Remembering and Knowing the Past

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In popular thought, a powerful association exists between memory and information storage: memory is a means of storing information. To have memory, in this view, means to be able to produce or receive information and then to keep it in the system over long periods of time. Thus trees with their rings, card files, and phonograph records can be said to have memory, along with brains and computers.

In earlier times, science shared this idea about memory as storage, and in some quarters it still does. The physiological study of memory was concerned with the identification of brain regions in which information was stored and with the discovery of neural correlates of changes in storage. The psychological study was geared toward determining the nature of the information in the memory store, as well as the factors that contributed to the decay and loss of information from it.

These early ideas overlooked the simple fact that storage is only one of the two major component processes of memory. The other one is retrieval—that is, the recovery or utilization of stored information. A complete memory system must be capable of both storing and subsequently using information. In this more enlightened view, there exists a huge gap between mere storage devices, such as tree rings, card files, and phonograph records, on the one hand, and true memory systems, such as those possessed by computers and living things, on the other. It has been only in the last twenty years or so that students of human memory have begun to pay systematic attention to the other side of the memory coin, the retrieval processes.

In this article, I will discuss two kinds of retrieval processes in human memory. I refer to one kind as the retrieval of episodic information, or simply episodic retrieval, and to the other as the retrieval of semantic information, or simply semantic retrieval. I also use the terms remembering and recollecting for episodic retrieval, and the terms knowing and recalling for semantic retrieval.

On casual reflection, the remembering of personal episodes and the knowing of impersonal facts seem to constitute rather similar processes. Moreover, they differ from other forms of utilization of stored information in humans and from all forms of retrieval in computers. Both depend on information previously stored, both have to do with access to such information, in both cases the access occurs to some specific information, in both cases such specificity of access is governed by present cues or prompts, and in both cases the retriever of the information can "hold in mind," or contemplate, the products of the retrieval process, without having to engage in any form of overt behavior.

Remembering one's past is a different and perhaps more advanced achievement of the brain than simply knowing about it

The total process of remembering, too, is similar to that of recalling facts. In one case, we witness an event, and we remember or recollect it by bringing it into awareness again at a later time. When we do so, we recover a bit of our past. In the other case, we read an article, and we recall its contents at a later time. When we do so, we again recover something that happened in the past.

Finally, even our language tends to treat the two forms of recovery of information stored in memory rather indiscriminately. Thus, when someone says that she knows very well what she said to her friend the night before, we have no difficulty interpreting it to mean that she remembers a particular happening. And when she says that she remembers well the main points of the article she read recently, we automatically interpret it to mean that she now knows something about a certain topic that she did not know before.

Impressions of these many parallels between remembering and knowing, and their embodiment in and expression through everyday language, have exercised a strong hold on the minds of students of memory. For a long time the prevalent view was that memory is essentially unitary and that different forms of retrieval represent one and the same set of underlying processes, differing only in the kind of factual information retrieved: episodic remembering is the retrieval of personal, temporally dated, and self-relevant facts, whereas semantic knowing is the retrieval of impersonal, undated, and world-relevant facts.

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The purpose of the present article is to question the traditional view that remembering the past and knowing things learned in the past represent similar cognitive processes. I would suggest that remembering and knowing, as these terms are used here, are more appropriately conceptualized as operations of two hypothetical memory systems, episodic and semantic memory, and that in that sense they are not only similar, as all memory systems must be, but also basically different *(1)*. I will present two kinds of evidence in support of the argument. One kind consists in observations of a remarkable amnesic patient who cannot remember anything but knows many things; the other is provided by differences in regional cerebral blood-flow patterns in the brains of healthy volunteer subjects while they are retrieving episodic or semantic information.

The episodic system stores and makes possible subsequent recovery of information about personal experiences from the past. It enables people to travel back in time, as it were, into their personal past, and to become consciously aware of having witnessed or participated in events and happenings at earlier times. Thus, when you think about what you were doing before you started reading this article, you are engaged in episodic retrieval. The semantic system enables people to acquire factual knowledge and information in the broadest sense and to retrieve this information when it is needed in the course of ongoing activities. Retrieval of semantic information entails knowledge of the world acquired directly or indirectly on previous occasions, regardless of whether the retriever remembers when, where, or how such acquisition took place. When you think about something you know about—say the mining of gold or the circulatory system of the human body—you are engaged in semantic retrieval.

K.C.'s case is remarkable in that he cannot remember, in the sense of bringing back to conscious awareness, a single thing that he has ever done or experienced in the past

The relation between the two systems is a special one. The episodic system depends on but goes beyond the capabilities of the semantic system. It could not operate in the absence of the semantic system, but it can accomplish feats that the semantic system alone cannot. The semantic system, on the other hand, is capable of operating in the absence, or independently, of the episodic system, although its operations are facilitated by the episodic system. This hypothetical relation between episodic and semantic memory means that it is possible for an individual to know facts without remembering learning them, but not possible to remember without knowing what it is that is being remembered. In people with intact brains, such dissociations between remembering and knowing occur occasionally, embracing isolated experiences and bits of learned knowledge. The theoretical implications of such occurrences are uninteresting, because it would be possible to account for them by simply assuming that different aspects of what has once been experienced or learned are forgotten at different rates. In people with brain damage, however, the dissociation between remembering and knowing can become global, and its implications are correspondingly more interesting.

We are now ready to consider the evidence, beginning with a case study of amnesia.

The remarkable case of K.C.

On 30 October 1980, a 30-year-old man, whom we shall call K.C., had an accident that changed his life. Driving his motorcycle home from work in a town near Toronto, he went off a curve in the road at high speed. When help arrived, he was alive but unconscious, and he remained so for three days in the hospital. He had suffered a severe closed head injury. Now, nearly nine years later, with extensive brain lesions in the left frontal-parietal and right parietal-occipital regions and possibly in other parts of the brain, he is densely amnesic *(2)*.

K.C.'s case is remarkable in that he cannot remember, in the sense of bringing back to conscious awareness, a single thing that he has ever done or experienced in the past. He cannot remember himself experiencing situations and participating in life's events. This total absence of personal recollections makes K.C.'s case unique: no other reports exist of amnesic patients who have been incapable of recollecting *any* personal happenings.

Like many other "pure" amnesics whose memory disorder has resulted from brain damage, K.C. is by no means mentally retarded (Fig. 1). A stranger can carry on a conversation with him for a considerable time without noticing anything special about his mind. Those aspects of K.C.'s intellectual functioning that do not depend on remembering personal experiences are reasonably normal. His measured IQ is in the normal range, he has no problems with perceiving things or with paying attention, he recognizes familiar objects and people shown in photographs, his understanding and use of language are unimpaired, he can read and write, and his thought processes are intact. Even his short-term memory capabilities are preserved. He can repeat seven or eight digits in the order in which they were presented, and he remains aware of what he has been doing for a minute or two after the cessation of the activity.

Although K.C. does not *remember* any personally experienced events from either before or after his accident, he does *know* many things about the world. His knowledge of history, geography, politics, music, and many other fields of human endeavor is not quite as intact as it might have been without his brain damage, but his storehouse of relevant information is huge, making it possible for him to answer many questions requiring general knowledge. Part of his preserved knowledge is autobiographical: he knows things about himself and his past. But this kind of autobiographical knowledge is impersonal knowledge, to be distinguished from autobiographical memory. It is knowledge of one's life from the point of view of an observer rather than that of a

Figure 1. Research involving both normal and abnormal brain activity is modifying the traditional view of memory as simply storage of information. The amnesic patient K.C. has retained his knowledge of how to play chess, although he cannot remember having played chess ever before, with anyone. The dissociation between the normal retention of knowledge and the severely impaired ability to recollect personal events suggests a distinction between two kinds of memory, semantic (involving impersonal facts) and episodic (involving personal experience).

participant, like the knowledge one possesses about one's friends and family members.

It is particularly instructive to consider K.C.'s memory for personal events and impersonal facts that had originally been tightly linked in time and space. His memory is totally impaired for events, but is preserved to some extent for facts: he cannot remember the past, but he knows and can recall things he has learned in the past. The contrast between the loss of all episodic information and the preservation of some semantic information appears time after time.

Here are a few examples. K.C. knows that his family owns a summer cottage, knows where it is located, and can point out the location on a map of Ontario, and he knows that he has spent summers and weekends there. But he does not remember a single occasion when he was at the cottage or a single event that happened there. He has retained his knowledge of how to play chess, but he cannot remember having played chess ever before, with anyone. He can only guess that he played with his father, because he knows that his father plays chess. He knows that he owned a car and can recall its year and make. But he cannot remember a single trip he took in the car. He knows, and can describe in great detail, the exact sequence of steps to be taken—the "script"—when changing a flat tire on a car. But he cannot tell whether he himself ever had to change, or witnessed the changing of, a flat tire, since he does not recollect any such occasion from his life. For the three years immediately preceding his accident, K.C. worked for an engineering company. He knows that he did so, and he can recall the name of the company and the nature of its business. But he does not remember working there: he cannot provide a description of his workplace, and he does not recognize a color photograph of the office on the factory floor that he occupied for three years. Finally, he knows the meaning of technical terms such as "spiral mandrel" and "extruder screw," terms that he learned in the course of his work. But he does not remember a single event, or even any repeated events, that happened during that time.

These kinds of contrasts between what K.C. does not remember *of* his past and what he knows *from* it support the idea that episodic memory and semantic memory are subserved by different neural mechanisms. The kind of brain damage that K.C. suffered in his motorcycle accident seems to have resulted in serious impairment in the functioning of the episodic memory system and a lesser impairment in the semantic system.

If K.C. had only anterograde amnesia—that is, if he were unable to remember happenings only from the period following his accident—we would not know whether his memory deficit reflects failure of storage or failure of retrieval (*3*). But as his retrograde amnesia seems to be equally deep—that is, his inability to remember happenings from his life preceding the accident—we know that K.C. exhibits a massive failure to retrieve information that he must once have encoded, stored, and retrieved normally. This striking deficit in the ability to retrieve any part of a very large category of previously accessible personal experiences, coupled with relatively better preservation of the ability to retrieve equally large amounts of impersonal knowledge, suggests that K.C.'s episodic memory system has ceased functioning, whereas his semantic memory system, as well as other memory systems, has suffered less damage.

Permanent present in subjective time

Since K.C.'s thought processes are reasonably intact, he is capable of compensating for the lost ability to recollect his personal past by making appropriate inferences from what he knows at present. For instance, although he does not remember anything about the tragic event of his older brother's death through drowning over ten years ago, he does know that his brother is dead. Therefore, when asked, "What was the saddest moment in your life, ever?" he answers, "When my brother Roger died." If taken at face value, the answer leaves the impression that he remembers his brother's death. Further detailed examination, however, confirms that he does not.

As we have seen, critical features of episodic information have to do with the self in time. The concept of a personal past ties together these two entities. K.C. has no particular difficulty apprehending and discussing either himself or physical time. He knows what facts about himself could be said to be true and what facts could not; he also knows what most other people know about physical time, its units, its structure, and its measurement by clocks and calendars. It is his apprehension of subjectively experienced time that seems to be grossly impaired.

The impairment not only encompasses the past, it also extends to the future. Thus, when asked, K.C. cannot tell a questioner what he is going to do later on

that day, or the day after, or at any time in the rest of his life. He cannot conjure up images about his future in his mind's eye any more than he can do so about his past. Without the ability to remember what he has done or to contemplate what the future might bring, K.C. is destined to spend the remainder of his life in a permanent present.

Varieties of memory

Cognitive neuropsychologists have learned a good deal about memory by observing amnesic patients. The patterns of selective impairments in memory functions that characterize amnesia illuminate the highly complex nature of human memory in a manner difficult to duplicate by other means. Although individual case studies can never provide decisive evidence, the extent and depth of analysis of a single patient's impaired and preserved functions, and intrasubject replicability of observations, can at least partly compensate for the lack of intersubject replicability.

Although K.C. is in some respects unique, the overall pattern of his cognitive functioning is in good agreement with many other studies that have revealed amnesic patients' greater impairment in episodic than semantic memory. It is almost always the case that their ability to remember recent events is severely impaired, whereas their ability to pick up, retain, and express new semantic knowledge is less so. Even the world's best-known and most thoroughly studied amnesic patient, H.M., has learned some rudimentary, impersonal facts since the operation that rendered him amnesic in 1954, although he does not remember any single experience after that event *(4)*.

The story of K.C. tells us that although remembering is a form of knowing, retrieval of information stored in memory on earlier occasions is not the same as, nor does it involve, remembering those occasions. Retrieval of both episodic and semantic information depends critically on the availability of information put away at an earlier time in a person's life, but the ability to retrieve one kind can be totally lost as a function of brain damage while the ability to retrieve the other kind is at least partially retained. Thus it seems that the remembering of one's personal past requires intact brain mechanisms that are not necessary for the retrieval of factual knowledge about things in the world. It is in this sense that remembering and knowing may be thought to be basically different.

Cortical maps of memory

The central problem that faces the student of memory is of course to understand the *normal* functioning of learning and memory systems. Although the study of amnesic patients provides us with valuable clues about memory systems of the brain, we must exercise caution in interpreting the data. There is no guarantee that a damaged brain acts like a whole brain in carrying out its activities. If a lesion produces a dissociation between two tasks, one possible conclusion is that the two tasks are subserved by different brain mechanisms, only one of which has become dysfunctional as a result of the lesion. But other interpretations are also possible. For instance, it could be assumed that the two functions are normally subserved by the same system. When that system is damaged, an alternate mechanism enables the brain to carry out one function, even if at a lower level of efficiency, but not the other. In brief, data of the sort we see in the case of K.C. do not rule out the possibility that in the normal brain a single system subserves all memory functions and that under abnormal conditions alternate mechanisms "switch on," albeit more successfully for some functions than others *(5)*.

Studies of normal brain activity associated with different cognitive functions are clearly needed to complement studies of patients with brain lesions. One technique that has been used to this end consists in the measurement of regional cerebral blood flow. A small dose of a radio-

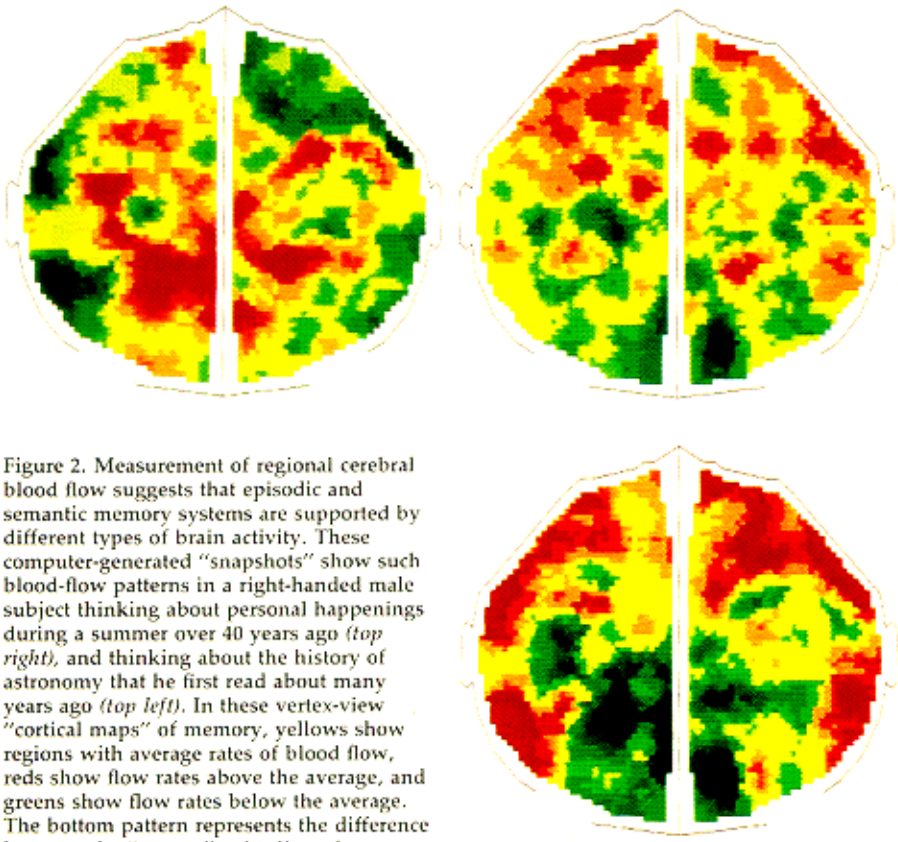

Figure 2. Measurement of regional cerebral blood flow suggests that episodic and semantic memory systems are supported by different types of brain activity. These computer-generated "snapshots" show such blood-flow patterns in a right-handed male subject thinking about personal happenings during a summer over 40 years ago *(top right)*, and thinking about the history of astronomy that he first read about many years ago *(top left)*. In these vertex-view "cortical maps" of memory, yellows show regions with average rates of blood flow, reds show flow rates above the average, and greens show flow rates below the average. The bottom pattern represents the difference between the "remote" episodic and "remote" semantic information. Here yellows indicate no difference, reds indicate greater activation during episodic thinking, and greens indicate greater degrees of activation during semantic thinking. The implications of these patterns and those shown in Figure 3 are that the anterior regions of the cortex are relatively more involved in episodic memory than are the posterior regions.

active tracer with a short half-life is diffused into the bloodstream of a conscious subject. Some of the blood is carried to and distributed throughout the brain tissue. Extracranial radiation detectors surrounding the subject's head simultaneously record the accumulation or the clearance of the radioactive indicator from small cortical regions. Levels of blood flow can be calculated from such data with the help of a high-speed computer. The amount of blood flowing through brain tissue reflects the intensity of functional neuronal activity and the metabolic requirements of such activity. The measurement of the relative distribution of blood flow in different cortical regions, therefore, provides information about the level of neuronal activity in those regions *(6)*.

I recently had an opportunity to collaborate with Jarl Risberg and David Ingvar of the University of Lund in Sweden, in a preliminary study of regional cerebral blood flow and memory. Ingvar is one of the pioneers who developed the technique of measuring such blood flow; he was one of the first to apply it to the study of cognitive functions. Risberg has been responsible for many important improvements in the technique and its use for a number of purposes. In our collaborative venture, we measured regional cerebral blood flow in healthy volunteer subjects while they were retrieving episodic or semantic information. We wanted to know to what extent the patterns of cortical blood flow associated with these two mental activities are similar and to what extent they are different.

Most studies of regional cerebral blood flow over the last 15 years or so have been based on a process that involves the inhalation of ^{133}xenon as the tracer. However, in our project we used intravenously administered ^{195m}gold, the latest improvement, developed by Risberg, in measuring regional cerebral blood flow, which has the advantage of high temporal resolution, providing reliable "maps" of cortical blood-flow patterns in less than three seconds. Such a short measurement period compares very favorably with the periods required by ^{133}xenon (several minutes) or those required for determining three-dimensional patterns of brain activity using the PET (positron emission tomography) technique (minimum of 40 seconds).

The cerebral blood flow of each subject in our study was measured eight times in a single session. Each measurement lasted 80 seconds; successive measurements were separated by several minutes. During each measurement, the subject, lying on a couch with eyes closed, silently thought about either a particular personal happening (episodic retrieval) or about some general, impersonal knowledge acquired from secondary sources, such as books or television (semantic retrieval). No specific external stimulus was provided to the subject during the measurement period, nor did the subject make any overt responses. The cortical blood-flow patterns thus reflected "pure" mental activity.

In addition to varying the nature of the retrieved information—episodic or semantic—we also varied the "age" of the experiences to be retrieved or of the original acquisition of the information. The retrieved or thought-about information was either recent, a few days old at the time of retrieval, or remote, with the age of the original experience or acquisition measured in years.

In at least some subjects the brain activity associated with silent thinking about past personal episodes can be reliably shown to be different from that associated with silent thinking about semantic information

The blood flow was recorded by a battery of 254 gamma-ray detectors snugly surrounding the subject's head. Each detector, collimated to scan an area approximately 1 cm^2, measured the rate of arrival of the radioactive indicator in its field of view for separate 0.2-second intervals. The computer was programmed to integrate these readings over 12 such successive periods, for a total of 2.4 seconds. It also converted the output of each detector into a relative measure, indicating various degrees of activation above or below the average level of

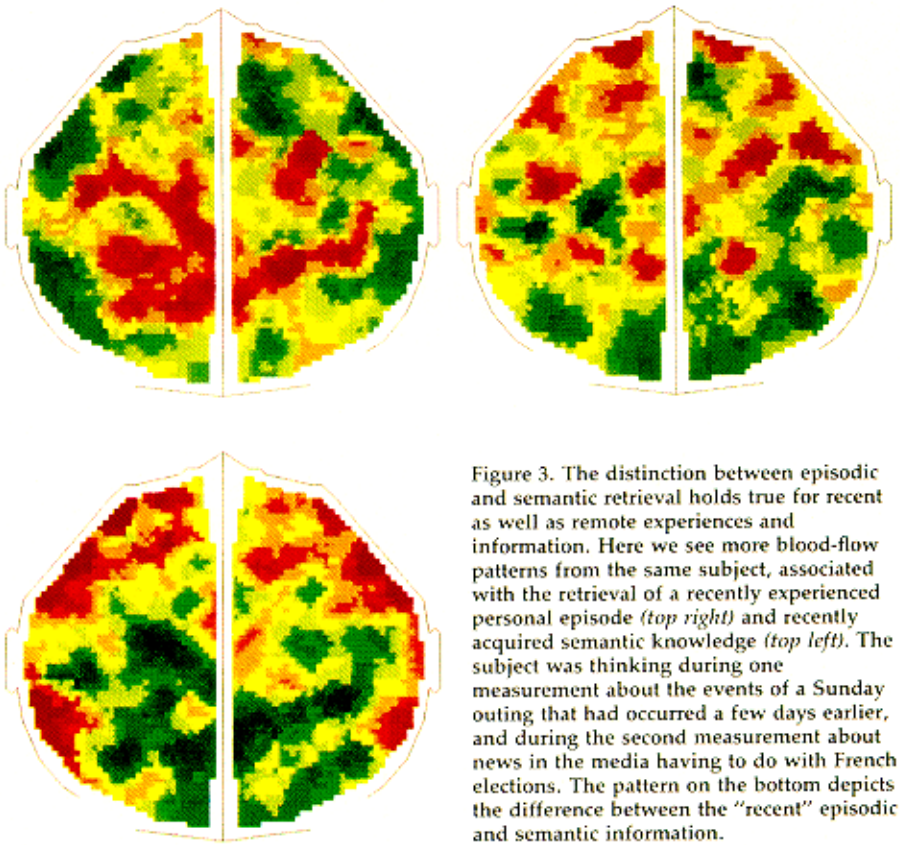

Figure 3. The distinction between episodic and semantic retrieval holds true for recent as well as remote experiences and information. Here we see more blood-flow patterns from the same subject, associated with the retrieval of a recently experienced personal episode *(top right)* and recently acquired semantic knowledge *(top left)*. The subject was thinking during one measurement about the events of a Sunday outing that had occurred a few days earlier, and during the second measurement about news in the media having to do with French elections. The pattern on the bottom depicts the difference between the "recent" episodic and semantic information.

activation for the hemisphere. The resulting 2.4-second "snapshot" of cortical activity was displayed in the form of a colored, two-dimensional, vertex-view map of the head, consisting of over 3,000 pixels. The blood-flow rate associated with each pixel was determined by linear interpolation of the output of nearby detectors.

The results we obtained from some subjects in our study did not show any discernible systematic effects, for reasons that we can only speculate about. Hence the designation of the study as only a preliminary one. But several other subjects did produce patterns of blood flow that showed systematic correlation with episodic and semantic thinking. I will present results from one such "reliable" subject here.

These results are shown in Figures 2 and 3. Each figure consists of three schematized vertical views of the cortex, with the front of the head pointing toward the top of the page. The color of each cortical region indicates the level of flow in that region relative to the mean flow for the hemisphere. Yellow represents the mean flow, the reds show flow rates higher than the mean (up to 24% higher), and the greens show flow rates lower than the mean (up to 24% lower).

Figure 2 shows two snapshots of the brain of one of the volunteer subjects, a right-handed professor of psychology at the University of Toronto. On the right is shown the pattern of his cortical activity while he was retrieving remote episodic information, namely thinking about the events of a summer 47 years ago. On the left is a snapshot taken while he was retrieving remote semantic information, thinking about the history of astronomy and the achievements of Copernicus, Brahe, and Kepler, which he had first read about many years before. The third pattern, on the bottom, depicts the difference between the episodic and semantic patterns. In this difference pattern, yellows indicate no difference, reds show relatively greater activation during episodic retrieval, and greens show relatively greater activation during semantic retrieval.

Figure 3 shows the same subject's blood-flow patterns while he was recollecting a recent personal experience and retrieving recently acquired semantic information. The pattern of episodic retrieval, on the right, represents thinking about a Sunday afternoon excursion that had taken place a few days earlier, and the semantic pattern, on the left, represents thinking about the ongoing election campaign in France, as known to the subject indirectly through various media reports. Again the bottom pattern represents the difference between the episodic and semantic patterns.

If, in keeping with the preliminary nature of the study, we ignore the details of the individual patterns and concentrate on broad generalities, we can see that the difference patterns in Figures 2 and 3 are similar in that episodic retrieval was accompanied by a relatively greater degree of activation of the anterior regions of the cortex and semantic retrieval was accompanied by a relatively greater degree of activation of the posterior regions.

It would be premature to read too much theoretical significance into these results. More systematic research is clearly called for. But in the present context, the finding that in at least some subjects the brain activity associated with silent thinking about past personal episodes can be reliably shown to be different from that associated with silent thinking about semantic information is consistent with the idea that episodic and semantic memory systems involve different brain processes. Moreover, it is not without interest that the observed blood-flow patterns indicate relatively greater involvement of the frontal lobes during episodic retrieval than during semantic retrieval, as it agrees with evidence from several lesion studies that points to the critical role played by the frontal lobes in the temporally organized and spatially bound episodic memory (7). It is worth mentioning that K.C., too, has massive lesions in his left frontal lobe, and it is conceivable, although not verifiable, that these lesions are at least partly responsible for his inability to remember past events.

Thus our preliminary study suggests not only that it is possible to obtain reasonably direct evidence regarding brain activity that subserves mental experience, but also that such brain activity differs for remembering the personal past and retrieving impersonal knowledge acquired in the past.

Memory and the brain

Close to 40 years ago Karl Lashley declared that, after a long search, he had failed to find the engram, the neural trace in the brain storing past experiences. This failure suggested to Lashley that no part of the brain is more important than any other part in subserving learning. We know better now, and we also believe we know some of the reasons that Lashley failed: he did not fully appreciate the complexity and multifariousness of memory, and he did not use sufficiently refined measures of its different forms.

Although our knowledge concerning the neurophysiology and neuroanatomy of learning and memory is still highly fragmentary, some rather rough outlines of the general picture have begun to emerge. Thus, we now have reasons to believe that the operations of semantic memory are critically dependent on the medial temporal lobes and related structures, such as the hippocampus and the amygdala, as well as on certain structures in the midline diencephalic region, such as the dorsomedial nucleus of the thalamus and the mammillary bodies. Damage to any one of these structures is likely to produce difficulties with storing and retrieving knowledge about the world. Since episodic remembering also depends on the intact semantic-memory system, damage to these structures necessarily compromises the operation of the episodic system. Typical amnesic patients have difficulty both with learning new facts and with remembering recently experienced events.

Episodic remembering, however, seems to depend on intact frontal lobes in a way that semantic knowing does not. The results of our preliminary study of regional cerebral blood flow seem to point in that direction, suggesting that the frontal lobes play a special role in the retrieval of episodic information. Although it is known that damage to the frontal lobes alone does not produce a full-blown amnesic syndrome, it does result in an impairment of remembering the temporal-spatial characteristics of experienced mental contents, a critical feature of episodic remembering. Patients with frontal-lobe damage may be able to acquire new factual knowledge, to

learn and retain what the new facts are and what they mean, but they cannot always remember when and where they acquired the knowledge. When frontal-lobe damage is superimposed on medial-temporal-lobe or diencephalic damage, a behavioral syndrome results showing not only semantic-memory impairment but also particular difficulty remembering past events as personal happenings.

Evidence of the sort reviewed in this article suggests that the traditionally held views about the unity of memory are no longer tenable. A more appropriate view seems to be that of multiple memory systems. Remembering one's past is a different, perhaps more advanced, achievement of the brain than simply knowing about it.

References

1. Discussions of the distinction between episodic and semantic memory can be found in E. Tulving, 1983, *Elements of Episodic Memory*, Oxford Univ. Press; L. S. Cermak, 1984, The episodic-semantic distinction in amnesia, in *Neuropsychology of Memory*, ed. L. S. Squire and N. Butters, Guilford Press, pp. 55–62; E. Tulving, 1987, Multiple memory systems and consciousness, *Human Neurobiol.* 6:67–80.
2. A more complete account of K.C.'s case is presented in E. Tulving, D. L. Schacter, D. R. McLachlan, and M. Moscovitch, 1988, Priming of semantic autobiographical memory: A case study of retrograde amnesia, *Brain and Cognition* 8:3–20. I thank K. C. and his family for their permission to tell his story and to present his photograph.
3. For a general description of the amnesic syndrome, see P. Rozin, 1976, The psychobiological approach to human memory, in *Neural Mechanisms of Learning and Memory*, ed. M. R. Rosenzweig and E. L. Bennett, MIT Press, pp. 3–46; E. Warrington and L. Weiskrantz, 1982, Amnesia: A disconnection syndrome? *Neuropsychologia* 20: 233–48; A. Parkin, 1987, *Memory and Amnesia*, Blackwell.
4. Cases of amnesia similar to that of K.C. have been reported by L. S. Cermak and M. O'Connor, 1983, The anterograde and retrograde retrieval ability of a patient with amnesia due to encephalitis, *Neuropsychologia*, 21:213–34; N. Butters and L. S. Cermak, 1986, A case study of the forgetting of autobiographical knowledge: Implications for the study of amnesia, in *Autobiographical Memory*, ed. D. C. Rubin, Cambridge Univ. Press, pp. 253–72; E. Goldberg and R. M. Bilder, 1987, Neuropsychological perspectives: Retrograde amnesia and executive deficits, in *Handbook of Memory Assessment of Older Adults*, ed. L. Poon, Am. Psychol. Assoc. Press. A recent description of H.M.'s lost and preserved cognitive abilities is in S. Corkin, 1984, Lasting consequences of bilateral medial temporal lobectomy: Clinical course and experimental findings in H.M., *Seminars in Neurol.* 4:249–59.
5. For discussions of the neuroanatomy of different forms of memory in humans and other primates, see M. Mishkin and T. Appenzeller, 1987, The anatomy of memory, *Sci. Am.* 256(6):80–89; L. R. Squire, 1987, *Memory and Brain*, Oxford Univ. Press; L. Weiskrantz, 1987, Neuroanatomy of memory and amnesia: A case for multiple memory systems, *Human Neurobiol.* 6:93–105.
6. For descriptions of the technique of measuring regional cerebral blood flow, see N. A. Lassen, D. H. Ingvar, and E. Skinhoj, 1978, Brain function and blood flow, *Sci. Am.* 239(10):62–71; J. Risberg, 1987, Development of high-resolution two-dimensional measurement of regional cerebral blood flow, in *Impact of Functional Imaging in Neurology and Psychiatry*, ed. J. Wade, S. Knežević, V. A. Maximilian, Z. Mubrin, and I. Prohovnik, London: John Libbey, pp. 35–43; J. Risberg, in press, Regional cerebral blood flow measurements with high temporal and spatial resolution, in *Visualization of Brain Functions*, ed. D. Ottoson, Macmillan. For an application of the technique to the study of cognition, see P. E. Roland and L. Friberg, 1985, Localization of cortical areas activated by thinking, *J. Neurophysiol.* 53:1219–43. For more details and results of the study described here, see E. Tulving, 1989, Memory: Performance, knowledge, and experience, *Eur. J. Cognitive Psychol.* 1:3–26.
7. Recent reviews of the role of the frontal lobes in memory have been provided by B. Milner, M. Petrides, and M. L. Smith, 1985, Frontal lobes and the temporal organization of memory, *Human Neurobiol.* 4:137–42; D. L. Schacter, 1987, Memory, amnesia, and frontal lobe dysfunction, *Psychobiology* 15:21–36.