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Semantic Memory and the Human Hippocampus

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Summary

It has been unclear whether the hippocampus is uniquely important for episodic memory (memory for events that are specific to time and place) or whether the hippocampus is also important for learning and remembering facts (semantic memory). In two studies, we assessed the capacity for semantic memory in patients with bilateral damage thought to be restricted primarily to the hippocampal region who developed memory impairment at a known time. Since the onset of their memory impairment, the patients have acquired less factual knowledge than controls. The patients also exhibit temporally limited retrograde amnesia for factual information from the several years preceding the onset of memory impairment. Remote memory for factual knowledge (from 11–30 years before amnesia) is intact. The results show that the hippocampal region supports semantic memory as well as episodic memory and that its role in the acquisition and storage of semantic knowledge is time limited.

Introduction

Declarative memory supports conscious recollection of the past and depends on the integrity of the medial temporal lobe, including the hippocampal region (CA fields, dentate gyrus, and subicular complex) and the adjacent entorhinal, perirhinal, and parahippocampal cortices (Squire and Zola-Morgan, 1991). Episodic memory and semantic memory are two types of declarative memory (Eichenbaum and Cohen, 2001; Squire, 1992; Tulving, 1983). Episodic memory refers to the capacity to re-experience an event in the context in which it occurred. Semantic memory refers to the capacity for recollecting facts and general knowledge about the world.

An important question has been how the distinction between episodic memory and semantic memory might be reflected in the organization and function of the brain systems that support memory. One view is that the hippocampal region is uniquely important for episodic memory and that adjacent cortical structures support semantic memory (Tulving and Markowitsch, 1998; Vargha-Khadem et al., 1997; for related views, see Brown and Aggleton, 2001; Yonelinas, 2002). Another view is that the hippocampal region is important for both episodic and semantic memory (Manns and Squire, 2002; Squire and Zola, 1998). The most direct way to decide between these views is to ask whether semantic memory is spared or impaired in patients with bilateral damage limited to the hippocampal region.

It has been difficult to address this question by experiment for two reasons. First, it has rarely been possible to include in a study more than one or two well-characterized patients with damage limited primarily to the hippocampal region. Second, in tests of factual knowledge that are designed to assess semantic memory, normal individuals could be advantaged by being able to remember episodic details about the time or place in which they acquired the factual information. If so, impaired performance by patients on tests about facts could reflect their poor episodic memory rather than poor semantic memory (Tulving, 1991).

In two experiments, we have assessed the capacity for semantic memory in patients with damage thought to be limited primarily to the hippocampal region (Figure 1; Table 1). Both experiments assessed how much patients had learned since the onset of amnesia (during their period of anterograde amnesia) as well as how much they could remember from the period before the onset of amnesia. Thus, we assessed both the severity of anterograde amnesia for factual knowledge and the severity and extent of retrograde amnesia for factual knowledge. In experiment 1, five patients were asked questions about notable news events that had occurred either before or after the onset of their amnesia. In experiment 2, six patients were asked whether famous persons who had been well known for a long time were still living. A follow-up study attempted to remove the contribution of episodic memory to test performance. The findings show that patients with damage limited primarily to the hippocampal region have impaired semantic memory and that the impairment is evident in both anterograde and retrograde amnesia.

Results

Experiment 1

Figure 2 shows performance on questions about news events (1950–2002) for 12 controls and for five patients with damage restricted primarily to the hippocampal region. Two or three controls were matched to each patient, and the test questions for each patient (and that patient's controls) were assigned to the period of anterograde or retrograde amnesia according to when the patient became amnesic. In this way, average scores could be calculated across patients for the period of anterograde amnesia (AA), the period up to 5 years before the onset of amnesia, the period 6–10 years before the onset of amnesia, and so on. For the period of anterograde amnesia, the patients performed worse than controls, both on the free-recall test (patients, 24.4% ± 4%;

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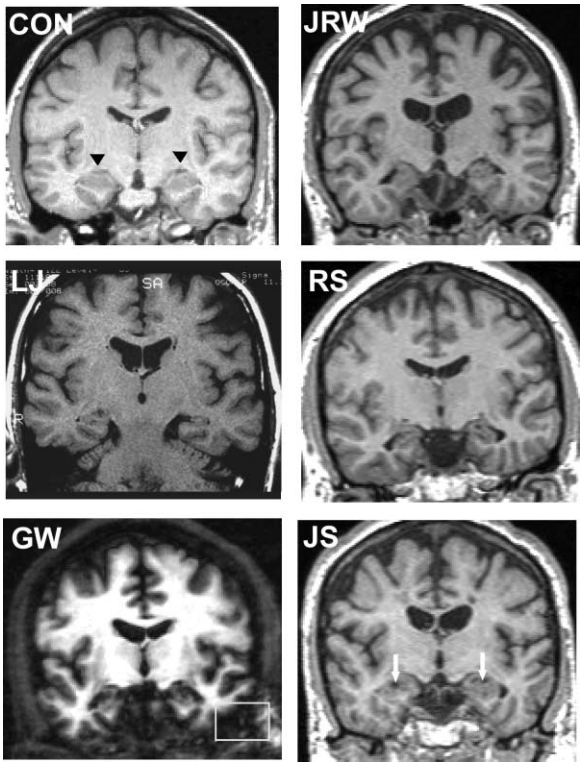

Figure 1. Magnetic Resonance Images for Five of the Six Amnesic Patients with Damage Limited Primarily to the Hippocampal Region and a Healthy Control

The images are T1-weighted coronal sections at the level of the anterior hippocampus. The left side of the brain is on the right side of the image (radiologic view). For four of the patients, the volume of the hippocampal region relative to intracranial volume is reduced by an average of 35% (see text). For patient J.S., the hippocampus was not reduced in volume but had several focal lesions (indicated by white arrows). Black triangles on the image for CON, aged 35, indicate the hippocampal region. An imaging artifact is visible in the area of the left lateral temporal lobe in the image of patient G.W. (box).

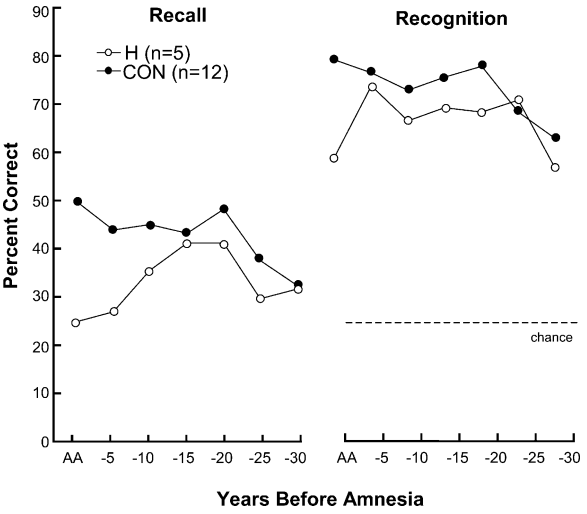

Figure 2. Recall and Recognition Performance for Patients with Damage Limited Primarily to the Hippocampal Region and Controls on a Test of News Events that Occurred 1950–2002

The scores for five patients (all but J.S.) and their controls have been aligned relative to the onset of amnesia (Table 1) so that performance can be shown for the time period after the onset of amnesia (AA, anterograde amnesia) and for 5 year intervals preceding the onset of amnesia (retrograde amnesia). The data point at −5 represents 1–5 years before amnesia, the point at −10 represents 6–10 years before amnesia, and so on. Standard errors for the patients (AA and −5 to −30 years) were 4%, 4%, 5%, 6%, 7%, 7%, and 7% for recall and 3%, 3%, 8%, 12%, 8%, 9%, and 3% for recognition. Standard errors for the controls were 4%, 6%, 7%, 6%, 6%, 7%, 8%, and 6% for recall and 2%, 4%, 5%, 7%, 7%, 3%, and 7% for recognition. H, patients with damage limited primarily to the hippocampal region; CON, controls.

controls, 49.2% ± 4%; $t_{(15)} = 3.48$, $p < 0.01$) and on the recognition test (58.3% ± 3% and 78.8% ± 2%; $t_{(15)} = 4.96$, $p < 0.01$). Thus, the patients were impaired at learning about news events that occurred after they became amnesic. In contrast, the patients had good access to knowledge about events that had occurred remote to the onset of amnesia (specifically, 11–30 years earlier; see data points −15 to −30). Thus, the patients scored 35.4% ± 5% correct on recall questions that covered this time period, and their controls scored 39.9% ± 6% correct on the same questions (for recognition, 65.8% ± 6% versus 70.7% ± 5%). Finally, the recall data were consistent with temporally limited retrograde amnesia covering a period of about 1–10 years before the onset of amnesia (patients, 30.7% ± 4% correct; controls, 44.0% ± 6% correct). Across the three time periods −5, −10, and −15 years before amnesia, the performance of the patients exhibited a significant linear trend ($F_{(1,4)} = 11.12$, $p < 0.05$), and there was a marginal interaction of linear trends across these three time peri-

Table 1. Characteristics of Amnesic Patients

Patient	Age (Years)	Education (Years)	Year Became Amnesic	WAIS-III IQ	WMS-R				
					Attention	Verbal	Visual	General	Delay
J.S.	36	14	1999	90	92	85	63	81	75
J.R.W.	38	12	1990	90	87	65	95	70	<50
G.W.	42	12	2001	108	105	67	86	70	<50
R.S.	45	12	1998	99	99	85	81	82	<50
L.J.	64	12	1988	101	105	83	60	69	<50
A.B.	64	20	1976	107	87	62	72	54	<50

Note. The Wechsler Adult Intelligence Scale-III (WAIS-III) and the Wechsler Memory Scale-Revised (WMS-R) yield mean scores of 100 in the normal population, with a standard deviation of 15. The WMS-R does not provide numerical scores for individuals who score below 50. IQ scores for J.S., J.R.W., and R.S. are from the Wechsler Adult Intelligence Scale-Revised. J.S. participated only in experiment 2.

ods for the patients and the controls ($F_{(1,15)} = 3.34$, $p = 0.09$).

For two of the patients for whom sufficient data were available, we also examined performance year by year during the few years immediately preceding the onset of amnesia (Squire et al., 1975; Zola-Morgan et al., 1986). Patients G.W. and R.S. had been given 25 or more questions covering the 2 year period immediately preceding amnesia (the other patients $<$ 7 questions). In the recall test, these two patients exhibited retrograde amnesia for the 1 year immediately preceding the onset of their amnesia (32.7% $\pm$ 4% versus 66.6% $\pm$ 8%, for the patients and their controls; $t_{(4)} = 2.91$, $p < 0.05$). We also examined their scores from earlier years. The only other year that revealed a measurable impairment for these two patients was the fourth year prior to the onset of amnesia (11.9% $\pm$ 12% versus 53.8% $\pm$ 9%; $t_{(4)} = 2.70$, $p = 0.05$), and performance was quite good for more remote years, 11–30 years before amnesia (36.8% $\pm$ 7% versus 38.8% $\pm$ 13%).

Temporally limited retrograde amnesia was not as evident in the recognition memory data. Across the three time periods -5, -10, and -15 years before amnesia, the patients as a group performed about as well as controls (69.3% $\pm$ 5% versus 74.5% $\pm$ 5%), and there was no evidence of a linear trend ($F_{(1,4)} = 0.11$, $p > 0.10$). Nevertheless, the two patients with the most data (G.W. and R.S.) did exhibit an impairment ($p < 0.05$), which was evident in the fourth (63.3% $\pm$ 3% versus 76.9% $\pm$ 2%) and sixth years (65.0% $\pm$ 2% versus 100.0% $\pm$ 0%) prior to amnesia. As in the case of recall, the recognition performance of these two patients in more remote years (11–30 years before amnesia) was quite good (79.9% $\pm$ 9% versus 82.0% $\pm$ 9%).

Experiment 2

Figure 3 shows performance for six patients and 14 controls (all but four were from experiment 1) when they made famous/nonfamous judgments for a list of 252 names and then living/nonliving judgments for those names judged correctly to be famous. The patients performed similarly to the controls on famous/nonfamous judgments about persons who were known before 1970, presumably because these judgments depended on very remote memory (Figure 3A) (86.0% $\pm$ 2.6% versus 91.2% $\pm$ 1.8% correct; d′ discriminability score = 2.49 $\pm$ 0.31 versus 3.11 $\pm$ 0.23, for patients and controls, respectively, $t_{(18)} < 1.50$ and $p > 0.10$ in both cases). In contrast, the patients had great difficulty deciding which of the persons they had correctly judged to be famous were no longer living. (Half of the famous persons had died between 1990 and 2001.) Thus, for questions about persons who had died during the period of anterograde amnesia, the patients performed at chance levels and poorer than controls (Figure 3B) ($d' = 0.21 \pm 0.15$ versus 0.97 ± 0.16, for patients and controls, respectively; $t_{(18)} = 2.82$; $p = 0.01$). The same result was obtained when the score was calculated as the hit rate (a correct judgment of nonliving when the person was deceased) minus the false alarm rate (an incorrect judgment of nonliving when the person was in fact living) (0.2% $\pm$ 9.4% versus 41.6% $\pm$ 4.2%, for patients and controls, respectively; $t_{(18)} = 4.70$; $p < 0.01$). Thus, after they became amnesic, the patients acquired less knowledge than controls about which famous persons had died.

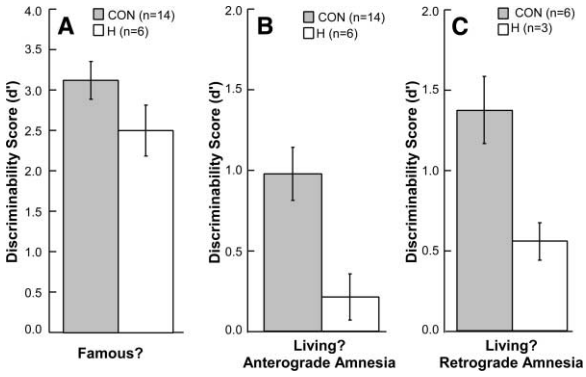

Figure 3. Performance for Patients with Damage Limited Primarily to the Hippocampal Region and Controls on a Test that Asked Whether Famous Persons Were Still Living

The famous persons had become known before 1970, and half of them had died between 1990 and 2001. (A) Patients performed similarly to controls at discriminating famous names from fictitious names but (B) were impaired at deciding which of the correctly identified famous persons had died during the period of anterograde amnesia. (C) For three of the patients, many of the deaths (mean = 40) occurred prior to the onset of their amnesia, and these patients were impaired at making judgments about these names as well (retrograde amnesia). H, patients with damage limited primarily to the hippocampal region; CON, controls. Brackets indicate SEM.

Three of the patients became amnesic after 1996 (G.W., R.S., and J.S.), and for these patients a measure of retrograde amnesia could be obtained by considering test items (mean = 40) about persons who had died before the onset of amnesia. Figure 3C shows that these three patients performed worse than their six controls for the retrograde time period ($d' = 0.56 \pm 0.12$ versus 1.38 ± 0.21; $t_{(7)} = 2.58$; $p < 0.05$). The results were similar when performance was calculated as the hit rate minus the false alarm rate (19.3% $\pm$ 4.7% versus 43.9% $\pm$ 5.4%; $t_{(7)} = 3.00$, $p < 0.05$). Thus, the patients not only had difficulty acquiring factual knowledge after they became amnesic, they also had difficulty recollecting factual knowledge about events that occurred during the few years before they became amnesic. Depending on the patient, these events would have occurred from 1 year to 11 years before amnesia. Thus, these findings for retrograde amnesia in experiment 2 are consistent with the finding of temporally limited retrograde amnesia in experiment 1. The observation of temporally limited retrograde amnesia suggests that impaired factual knowledge in these patients cannot be explained by reduced exposure to world events, social withdrawal, depression, or other factors that might occur with the onset of an amnesic condition. The impairment extended into the premorbid period when the patients were healthy and active.

It has been suggested that a finding of impaired semantic memory in amnesia might be misleading because controls (but not patients) might be able to recollect episodic details about how, when, or where they acquired their factual knowledge and thereby recollect the facts themselves more accurately (Tulving, 1991). Accordingly, an impression that semantic memory is

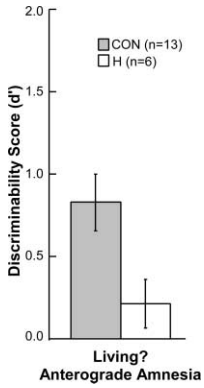

Figure 4. Performance for Patients and Controls on the Same Test as in Figure 3 but After the Contribution of Episodic Memory to the Living/Nonliving Judgment Was Removed

For a few names (13% of the test items) that controls had correctly identified as the names of persons who had died, controls were able to recollect episodic details about the circumstances in which they learned of the deaths. When these test items were excluded, controls still performed better than the patients. H, patients with damage limited primarily to the hippocampal region; CON, controls. Brackets indicate SEM.

impaired could arise because controls (but not patients) can augment their memory scores for factual information by calling on episodic memory about the facts in question. We addressed this possibility in follow-up questions by asking 13 of the 14 controls to recollect any circumstances in which they had heard that an individual had died (either at the time of the death or at any time afterwards). The controls were able to recollect at least some information of this kind for 13% of the individuals that they had correctly identified as having died. When those famous names were removed from the data analysis, the patients still exhibited anterograde amnesia (Figure 4; $d' = 0.21 \pm 0.15$ versus 0.83 ± 0.17 for patients and controls, respectively; $t_{(17)} = 2.24$, $p < 0.05$). Further, the three patients for whom retrograde amnesia could be assessed (Figure 3C) exhibited a trend towards retrograde amnesia when the famous names that were associated with episodic memories were removed, as in the analysis of anterograde amnesia ($d' = 0.56 \pm 0.12$ versus 1.17 ± 0.22 for three patients and six controls, respectively; $t_{(7)} = 1.85$, $p = 0.10$). Thus, even when one considers only factual knowledge that has been abstracted from the context in which it was acquired (i.e., semantic memory), the patients still performed more poorly than controls.

Discussion

Patients with bilateral damage thought to be limited primarily to the hippocampal region exhibited marked deficits in learning and remembering factual knowledge (semantic memory). Experiment 1 showed that patients were impaired at acquiring knowledge about events in the news that had occurred after the onset of amnesia. Memory for remote events (11–30 years before amnesia) was intact, and time-limited retrograde amnesia was apparent during the several years before amnesia. In experiment 2, the patients could identify famous persons who had come into prominence before 1970. Presumably, these persons became known to the patients long before the onset of amnesia, and familiarity with their names was therefore outside the scope of retrograde amnesia. Despite their familiarity with the famous names, the patients could not identify which of these persons had died after the onset of amnesia. In addition, there was evidence of retrograde amnesia for this same information (i.e., whether persons were living or nonliving) for the few years before the onset of amnesia. Impaired semantic memory could not be explained by supposing that controls (but not patients) could recollect episodic details about the circumstances in which they acquired their factual knowledge and thereby could recall the facts more accurately. The results indicate that the hippocampal region is essential for the normal acquisition of semantic memory and that this region remains important for several years after learning. Impaired acquisition of semantic knowledge has also been reported in a prospective study where possible differences between groups in exposure to the material being tested are not a factor (Manns and Squire, 2002, Figure 4.2).

The capacity for semantic memory has often been reported to be quite good (though not intact) in single-case studies of memory-impaired patients with damage to the medial temporal lobe and apparently better than the capacity for day-to-day (episodic) memory (Haymann et al., 1993; Kitchener et al., 1998; Van der Linden et al., 2001; Verfaellie et al., 2000). Yet, given that semantic memory can be based on multiple learning events and that episodic memory is by definition unique to a single event, it is perhaps not surprising that semantic memory in memory-impaired patients can be impaired and still appear to be superior to episodic memory. The difficulty is in determining whether the semantic memory that is acquired after the onset of amnesia is disproportionately spared in memory-impaired patients or whether the amount of semantic memory that is acquired after the onset of amnesia is what one would expect given the residual capacity for episodic memory (Squire and Zola, 1998). This issue remains a challenge for experimental work.

In any case, other studies, each involving one or two patients with limited hippocampal damage, have reported that memory for facts was distinctly impaired (Reed and Squire, 1998; Kapur and Brooks, 1999; Holdstock et al., 2002). The extent to which episodic recollection might have contaminated the measure of semantic memory was not evaluated. The present study accounts for the contribution of episodic memory to the retrieval of factual information and shows in a group of patients that limited hippocampal damage impairs semantic memory.

The present findings also provide support for the notion that the human hippocampus has a time-limited role in the formation and storage of semantic knowledge. Following hippocampal damage, remote memory was intact, and retrograde amnesia was limited to a period of a few years. This observation, based on the current group of six patients, is broadly consistent with what has been reported previously for individual patients with limited hippocampal damage (Reed and Squire, 1998; Kapur and Brooks, 1999), including cases in which the damage could be evaluated by postmortem neurohisto-

logical analysis (Zola-Morgan et al., 1986; Rempel-Clower et al., 1996). Temporally graded retrograde amnesia following restricted hippocampal lesions has also been commonly observed in experimental animals, though the retrograde amnesia in those studies ranged over weeks or months rather than the several years that has been observed in studies of humans (Squire et al., 2001). When retrograde amnesia has been found to be more extensive and ungraded, covering many decades, there was typically damage involving the lateral temporal lobe (Kapur, 1993; Kopelman and Kapur, 2001; Squire and Alvarez, 1995). Extensive, ungraded retrograde amnesia was also reported in a single-case study in which damage was interpreted as limited to the hippocampal region (Cipolotti et al., 2001). However, the radiological data indicated significant volume loss beyond the hippocampal region (the left parahippocampal gyrus and the left entorhinal cortex were reduced in volume 31% and 28%, respectively, 2.90 and 1.45 standard deviations below the control mean). Also, measurements were not reported for frontal, parietal, and occipital lobes.

The effects of adult-onset hippocampal damage, as described here, can be compared with reports that patients who sustained limited hippocampal damage early in life nevertheless attained levels of literacy and factual knowledge within the low-average to average range (Vargha-Khadem et al., 1997; Baddeley et al., 2001). The best studied of these cases (Jon) has above-average intelligence and performs normally on language and other scholastic tests, despite having marked day-to-day memory problems since early childhood. Jon also performs well on standard tests of recognition memory. Nevertheless, Jon was impaired at learning facts from the news that were presented to him in the laboratory on videotape. Considering what Jon has been able to achieve, it is possible that early hippocampal damage provides an opportunity for functional reorganization or compensation through learned strategies with the result that considerable semantic knowledge can be acquired about the world. At the same time, his performance in the laboratory raises an alternative possibility—that semantic learning is impaired after early hippocampal damage and that the amount of semantic knowledge eventually acquired by patients with developmental amnesia, given sufficient effort and repetition, is no more than should be expected from estimates of their day-to-day (episodic) memory ability. Direct comparisons of adult-onset and developmental amnesia should clarify these points.

If the distinction between episodic and semantic memory does not illuminate the function of the hippocampal region, the distinction does seem useful for understanding frontal lobe function. Thus, it has been proposed that episodic and semantic memory are both dependent on the integrity of the hippocampal region and other medial temporal lobe structures and that episodic memory depends additionally on the frontal lobes (Shimamura and Squire, 1987; Tulving, 1989).

New memory may always be acquired as part of an episode. With the passage of time, memory for the source of the information (episodic memory) is often lost, even as factual information (semantic memory) is retained. So long as episodic memory persists, the frontal lobes are important for linking the acquired information to the context in which it was learned.

Finally, the suggestion that episodic and semantic memory do not describe separate functions of the hippocampal region and adjacent cortex does not count against the view that the anatomical components of the medial temporal lobe make distinct contributions to memory function. However, the structures of the medial temporal lobe are richly interconnected (Lavenex and Amaral, 2000), and attempts to differentiate between the hippocampal region and the adjacent cortex based on sharp dichotomies such as episodic and semantic memory are unlikely to be successful. We suggest, as have others (Suzuki and Eichenbaum, 2000; Norman and O'Reilly, 2003; Stark and Squire, 2002), that the division of labor among medial temporal lobe structures is not absolute and that differences in function will prove to be matters of degree that apply in a graded way across the hippocampal region and adjacent cortex.

Experimental Procedures

Participants

Six amnesic patients (five men and one woman) with damage limited primarily to the hippocampal region (CA fields, dentate gyrus, and subicular complex) participated (Table 1). All the patients had moderately severe memory impairment (Manns et al., 2003). Their scores for copy and delayed (12 min) reproduction of the Rey-Osterrieth figure (Osterrieth, 1944; maximum score = 36) were 29.0 and 3.7, respectively (controls = 30.3 and 20.6; Squire et al., 1989). Paired-associate learning was also impaired (ten word pairs per trial for three trials; patients = 1.7, 2.3, 3.0; eight controls = 6.0, 7.6, 8.9).

Patients A.B. and J.R.W. became amnesic after an anoxic episode associated with cardiac arrest. G.W. and R.S. became amnesic following a drug overdose and associated respiratory failure. J.S. became amnesic following accidental carbon monoxide poisoning. L.J. became amnesic during a 6 month period with no known precipitating event. Her memory impairment has remained stable since that time.

For five of the six patients, bilateral hippocampal damage was quantified by magnetic resonance imaging (MRI) in a 1.5T clinical scanner (Figure 1). The volume of the full anterior-posterior length of the hippocampus and the parahippocampal gyrus was measured using criteria based on histological analysis of healthy brains (Amaral and Insausti, 1990; Insausti et al., 1998). For each patient, the hippocampal and parahippocampal gyrus volumes were divided by the intracranial volume to correct for brain size (for L.J., only areal measurements based on coronal sections were available). Relative to age and gender-matched healthy controls (three to four for each patient), J.R.W., G.W., R.S., and L.J. have an average bilateral reduction in hippocampal size of 29%, 45%, 40%, and 28%, respectively. For J.S., the hippocampus was not reduced in volume, but focal lesions were present (see Figure 1). In comparison, for all patients, the size of the parahippocampal gyrus was within normal limits (mean = 2%, range = −15% to +15%). The sixth patient (A.B.) is unable to participate in magnetic resonance imaging studies but is thought to have hippocampal damage on the basis of etiology (anoxia) and a neurologic examination indicating well-circumscribed amnesia. In addition, high-resolution computed tomography (CT) images obtained in 2001 were consistent with restricted damage to the hippocampal region (Schmolck et al., 2002). Of course, for all the patients, definitive information regarding the locus and extent of damage can come only from postmortem histological analysis. A total of 16 controls (11 men and 5 women) were also tested. They averaged 52.6 ± 3.3 years of age (patients = 48.5 ± 5.1) and 13.4 ± 0.5 years of education (patients = 13.7 ± 1.3).

Procedure

Experiment 1

Participants were asked 251 questions about notable news events that had occurred from 1950 to early 2002 (e.g., Which tire manufac-

turer recalled thousands of tires? What software company was accused of running a monopoly?). About half the questions (n = 138) focused on the period 1995–2002. Testing proceeded first in a free-recall format and then in a four-alternative, multiple-choice format. The data for each patient (and two to three controls matched to each patient) were analyzed according to the year the patient became amnesic (Table 1). In this way, a score for each patient (and his or her controls) was calculated for the period of anterograde amnesia and, in 5 year intervals, for a period of up to 30 years of retrograde amnesia. For example, for patient A.B., who became amnesic in 1976, most of the questions (n = 196) assessed his anterograde amnesia (1977–2002). The retrograde period for A.B. was taken to be 1975–1945 (he and his controls received an additional eight questions for the period 1945–1949 to permit his retrograde amnesia to be evaluated across 30 years). For patient G.W., who became amnesic in mid 2001, 28 questions assessed his anterograde amnesia (in 2002), and 74 questions assessed his retrograde amnesia (1971–2000). The remaining questions assessed more remote time periods, and performance on these questions was therefore not recorded for G.W. Across participants, an average of 32.1 questions were available for each of the time intervals in Figure 2 (minimum = 9.4 at the −25 year interval). The data in Figure 2 remained virtually the same when the data were recalculated using five different assignments of controls to patients.

Experiment 2

A list of intermixed famous (n = 126) and fictitious (n = 126) names were read aloud one at a time (e.g., Rosemary Clooney, Frank Dixon, Doris Day). All of the famous names were the names of people who had become known by 1970. Half of these individuals had died between 1990 and 2001. (Four additional individuals died before testing was completed.) Participants first decided whether each name was or was not the name of a famous person. Then, for persons correctly judged to be famous, participants decided whether the person was still living or had died (Kapur et al., 1989). So that age could not be used as a cue, the average age of the famous persons who were living was the same as the age that the deceased persons would have reached had they still been living. As in experiment 1, the data for each patient (and two to three controls matched to each patient) were analyzed separately for the period of anterograde amnesia and for the period of retrograde amnesia. (Because only three of the six patients became amnesic after 1990, and there were no living/nonliving questions from the period before 1990, a score for retrograde amnesia could be obtained for only these three patients.) The data presented in Figures 3B and 3C remained virtually the same when the data were recalculated using five different assignments of controls to patients.

After testing was completed, 13 of the 14 controls were asked to recall any circumstances in which they had heard about the deaths of the famous persons. For each famous person that they had identified correctly as having died, the controls were asked to recollect any specific information that could have helped them come to the answer, such as where they were when they heard news related to the person's death, who was with them, and how the information had come to them (e.g., newspaper or friend). Whenever any specific information could be recounted about the death of one of these persons, that name was identified as one in which episodic memory might have contributed to the correct answer on the living/nonliving question, and the name was removed from the data analysis (Figure 4).

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