembered Time 1 forward to imagined Time 3, which will follow Time 2. Episodic experiences of our personal past become a foundation for expectations about our personal future, and we can speak of individuals remembering the future. The time's arrow of proscopic (nonepisodic) memory becomes the time's circle of palinscopic (episodic) memory.

All this may sound a bit uninhibited. Scientists are people who say, "Don't tell me; show me!" It is easy to make all sorts of claims about all sorts of things in the universe, from superstrings and black holes to repressed memories and consciousness; but unless we can back these claims with empirical evidence, they remain what John Horgan, in his 1996 book entitled *The End of Science*, calls ironic science: commentary on the world, rather than a description of the world. When we talk about subjective time and auto-noetic awareness, we do not mean to merely entertain the reader; we mean scientific business.

Our general approach is to relate concepts such as auto-noetic awareness to happenings in the brain. When one simply describes how one remembers a past event and how it differs from reciting a learned fact, it is easy to remain uncertain about what it all means. But when such introspections are linked with objectively observable physiological changes in the brain, the story becomes a bit more interesting scientifically. And that is what we plan to do: link subjectively felt conscious awareness of past events to the activity of the living brain.

Before we look at the brain, however, we will find it useful to contrast episodic memory with its closest relative in the other (proscopic) family of memories. This exercise will not only give a better concept of episodic memory, but also prepare for appropriate comparisons when we focus on the brain.

Semantic Memory

This closest relative is called semantic memory. The name is somewhat misleading, but for historical reasons we are stuck with it (Tulving, 1983). Semantic memory is the kind of memory that makes it possible for organisms to acquire, store, and use information about the world in which they live, in the broadest possible sense. So whenever you see "semantic memory," think "knowledge of the world." The important thing is to remember that "semantic" here does not imply language in any sense. All kinds of animals who have no linguistic ability have excellent semantic memory—they know a lot about the kind of world in which they live. There is no evidence, however, that any species other than humans has episodic memory of the kind we have described.

Episodic and semantic memory have a large number of features in common, which is why they can be classified together as declarative, or cognitive, or propositional forms of memory. Table 7.1 gives a list of some of these commonalities: they are both large and complex and can hold immense amounts of information; they can handle a great variety of different kinds of information—visual, auditory, verbal, pictorial, spatial, and so on; the information they contain is representational and can be expressed in propositional and symbolic form; these propositions can be assessed for their truth value; the information they hold is flexibly accessible through a variety of retrieval routes, queries, prompts, and cues; both memory systems interact closely with other brain and behavior systems such as language, emotion, affect, and reasoning; finally, information in both is accessible to conscious contemplation: we can consciously reflect on what we know about the world and everything in it as well as we can think about what happened yesterday or what we did in summer camp at age ten.

If one focuses exclusively on all these commonalities, it is easy to conclude that the two kinds of memory are essentially the same, differing only with respect to the kind of material or kind of information with which they deal: (personally experienced) events versus (generally shared) facts. However, there are differences; and we believe they are crucial.

Some of these major differences between episodic and semantic memory are summarized in Table 7.1: they serve different functions; episodic memory is concerned with remembering past experiences as such, whereas semantic memory is concerned with the acquisition and use of knowledge; they differ with respect to evolutionary history, with episodic memory arguably representing the latest development; episodic memory lags behind semantic memory in human development (Perner and Ruffman, 1995); the underlying neuroanatomy differs, with episodic memory relying more on the frontal lobes (Schacter, 1987; Squire, 1987; Wheeler, Stuss, and Tulving, 1997); the time orientation is different, in that episodic memory is the only form of memory oriented toward the past. Finally, the conscious awareness that accompanies retrieval is also different: episodic memory is accompanied by a special kind of (autonoetic) conscious awareness, whereas semantic knowing is accompanied by another kind of (noetic)

Table 7.1 Commonalities and differences of episodic and semantic memory

Commonalities	Differences
Large and complex	Memory functions (remembering/knowing)
Support all kinds of information	Evolutionary
Representational	Developmental
Propositional	Neuroanatomical correlates
Truth value	Time orientation (past/future)
Flexibly accessible	Conscious awareness (autonoetic/noetic)
Interact with other systems	
Accessible to conscious contemplation	

conscious awareness (Tulving, 1993). Some of these differences are better established than others, and we could discuss all of them at length. One that is of particular significance for present purposes is the distinction between noetic and autonoetic awareness.

Memory and Consciousness

Although the terms "consciousness" and "awareness" are frequently used interchangeably, we draw a sharp distinction between them. In this chapter as elsewhere (Tulving, 1993), consciousness refers to the general capability of the brain that makes it possible for the individual to become aware of its world, whereas awareness refers to a particular expression or manifestation of that capability. Within any one kind of consciousness can be many kinds of awareness. Consciousness does not require an object; it is not about anything. Awareness does require objects and always is of something. One can be "in" a given state of consciousness, and within that state be aware of different things, depending on the object of awareness.

Most evolved forms of learning and memory in the animal kingdom have little to do with consciousness. The same is true of many of the forms of learning and memory on which human survival and happiness depend. Consciousness enters the picture only at the stage of higher forms of human memory, generically referred to as declarative or cognitive memory (Squire, 1987; Squire, Knowlton, and Musen, 1993; Tulving, 1983), composed of the two subtypes described

above—semantic (knowledge of facts) and episodic (remembrance of events).

Awareness of one's past can occur through either of two forms of consciousness. The evolutionarily more recent and hence more sophisticated is auto-noetic consciousness, the standard experiential mode of retrieval operations in the episodic memory system. It allows one to mentally travel back and forth in subjectively experienced time, a feat of the brain/mind that is probably unique in the animal kingdom. When we remember a particular past event, regardless of how vividly or accurately, we rely primarily on our auto-noetic consciousness. When we are auto-noetically aware of a past situation or past event, we focus our attention directly on our own past experience.

The evolutionarily older and more primitive form of consciousness that can provide access to the past is noetic consciousness. Noetic awareness accompanies an individual's interaction with aspects of his or her environment in the present. It is the standard experiential mode of retrieval operations in the semantic memory system. An individual thinking about the facts of the world is consciously aware of the relation between those thoughts and aspects of the world that are not perceptually present at the time. The experiential flavor of the noetic awareness of publicly sharable facts differs from that of auto-noetic awareness of personally experienced past events.

A Patient with No Auto-noetic Awareness

The story of a brain-damaged individual concretely illustrates the separability of noetic and auto-noetic awareness. The case involves a man known as KC who has been extensively described elsewhere (Hayman, MacDonald, and Tulving, 1993; Tulving, Schacter, McLachlan, and Moscovitch, 1988). As a result of traumatic brain damage suffered in a motorcycle accident at age thirty, KC lost the ability to remember any personally experienced events, although in most other aspects his cognitive functions are reasonably intact and he remains indistinguishable from many other people who have suffered no brain damage. He knows much about the world and can even acquire new semantic information, although very slowly and laboriously. Thus, his noetic consciousness, his ability to become aware of aspects of the world not present to the senses, is entirely or largely intact. But he

cannot consciously recollect any single or even repeated event from his entire life, regardless of how memorable the event by ordinary standards and regardless of how heavily he is cued or prompted. Thus, his auto-noetic consciousness, his ability to become aware of past personal happenings, is totally dysfunctional.

Although they are rare, similar patients have been described by others (Calabrese et al., 1996; Hodges and McCarthy, 1993; Markowitsch et al., 1993). These patients do have mental access to their personal past, but the access is like that to any other aspect of the world with which they are familiar. Brain damage can produce individuals who are noetically aware of many autobiographical facts, but this kind of awareness is greatly impoverished in comparison with that afforded by auto-noetic consciousness.

Studies on the effect of frontal lobe lesions on behavior implicate this brain region as an important neuroanatomical correlate of episodic memory and, consequently, of its associated state of auto-noetic awareness (Wheeler et al., 1997). Functional neuroimaging studies have similarly revealed the contributions of the frontal lobes (among other regions) to episodic memory.

PET Studies of Episodic Memory

The relation between brain and mind has fascinated and frustrated scientists interested in memory for a long time. A popular way of posing the problem has been in terms of "localization of function," and a popular version of the question has been, Where are the memories in the brain?

Today we have many different kinds of memory, and multiple memory systems, and we think about them in terms of their constituent processes, such as encoding and retrieval. We also have substantial evidence suggesting that there are no specific memory centers in the brain, and probably not even specific storage sites. This is why we no longer ask, Where are the memories in the brain? Rather, we wonder about the neuroanatomical correlates of episodic encoding, or episodic memory retrieval.

We could ask this simple question: How similar and how different are the episodic encoding and retrieval circuits in the brain? A

positron emission tomography (PET) experiment conducted by Shitij Kapur and Roberto Cabeza (Cabeza et al., 1997; Kapur et al., 1996) together with other members of the Toronto group suggests that the answer is: Surprisingly different. The subjects were twelve young men and women, university students. During different PET scans they were engaged in two different tasks. In the encoding task, they studied pairs of words, such as penguin-tuxedo, in preparation for the subsequent test. In the retrieval task, they saw previously studied pairs, one pair at a time, and had to decide whether the pair had appeared in the study list. This is an episodic-memory retrieval (recognition) condition. During the sixty-second scanning window, all the test pairs in fact were "old."

The brain maps of activation yielded by the subtraction of the retrieval activations from the encoding activations showed regions that were preferentially more active during encoding than during retrieval. These regions included the left prefrontal cortex, left anterior cingulate cortex, and left parahippocampal gyrus. The brain maps of activation yielded by the subtraction of encoding activations from the retrieval activations showed brain regions that were more active during retrieval than during encoding. The right prefrontal cortex, right anterior cingulate, and right inferior parietal cortex were the regions showing significant activation during the retrieval task.

Two observations are worth noting. First, there are striking differences between the brain regions activated during the encoding task and those activated during the retrieval task. We can assume that some common regions as well are activated during both encoding and retrieval, although they do not show in these analyses because they are "subtracted out" in the process. Nevertheless, the differences are surprisingly extensive. The two sets of activations are heavily lateralized in the two hemispheres: encoding activations are all in the left hemisphere, and retrieval activations are all in the right hemisphere. This stark dichotomy is not always observed, of course, but it does illustrate a kind of functional hemispheric laterality that seems to be real.

The second point is that, as almost always happens in these studies, the condition we call episodic encoding is also a condition of semantic-memory retrieval. The subjects use their knowledge of words, their

meanings, and their relations when they impress the presented pairs of words on mind.

Hemispheric Encoding/Retrieval Asymmetry (HERA)

The data we have just described nicely complement the data yielded by many other PET studies, including the very first ones designed to investigate encoding and retrieval processes in episodic memory. These studies were done at the Hammersmith Hospital in London, England (Fletcher et al., 1995, 1996, 1997; Shallice et al., 1994); at Washington University in St. Louis (Buckner et al., 1995, 1996); and in Toronto (Kapur et al., 1994; Nyberg et al., 1996; Tulving et al., 1994b). Considered together, the data suggested a surprising empirical regularity: the left prefrontal cortex seemed to be differentially more involved than the right in retrieval of information from semantic memory, and in the simultaneous encoding information into episodic memory, whereas the right prefrontal cortex seemed to be differentially more involved than the left in episodic memory retrieval.

This pattern is referred to as HERA: hemispheric encoding/retrieval asymmetry in the frontal lobes (Tulving et al., 1994a). Although initially unexpected, and therefore greeted with some skepticism, the HERA pattern is now well established and indeed represents one of the most robust findings reported in the literature (Nyberg, Cabeza, and Tulving, 1996).

The overall HERA pattern can be economically described in terms of the interactions of three pairs of concepts: (a) encoding versus retrieval, (b) episodic versus semantic memory, and (c) left and right frontal lobes. This overall regularity is largely unaffected by specific conditions of the relevant experiments. Available evidence suggests that it holds equally for verbal and nonverbal materials. For instance, encoding of human faces has been shown to activate the left prefrontal cortex (Haxby et al., 1996) in the absence of comparable activation on the right, while recognition of previously studied faces has been shown to activate the right prefrontal cortex, in the absence of comparable activation on the left. Similar observations have been made with other nonverbal materials and line drawings of objects (for example, Owen, Milner, Petrides, and Evans, 1996). The encoding ac-

tivations on the left have been observed under conditions of both intentional and incidental learning (Rugg, Fletcher, Frith, Frackowiak, and Dolan, 1997); the retrieval activations on the right have been observed in both recall and recognition tasks (Cabeza et al., 1997).

Although the general left/right encoding/retrieval pattern is remarkably consistent, within this general regularity exists considerable variability in localization of function, depending on the specific conditions of the various studies. This variability invites more detailed examination of the data. Analyses have begun, and the results are promising: it is possible to identify specific prefrontal regions that are involved in encoding and retrieval of particular aspects of the information (Buckner, 1996).

Analysis of the PET data from even a single experiment can rapidly become very taxing and complicated; analyses of data from many experiments are exceedingly so. One way of coping is to focus on specific aspects of the data, without forgetting that they are always part of a much larger and more comprehensive picture.

Retrieval Mode and the Frontal Lobes

In pursuing the implications of HERA, we focused on the episodic retrieval activation in the right frontal lobe, and asked the question, What does this right-frontal activation signify? Retrieval, like encoding, is not a single unitary process; it comprises many separate processes. When subjects are shown a group of words in an episodic recognition task and asked whether they have seen them previously in the experiment, several things happen: subjects go into what we call the episodic retrieval mode, trying to fit the present input into their mentally recovered past (Was this one of the words I saw while they were showing me all those words on the screen as I was lying here ten minutes ago?). They succeed incorrectly in recognizing many test items; they feel good about what they realize are successful "hits"; and they may also feel frustrated because of occasional felt uncertainties about their overall performance. All of this happens when subjects take a recognition test, and the right-frontal activation may signify any one thing or a combination of several.

We wondered initially, What will happen if we ask subjects to take a recognition test of previously studied words, but do not let them succeed in such recognition. We tested them, during the scanning win-

dow, with words that were all "new," that is, words they had not seen in the studied list. If the right frontal lobe "lit up," it signified the retrieval mode, the attempt to remember past happenings, and it meant that actual success or failure ("contacting the memory traces") did not matter. If the right frontal lobe did not light up in this situation, that meant that it had done so in previous studies because the subjects always succeeded in recognizing a substantial portion of test words.

We conducted two such studies and got identical results (Kapur et al., 1995; Nyberg et al., 1995). Right frontal activation was observed in a situation where subjects were tested with genuine "old" test words, and succeeded. With both retrieval attempt and retrieval success we achieve a nice confirmation of the HERA pattern: retrieval activation on the right, nothing showing on the left.

Our next question was, What happens when we test the subjects with new words, which they attempt to retrieve but fail by design? The pattern of brain activation was exactly the same: prominent activation on the right, nothing on the left. In the two conditions being directly compared here (one subtracted from the other), none of the words the subjects saw had been seen before in the experiment. But in this condition subjects were in retrieval mode; in the other condition they were not, they merely read the presented words. Thus, it seemed that right frontal activation was associated with the subject's being in episodic retrieval mode, rather than any success in the retrieval attempt.

A third comparison confirmed this picture: the subtraction of unsuccessful from successful retrieval. Subjects were in the retrieval mode in both conditions being compared, and the right-frontal retrieval-mode activation was subtracted out.³

Although it is far too early to begin formulating coherent stories of episodic memory in the brain, the available data do permit some speculations. One possible scenario is the following. The right frontal cortical regions, in concert with other parts of the retrieval network, are involved in the establishment and active maintenance of a specific neurocognitive state, or set, that is necessary but not sufficient for successful episodic retrieval. Probably many other such neurocognitive sets are actively maintained and in operation in the brain all the time. They determine the kind of processing that is performed on incoming and on-line information and presumably inhibit the many other kinds

of processing that the brain is capable of performing on the same stimuli. The point is that the establishment, maintenance, and switching of these frontal sets require massive and presumably highly complex neuronal activity of a kind possible only for highly developed brains, such as those of humans and possibly other higher primates. This is where the story of episodic memory as a very recent evolutionary adaptation comes in.

One can imagine that, like other cognitive sets that psychologists have been studying since the days of the Würzburg School, episodic retrieval sets too represent a clever trick of nature that enables the brain to do a great deal of task-relevant processing of a stimulus before the stimulus occurs. In the case of episodic retrieval sets, it is possible to imagine that the processing done before successful ephory occurs is that involved in suffusing the act of retrieval with the feeling of "warmth and intimacy" that William James ascribed to the recollection of personally experienced events. In more contemporary terms, we could say that the right frontal lobe plays a critical role in the creation of auto-noetic awareness of the past, the kind of awareness that distinguishes episodic memory retrieval from semantic memory retrieval.

We are obviously treading on rather thin ice here; much more work is needed before we can tell how useful these kinds of speculations are. Indeed, before we can begin seriously wondering about the neuroanatomical correlates of auto-noetic awareness—the awareness of self in one's subjective past—we should try to obtain evidence that auto-noetic awareness can be distinguished from other kinds of awareness at the level of brain activity.

This is not an easy task. The major complication lies in the fact that conscious awareness is inextricably tied to preconscious and nonconscious processes that are always present in all cognitive activity. The difficulty caused by the tight coupling of conscious and nonconscious cognitive processes is well known to students of consciousness. The solution is logically simple: if we wish to capture something of the neural correlates of conscious awareness, we must be able, somehow, to pry apart the conscious and nonconscious processes in cognition.

Conscious Awareness and Electrophysiological Activity

We have recently completed an event-related potentials (ERP) study in which we took the first step toward such dissociation of different

kinds of conscious states and correlating them with the electrophysiological activity of the brain (Düzel, Yonelinas, Heinze, Mangun, and Tulving, 1997). We adopted an experimental design that allowed us to do two things. First, we separated auto-noetic awareness of past events from noetic awareness, and separated each of them from the absence of any awareness of past events. Second, we separated the electrophysiological signatures of the two different states of conscious awareness from the electrophysiological signatures of those brain processes that were present but did not contribute to these states. In designing the experiment, we made use of two paradigms that have been explored in cognitive psychology. One is the so-called R/K (remember/know) paradigm that has been used in studies of episodic recognition (Gardiner and Java, 1993). It is quite simple: When the subject claims to recognize a test item as "old," she is asked to reflect on the nature of her awareness of the past. Does she auto-noetically remember the event of the target item's occurrence in the study list, or does she noetically know the fact that the target item was part of the list, without any auto-noetic recollection of the event?

The other paradigm—which we refer to as the DRM paradigm, after the initials of its developers—was initially constructed by Deese (1959) and further developed by Roediger and McDermott (1995). This paradigm, in which close semantic associates of studied words are used as "lures" in the yes/no recognition test, produces very high rates of false alarms.

In brief, we adapted this paradigm to produce a large number of true and false targets for recognition tests in which subjects made "remember" (auto-noetic awareness) and "know" (noetic awareness) judgments about all test items they called old. Subjects claimed both auto-noetic and noetic awareness for both true and false targets. Thus we had four kinds of outcomes of the recognition test, and we examined the ERP waveforms associated with each. We assumed that the components of the ERP waveform that were identical for true and false targets reflected common features of retrieval, namely the subjects' judged state of conscious awareness. We also assumed that the components of the waveform that differed for the true and false targets reflected processing differences of which the subjects were unaware. Those would be processes involved in the creation of the "en-

grams" that would be used in retrieval, and would necessarily be different for true and false engrams.

The study yielded two important findings. First, many components of the ERP waveforms were quite different for R and K judgments, that is, for auto-noetic and noetic states of awareness of past events. Second, in the 600- to 1,000-millisecond recording window, the R and K judgments were essentially identical for true and false targets.

The scalp distribution associated with "remember" responses showed a widespread positivity, involving the anterior regions bilaterally and the left posterior regions more than the right posterior regions. In contrast, "know" responses were associated with a widespread negativity. The results are unambiguous: the brain's electrophysiological activity that is associated with auto-noetic awareness of past events is rather strikingly different from the electrophysiological activity that is associated with noetic awareness.

Conclusion

We began this chapter by pointing to a fundamental distinction between different forms of memory in terms of how their operations are oriented in time. Contrary to traditional thinking, most forms of memory are future oriented. Conscious awareness of specific past happenings is irrelevant in these forms of memory. The single exception to the general picture is episodic memory. It is in many ways similar to semantic memory, but goes beyond it in that it is oriented to the past. It allows organisms that possess it to travel auto-noetically through subjective time: from the present to the past, and through the past to the future. It is reasonable to assume that episodic memory is a recent evolutionary adaptation, possibly unique in humans. As such, it is subserved by special neural mechanisms. Indeed, early PET studies have pointed to specific neuro-anatomical regions involved in episodic encoding and retrieval. An especially striking finding is hemispheric encoding/retrieval asymmetry (HERA) in the prefrontal cortex, possibly extending posteriorly: the left frontal lobes are differentially involved in semantic-memory retrieval and episodic-memory encoding, whereas the right frontal lobes are differentially involved in episodic-memory retrieval.

In the last part of the chapter we described data from an event-related potentials study that provided electrophysiological evidence for the distinction between auto-noetic and auto-noetic awareness as two modes of mental access to the past. Auto-noetic awareness is identified with episodic memory and seems to depend critically on the frontal lobes. Noetic awareness, the evolutionary predecessor of auto-noetic awareness, accompanies retrieval of information from semantic memory. Episodic retrieval mode is a neurocognitive set, maintained in the form of massively coherent neuronal activity in regions of the brain including the right prefrontal cortex. Auto-noetic awareness of one's past, and one's future, is an emergent feature of such activity.

A general lesson to be drawn from this chapter is that episodic memory and auto-noetic consciousness are true marvels of nature whose uniqueness has been frequently underestimated. With the advent of modern techniques for measuring and imaging the workings of the living brain, the prospects for a fuller appreciation of these wonders are much brighter.

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Notes

1. We are grateful to Professor Jaan Puhvel for adapting this term for us from the classical Greek.
2. Again, our thanks to Professor Puhvel for adapting this term.
3. There are, of course, other activations in post-Rolandic cortical regions that do reflect the differences between successful and unsuccessful retrieval, reflecting other retrieval processes and perhaps including sites at which previously stored traces are activated. But that is another story, and much more work is needed before we can have much confidence in what the data seem to be telling us.

Memory, Brain, and Belief

Edited by

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Harvard University Press

Cambridge, Massachusetts

London, England / 2000

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Printed in the United States of America

Library of Congress Cataloging-in-Publication Data

Memory, brain, and belief / edited by Daniel L. Schacter and Elaine Scarry.

p. cm.

Includes bibliographical references and index.

ISBN 0-674-00061-7 (alk. paper)

1. Memory Congresses. 2. Belief and doubt Congresses.
3. Cognitive neuroscience Congresses. I. Schacter, Daniel L.
[DNLM: 1. Memory Disorders—physiopathology Congresses. 2. Brain
Congresses. 3. Delusions Congresses. 4. Knowledge Congresses.
5. Memory—physiology Congresses. 6. Self Concept Congresses. WM
173.7 M53253 2000]

QP406.M44 . 2000

612.8'2—dc21

DNLM/DLC

for Library of Congress 99-40552