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On the Acquisition of New Declarative Knowledge in Amnesia

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In 2 experiments, the acquisition of new declarative knowledge was examined in amnesic patients and in 7 groups of controls, with a *study-only procedure* that delayed testing until the conclusion of training. The study-only procedure was compared with a standard procedure in which study and test trials alternated (*study–test*). The amnesic patients acquired new factual (declarative) knowledge at an abnormally slow rate, learning more with the study-only procedure than with the study–test procedure. Controls exhibited the opposite pattern. The advantage of the study-only procedure for amnesic patients was related to the presence of frontal lobe dysfunction. The 2 groups exhibited a similar ability to use their knowledge flexibly, suggesting that the information acquired by amnesic patients was based on their residual capacity for declarative memory. In addition, the capacity for factual learning in amnesia was proportional to the capacity to recollect specific events in the learning session.

An important feature of the amnesic syndrome is impaired acquisition of new declarative knowledge, including information about specific events and episodes as well as information about factual material. In this sense, it is sometimes stated that the impairment in amnesia involves both episodic and semantic memory (Baddeley, 1982; Squire, 1992; Talland, 1965). For example, the severely amnesic patient H.M. (Scoville & Milner, 1957) and a group of amnesic patients with Korsakoff's syndrome were unable to learn the meanings of 10 rare English words, despite many learning trials (Gabrieli, Cohen, & Corkin, 1983, 1988). Similar findings of impaired semantic learning by amnesic patients are widespread in the clinical and experimental literature (e.g., Cutting, 1978; Shimamura & Squire, 1987; Squire & Shimamura, 1986).

Nevertheless, amnesic patients can usually acquire some new semantic information, albeit at an abnormally slow rate. For example, new learning has been demonstrated for factual statements (Hayman, MacDonald, & Tulving, 1993; Schacter, Harbluk, & McLachlan, 1984; Shimamura & Squire, 1987, 1988), and for computer-related commands and computer vocabulary (Glisky & Schacter, 1988; Glisky, Schacter, & Tulving, 1986a, 1986b).

Two lines of inquiry can be identified in these studies. One focus has been to identify what types of new semantic material amnesic patients can learn (e.g., facts, vocabulary, computer commands). A question of particular interest in this context has been whether the rate of such learning in amnesic patients can be accelerated by special learning procedures. The second focus has been to determine whether the semantic information that amnesic patients can acquire is qualitatively similar to the information that unimpaired individuals acquire or whether it is qualitatively different in some way (e.g., for amnesic patients, is access to the acquired information less flexible, and is the capacity for semantic learning disproportionately better than the capacity for episodic learning?). In their case study of the severely amnesic patient K.C., Tulving, Schacter, McLachlan, and Moscovitch (1988) found that he was able to learn a large amount of semantic information under conditions that prevented him from making errors during training (Tulving, Hayman, & MacDonald, 1991). Following many trials of training using word-fragment cues that constrained his responses (e.g., "police shot __*ss*__*ss*__*n*"; correct answer: *assassin*), he was able to produce the final target word from the first two words in the absence of the word fragment. This result contrasted sharply with earlier unsuccessful attempts to train K.C. using the standard "method of anticipation" (Brooks & Baddeley, 1976), in which study and test trials alternated (Tulving et al., 1988).

In a second study of patient K.C., Hayman et al. (1993) noted that amnesic patients may be particularly susceptible to the adverse effects of interference (Cermak & Butters, 1972; Mayes, Pickering, & Fairbairn, 1987; Warrington & Weiskrantz, 1973, 1974). Because errors produced during learning can be a source of competing or interfering responses during later learning trials, it was proposed that reducing the number of errors during training benefited K.C.'s learning because this procedure reduced interference during the learning process. The implication was that the procedures ordinarily used to investigate semantic learning in amnesia may have been unsuccessful in part because the errors generated by the patients during learning trials produced a high degree of interference that hampered acquisition.

The later study of K.C. specifically examined the effect of interference on his ability to learn new semantic information

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(Hayman et al., 1993). The task required K.C. to learn to produce a one-word response to a vague semantic cue (e.g. "a talkative featherbrain": *parakeet*). The effect of repetition (one vs. two presentations of the cue–target pairs per session) and of two types of interference (*preexperimental interference*, or the effect of preexisting associations to the sentence cues, and *intraexperimental interference* (manipulated by using two different learning procedures) were examined. The low-interference procedure involved the repeated study of information in the absence of testing (the study-only procedure), and the high-interference procedure was the standard "method of anticipation" in which study and test trials alternated (the study–test procedure).

After eight weekly training sessions (twice weekly for 4 weeks), K.C. was tested on all the semantic cue–target word pairs. The results were clear: Interference had large effects on the ability of K.C. to learn semantic information. The poorest performance (.12) resulted when preexperimental and intraexperimental interference were maximal, and the best performance (.92) resulted when both types of interference were minimized. The acceleration of K.C.'s learning by the study-only procedure was all the more striking because it was not expected on the basis of the literature for unimpaired individuals, which has consistently shown an advantage of the standard study–test procedure (Carrier & Pashler, 1992; Darley & Murdock, 1971; Estes, 1960; Gates, 1917; LaPorte & Voss, 1975; Rabinowitz & Craik, 1986; Runquist, 1986a, 1986b; Thompson, Wenger, & Bartling, 1978; Wenger, Thompson, & Bartling, 1980). Periodic testing usually improves later retention; nevertheless, K.C.'s learning was facilitated by omitting such testing.

The reason why K.C. was particularly vulnerable to the deleterious effects of interference during learning was not identified. However, it was noted that enhanced vulnerability to interference might be expected in patients who are deficient in the ability to remember and distinguish between similar events, that is, patients who are deficient in the capacity for episodic memory, which is impaired in amnesia. Specifically, a patient with impaired episodic memory would have difficulty recalling whether a response made on a previous trial was correct or incorrect and as a result would be adversely affected by competing incorrect responses that had been made on previous trials. Hayman et al. (1993) also speculated that frontal lobe damage may play a role in increasing the vulnerability to interference in a patient like K.C.—who has both amnesia and frontal-lobe dysfunction—because the capacity for episodic memory has been linked to the frontal lobes (Shimamura, Janowsky, & Squire, 1990; Shimamura & Squire, 1987; Squire, Knowlton, & Musen, 1993; Tulving, 1989; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994).

These studies have typically examined new learning in the context of existing distinctions between episodic and semantic knowledge (Tulving, 1983). It should be noted, however, that learning paradigms that putatively assess newly acquired semantic information (e.g., factual sentences, new vocabulary) can sometimes be conceived as assessing episodic memory, and the relative contributions of semantic and episodic memory can be difficult to determine in a particular memory task (Gabrieli, Cohen, & Corkin, 1988). In recognition of this issue, we have adopted the convention of referring to tests of fact learning and to tests of event memory, recognizing that these more descriptive terms may have relevance to the distinction between episodic and semantic memory. In addition, we have used the term *declarative memory*, recognizing that tests of event memory as well as tests of fact memory are considered to depend on declarative memory (Squire, 1987; Tulving, 1983).

In the current study we attempted to generalize the findings for K.C. to a group of amnesic patients and to extend the work in several ways. First, we asked whether the study-only procedure is generally advantageous for amnesic patients and whether the effectiveness of this procedure is more related to the medial temporal lobe and diencephalic damage that causes amnesia or more related to the frontal lobe damage that sometimes occurs together with amnesia (cf. Janowsky, Shimamura, & Squire, 1989).

Next, we asked three questions concerning whether the factual knowledge acquired by amnesic patients is qualitatively similar to the factual knowledge acquired by unimpaired individuals. Specifically, we asked whether factual knowledge acquired by amnesic patients can be used as flexibly and is as accessible in different contexts as factual knowledge acquired by controls (e.g., whether newly acquired information can be successfully retrieved in the presence of semantically altered cues), whether the capacity to learn new factual knowledge in amnesic patients is proportional to their ability to learn about events and their contexts, and whether the knowledge acquired by amnesic patients is long lasting.

In Experiment 1 these questions were addressed with a group of 9 amnesic patients in an extensive study of fact learning, which involved several training sessions scheduled over the course of several weeks. The basic design of Experiment 1 followed the design of the study by Hayman et al. (1993). Amnesic patients were trained on a set of 40 three-word sentences (factual material) during four weekly training sessions. Two learning trials were presented in each session, for a total of eight learning trials across the four sessions. The efficacy of study–test and study-only learning procedures was compared by assigning half (20) of the sentences to the study–test procedure and the remaining 20 to the study-only procedure.

One week after the fourth and last training session, retention for the 20 sentences learned with the study–test procedure was compared with retention for the 20 sentences learned with the study-only procedure. In an additional test scheduled 1 week later, the ability of the patients to transfer their acquired knowledge was assessed using cues that were synonyms of the original cues from training. Finally, 1 month after the transfer test, the long-term retention of factual information was assessed with the same cues that were used during training.

A direct comparison was also made between the capacities of the amnesic patients and controls to acquire memory for facts and memory for events and their contexts. At the beginning of the second week of training, participants were given a recognition memory test concerning events and details of the initial training session. In this way, the level of memory for events that occurred during the initial training session and the level of memory for facts acquired during the same session were sampled simultaneously in both groups. The question of interest was whether the relative levels of fact and event memory would be the same in the amnesic patients and controls, or whether amnesic patients exhibited a relative sparing of the ability to acquire fact memory. Finally, in addition to the control group that was tested together with the amnesic patients, a total of four additional control groups were tested at longer delay intervals to provide appropriate comparison groups for the amnesic patients for each of the experimental questions. In Experiment 2 we further examined the relation between fact memory and event memory in amnesia, on the basis of the results of the first experiment. Evidence from the first experiment suggested that fact memory and event memory are proportionally impaired in amnesia. However, the fact memory and event memory test differed in certain ways that complicated this comparison. Experiment 2 revisited the question of whether fact memory and event memory are proportionally impaired in amnesia, with a design that better equated the two tests.

Experiment 1

Method

Amnesic Patients

Nine amnesic patients participated in this study (all but H.W. and M.G. in Tables 1 and 2). Six patients had alcoholic Korsakoff's syndrome (4 men and 2 women). They all had participated in either a magnetic resonance imaging (MRI) study (Squire, Amaral, & Press, 1990; for N.F., Squire, 1994, unpublished observations) or a quantitative computed tomography (CT) study (Shimamura, Jernigan, & Squire, 1988), which demonstrated marked reductions in the volume of the mammillary nuclei, reduced thalamic tissue density, and frontal lobe atrophy.

Three other amnesic patients were also tested (2 men and 1 woman). Patient A.B., who was unable to participate in MR studies, became amnesic in 1976 after an anoxic episode and was presumed to have hippocampal damage on the basis of this etiology. Patient L.J. became amnesic gradually in 1988–1989 without any known precipitating event. Her memory impairment has remained stable since that time. MRI studies revealed bilateral reduction in the size of the hippocampal formation (Squire, 1994, unpublished observations). Finally, Patient N.A. became amnesic, primarily for verbal material, following a stab wound to the left diencephalic region with a miniature fencing foil (Squire, Amaral, Zola-Morgan, Kritchevsky, & Press, 1989; Teuber, Milner, & Vaughan, 1968).

These 9 patients averaged 60.1 years of age and 12.6 years of education. Immediate and delayed (12 min) recall of a short prose passage averaged 5.4 and 0 segments, respectively. Their scores on the information and vocabulary portions of the Wechsler Adult Intelligence Scale—Revised (WAIS–R; Wechsler, 1981) averaged 19.8 and 52.7, respectively. Scores on other memory tests appear in Table 2. The mean score on the Dementia Rating Scale (Mattis, 1976) was 131.1 (range = 125–139). Most of the points were lost on the memory subportion of the test (mean points lost = 6.9). The mean score on the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1978) was 55.3 (range = 48–59).

Control Groups

The principal group of controls and the participants in four delayed-control groups were either employees or volunteers at the San Diego Veterans Affairs Medical Center or were members of the retirement community of the University of California, San Diego. The principal group of controls was selected to match the amnesic patients with respect to age, education, and WAIS–R subtest scores for information and vocabulary. The four additional control groups were tested to facilitate comparisons of amnesic patients and controls with respect to three primary issues: (a) relative efficacy of the study–test and study-only procedures, (b) transfer of learning to synonym cues, and (c) the relationship between event and fact memory. Each delayed control group received the first training session and then after a delay interval received one of the tests used in the main experiment. Characteristics of the principal control group and the four delayed-control groups are shown in Table 3.

Materials

The materials consisted of 40 three-word sentences (subject–verb–object, e.g., "*medicine* cured *hiccup*"), based on the set used in a previous study of semantic learning (Tulving et al., 1991). Of the 40

Table 1
Characteristics of Amnesic Patients

Patient	Age (years)	Etiology	WAIS–R IQ	WMS–R Subtest: Attention	Verbal	Visual	General	Delay
N.C.	50	Korsakoff	90	62	80	60	69	<50
H.W.	76	Korsakoff	109	97	84	102	89	54
R.C.	77	Korsakoff	106	115	76	97	80	72
N.F.	58	Korsakoff	94	91	62	73	53	<50
V.F.	74	Korsakoff	103	93	77	65	67	64
P.N.	66	Korsakoff	99	81	77	73	67	53
J.W.	57	Korsakoff	98	104	65	70	57	57
M.G.	62	Thalamic	111	113	89	84	86	63
A.B.	56	Anoxia	104	87	62	72	54	<50
L.J.	56	Unknown	98	105	83	60	69	<50
N.A.	55	Penetrating brain injury	109	102	67	89	68	71
M	63		101.9	95.5	74.7	76.8	69.0	57.6

Note. WAIS–R = Wechsler Adult Intelligence Scale—Revised; WMS–R = Wechsler Memory Scale—Revised. The WAIS–R and the WMS–R index yield a mean score of 100 in the normal population, with a standard deviation of 15. The WMS–R does not provide scores for individuals who score below 50. Therefore, the four scores below 50 were scored as 50 for calculating a group mean.

Table 2
Memory Test Performance of Amnesic Patients

Patient	Diagram recall[a]	Paired associates[b] Trial 1	Trial 2	Trial 3	Word recall (%)[c]	Word recognition (%)[d]	50 words[e]	50 faces[e]
N.C.	3	1	0	1	23	71	31	37
H.W.	6	0	1	0	31	85	35	28
R.C.	3	0	0	3	19	85	37	30
N.F.	4	0	0	2	36	76	28	27
V.F.	8	0	0	0	27	91	27	31
P.N.	2	1	1	1	29	83	31	31
J.W.	4	0	0	2	28	96	29	34
M.G.	0	0	0	2	33	71	39	41
A.B.	4	1	1	2	33	83	32	33
L.J.	3	0	0	0	40	93	33	29
N.A.[f]	17	0	0	2	49	93	34	42
M	4.9	0.3	0.3	1.4	31.6	84.3	32.4	33.0
Healthy[g] (n = 8)	20.6	6.0	7.6	8.9	71	98	41.1	38.1
Alcoholics[g] (n = 8)	16.4	5.1	8.0	8.8	62	97	36.2	36.2

[a]The diagram recall score is based on delayed (12 min) reproduction of the Rey–Osterrieth figure (Osterrieth, 1944; maximum score = 36). The average score for copying the figure was 27.9, a normal score (Kritchevsky et al., 1988). [b]The paired associate scores are the number of word pairs recalled on three successive trials (maximum score = 10 per trial). [c]The word recall score is the percentage of words identified correctly on five successive study–test trials (Rey, 1964). [d]The word recognition score is the percentage of words identified correctly by yes–no recognition across five successive study–test trials. [e]The score for words and faces is based on a 24-hour recognition test of 50 words or 50 faces (modified from Warrington, 1984; maximum score = 50, chance = 25). [f]Patient N.A. is not severely impaired on the nonverbal memory tests because his brain injury is primarily left unilateral. [g]The mean scores for healthy control and alcoholic, nonamnesic subjects shown for these tests are from Squire and Shimamura (1986).

three-word sentences used in the present study, 16 were identical to sentences used in the earlier study, and the remainder were modified versions of those sentences. All sentences were constructed so that the third word of the sentence (hereinafter referred to as the *target*) was difficult to guess from the first two words (hereinafter referred to as the *sentence frame*).

The 40 sentences were divided into two lists of 20 items. For each participant, one 20-item list was assigned to be trained with the study–test procedure, and the other list was assigned to be trained with the study-only procedure (described below). The assignment of each 20-item list to the study–test and study-only learning procedure conditions was counterbalanced such that each list was assigned to

Table 3
Characteristics of Control Groups

Group	*N* Male	*N* Female	Age *M*	Age Range	Years education	WAIS–R subtest Information	WAIS–R subtest Vocabulary	Passage[a] Immediate	Passage[a] Delayed
					Experiment 1				
CON	5	6	62.8	51–76	13.1	20.4	53.3	5.8	5.0
CON-DELAY1	5	7	62.9	40–74	14.1	23.7	55.9	7.1	5.8
CON-DELAY2	4	8	64.4	49–77	14.8	21.2	55.3	8.5	6.5
CON-DELAY3	5	7	64.3	43–73	14.0	19.8	57.3	7.3	5.9
CON-DELAY4	5	6	59.9	46–68	14.0	21.0	50.6	6.8	6.1
					Experiment 2				
CON2	5	5	64.2	56–77	14.0	21.0	54.9	6.7	5.6
CON2-DELAY	4	7	63.1	51–76	13.5	21.3	56.0	7.5	5.6

Note. CON = principal control group for Experiment 1; CON-DELAY1 = control group tested after a delay to match the overall performance of the amnesic (AMN) group on the first test given on Session 5; CON-DELAY2 and CON-DELAY3 = control groups tested after two different delays to match the performance of the AMN group on the transfer test given on Session 6; CON-DELAY4 = control group tested after a delay to match the performance of the AMN group on the event test given on Session 2; CON2 = principal control group for Experiment 2; CON2-DELAY = control group tested after a delay to match the performance of the AMN group on the event test; WAIS–R = Wechsler Adult Intelligence Scale—Revised.
[a]Values refer to the number of segments recalled from a short prose passage.

each learning procedure equally often across participants. For each 3-word sentence, the second word of the sentence was always presented in lowercase letters, and all the letters of the first and last words were capitalized. When only the sentence frame was presented (e.g., as a retrieval cue for the target word), the third word of the sentence was replaced by *?????*, for example, "MEDICINE cured *?????*."

Each of the original 40 sentence frames was also modified to create a matching sentence frame that was similar in meaning to the original. These 40 modified sentence frames were used as cues in the transfer test, described below. They were constructed by replacing either the second word (verb) or both words of a sentence frame with synonyms (e.g., "SIGHTSEER desired *?????*," or "TOURIST desired *?????*" in place of the original sentence "TOURIST wanted SNAPSHOT"). For 21 sentences, both words of the sentence frame were replaced by synonyms; the remaining 19 sentences contained initial words that could not easily be replaced by a synonym (e.g., LIFEGUARD), and for these sentences only the second word (verb) was modified.

Procedure

Overview. The amnesic patient group (AMN) received a total of eight training trials with the 40 sentences, scheduled in four weekly sessions (see Table 4). For each patient, half of the sentences (20) were trained with the study–test procedure, whereas the other 20 sentences were trained with the study-only procedure. Which sentences were assigned to the study–test and study-only conditions was counterbalanced across the patients. In addition, at the beginning of Week 2, the patients were given an 18-item events test based on specific events that had occurred during the first week's training session. This test provided a way to compare the capacity for event memory with the capacity to learn the sentences. Then, on Week 5, there was a test of the 40 sentences studied during the previous 4 weeks, and on Week 6 a transfer test was given that involved synonyms from the sentences that had been studied. Finally, a test to assess long-term retention was given on Week 10.

The principal control group (CON) was tested concurrently with the AMN group and in the same way as the AMN group, with two exceptions. First, because the CON group's learning rate was much faster than the AMN group's learning rate, the CON group was given only two weekly sessions of training (Sessions 1 and 2). Accordingly, the test of the sentences, which occurred on Week 5 for the AMN group, occurred on Week 3 for the CON group; and the transfer test (Week 6 for the AMN group) was administered on Week 4 for the CON group. Second, no test of long-term retention was administered to the CON group.

In addition to the CON group just described, four additional control groups were tested at various study–test delays (CON-DELAY 1–4), after testing of the AMN and CON groups had concluded. Participants were randomly assigned to the CON group and to the CON-DELAY groups (described below).

Study–test and study-only procedures. Two learning procedures were used during training. The first was modeled after the traditional and widely used "method of anticipation" (Brooks & Baddeley, 1976) or study–test method, in which study trials alternate with test trials (Baddeley & Wilson, 1994; Hayman et al., 1993). The second learning procedure used during training was identical to the study–test procedure, except that the test trials were omitted (study-only method). This method does not allow participants any opportunity to make errors during training.

In the study–test procedure, the first two words of the sentence appeared, and the participant was instructed to respond with the appropriate target word. (On the very first trial, the target word had not been studied yet, and the instruction was simply to produce a word that could complete the sentence in a sensible way.) After the participant responded or after 15 s had passed, the target word appeared to complete the sentence. The participant then read the sentence aloud and rated how sensible the sentence was on a 5-point scale: "How much sense does this sentence make?": (1) *very little,* (2) *a little,* (3) *some (average),* (4) *a fair amount,* (5) *a lot.* The participant also estimated on a 5-point scale how many people could have guessed the target word from the first two words without previously seeing the target word: none, few, some, many, all. (The experimenter pointed to the answer and prompted, "How many people could have guessed this word from the first two?")

Table 4
Summary of Experimental Procedure

Group	Weekly learning sessions	Delay	Test	Delay	Test
		Experiment 1			
AMN	4	1 wk	S recall	1 wk	Transfer
CON	2	1 wk	S recall	1 wk	Transfer
CON-DELAY1	1	2 wks	S recall		—
CON-DELAY2	1	3–5 days	—		Transfer
CON-DELAY3	1	2 wks	—	—	Transfer
CON-DELAY4	1	4 wks	ET, S recall	—	—
		Experiment 2			
AMN	1	1 day	ET, S recall, S recogn.		—
CON2	1	1 day	ET, S recall, S recogn.		—
CON2-DELAY	1	6 wks	ET, S recall, S recogn.		—

Note. Dashes indicate that no test was given. The amnesic group (AMN) and the control group (CON) in Experiment 1 took the events test (ET) at the beginning of the second weekly learning session. CON-DELAY1 = control group tested after a delay to match the overall performance of AMN on the first test given on Session 5; CON-DELAY2 and CON-DELAY3 = control groups tested after two different delays to match the performance of the AMN group on the transfer test given on Session 6; CON-DELAY4 = control group tested after a delay to match the performance of the AMN group on the event test given on Session 2; CON2 = principal control group for Experiment 2; CON2-DELAY = control group tested after a delay to match the performance of the AMN group on the event test; ET = events test; S Recall = sentence recall; S recogn. = sentence recognition.

In the study-only procedure, the first two words of the sentence appeared initially, and 250 ms later the target word also appeared, thereby completing the sentence. The small delay in the appearance of the target word allowed the participant to see the sentence segmented into a cue and a response (as in the study–test procedure), but the target word appeared quickly enough to prevent the participant from making an erroneous response to the cue. After the entire sentence had been presented, the participant then read the sentence aloud and rated the sentence on the two rating scales described above in the study–test procedure.

Before training began with the study–test and study-only procedures, a pretest was first administered to all participants to determine the probability of completing sentence frames with the correct target word in the absence of prior study and to identify those sentence frames for which test participants had a strong preexisting response. Participants were instructed as follows:

> I'm going to show you some pairs of words that could be the first two words of a sentence. For each of these pairs, I'd like you to consider whether a word comes to mind that could complete the sentence in a sensible way. For example, I could show you the words *boy hit* and a word like *baseball* may come to mind as a word that could complete the sentence in a sensible way.

For each of 40 two-word sentence frames, participants were given 15 s to respond. If a participant responded with more than one word or gave a proper name, the participant was asked for an alternative answer. Participants were reminded frequently during the pretest that it was not necessary to give an answer to every cue, although they could do so if they wished.

After the pretest was administered, the learning trials began (2 trials per session). The training schedule for each session consisted of presenting all 40 sentences in two blocks of 20 sentences each: the list assigned to be trained with the study–test procedure and the list assigned to be trained with the study-only procedure. After all 40 sentences had been presented once with the appropriate learning procedure, the same sentences were presented a second time in the same order using the same procedure. The order of learning procedures (study–test or study-only) was counterbalanced across participants, with half of the participants beginning training with the study–test procedure and half beginning with the study-only procedure. On even-numbered sessions, the order of presentation of learning procedures was reversed for each participant; for example, a participant who began training on Session 1 with the study–test procedure began Session 2 with the study-only learning procedure.

Training continued in weekly sessions (2 trials per session) until the amnesic patients had received eight trials across 4 weeks of training and the controls had received four trials across 2 weeks of training. For testing (on Week 5 for amnesic patients and Week 3 for controls), all 40 sentence frames were presented in the same random order, and participants were given 15 s to produce the target word that they had studied on previous sessions. If a participant was unsure of an answer, guessing was encouraged. No feedback was given.

After the test of all 40 sentence frames, one additional trial of study–test and study-only learning was given, in the same manner as in the earlier learning sessions. This second learning trial was followed by a second test of all 40 sentence frames in a new random order. The additional learning was given because the learning level attained by some amnesic patients was low. Because considerable savings were observed within training sessions (see Figure 1), it was expected that a second learning trial and a second test in the same session would raise performance. To equate the retention interval between sentence presentation and the test for those sentences learned by the study–test procedure and those learned by the study-only procedure, the sentences were divided into sublists of 10 items each and were arranged in an ABBA order. Thus, for half of the participants, the first 10 sentences were presented with the study–test procedure, followed by

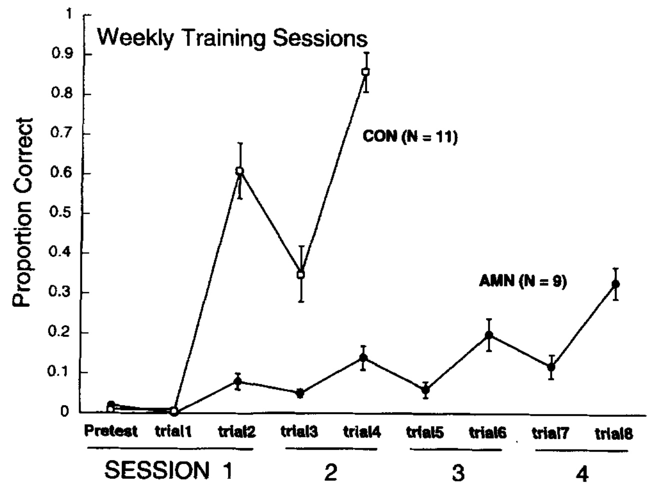

Figure 1. Experiment 1. Performance on a pretest involving all 40 two-word sentence frames and in weekly sessions in which 20 of the sentence frames were always tested, that is, those patients who were being trained with the study–test procedure. AMN = amnesic patients; CON = controls. Error bars indicate the standard error of the mean. For clarity, the error bars are omitted for the pretest and for Trial 1 of Session 1.

20 sentences with the study-only procedure, followed by the remaining 10 sentences presented with the study–test procedure. For the other participants, the study-only list was substituted for the study–test list in the ABBA design.

Long-delayed test of study–test and study-only learning. For the AMN group, a final test of retention for all 40 sentences was given 5 weeks later (10 weeks after the first training session). This test was identical to the test of study–test and study-only learning that had been given on Session 5 to the AMN group, except that the cues were presented in a new random order.

Events test. At the start of Session 2, a separate test was administered to assess retention of specific events that had occurred during Session 1. The test consisted of 18 two-alternative, forced-choice questions about information such as the duration of the previous session, the stimuli that had been used, the presence or absence of objects such as a stopwatch and a calculator, and two unique events that had been introduced arbitrarily into the first training session (a short test with 10 index cards and one item from the WAIS–R Block-Design subtest). Before this test was administered, the experimenter reminded the participant of the previous session and informed the participant that the questions would refer only to that session. Each test question was read aloud by the experimenter.

Transfer test. A transfer test was administered on Week 6 for the amnesic patients and on Week 4 for the control group. In the transfer test, participants were presented with 40 sentence frames that either matched the original cues used during training (e.g., "TOURIST wanted *?????*"; correct answer: SNAPSHOT) or cues that had been modified so that either the second word (verb) or both words of the sentence frame were replaced by synonyms (e.g., "SIGHTSEER desired *?????*", or "TOURIST desired *?????*"). The purpose of the transfer test was to determine how well the information learned during the preceding training sessions would transfer to related cues, that is, whether the learned information could be used in a flexible way.

The transfer test was created individually for each participant in the CON and AMN groups, on the basis of the performance on the most recent test of study–test and study-only learning for each participant (Trial 2 of Week 5 for amnesic patients; Trial 2 of Week 3 for controls). The intention was to assign to the original cue and synonym conditions approximately the same number of sentences that had been answered correctly in the most recent test. For each participant, half of the sentence frames were presented using the original cues, and the other half was presented using the synonym that had been prepared for that sentence. The remaining sentences, which had been answered incorrectly in the recent session, were randomly assigned to either the original cue or synonym cue condition, with the constraint that a total of 20 sentence-frame cues were presented for each cue type (if a participant answered an odd number of sentences incorrectly, the participant received 21 cues of one type and 19 of the other type). Thus, each participant was presented with a transfer test that consisted of a randomly mixed list of an average of 20 sentence frames using the original cue and 20 sentence frames using the synonym cue. On average, for the amnesic group 48% of the 20 synonym cues involved replacing one cue word and 52% involved replacing two cue words. For the controls, the corresponding percentages were 49% and 51%.

Participants were informed that they would be tested on previously learned sentences, but that sometimes one or both words of the sentence frame would be similar in meaning to (but different from) the words of the original sentence frame. Guessing was encouraged. Participants were given 15 s to respond to each of the 40 sentence frames. At the end of the transfer test there was a 5-min delay, followed by a second transfer test. This test was identical to the first one, except that cues that had been presented in the first test as original cues were presented in the second transfer test as synonyms, and vice versa. Also, the 40 cues were rearranged into a new random order.

Delayed-control groups. Four additional control groups were tested to facilitate comparisons of the amnesic patients and controls. Each delayed-control group received the same training Session 1 that the AMN and CON groups initially received. Session 1 was followed after a delay interval by one of the retention tests used in the main experiment: the test of study–test and study-only learning, the transfer test, or the test of event and fact memory. The delay interval used for each delayed-control group was intended to match the performance score of the delayed-control group to the score obtained by the AMN group on one of the three tests, as described below.

Delayed-Control Group 1. One control group (CON-DELAY1) was given Session 1 of learning and then tested after a delay interval of 2 weeks with the test of study–test and study-only learning. The question of interest was how the efficacy of the study–test and study-only learning procedures would compare when overall level of performance was equated for the AMN and control groups.

Delayed-Control Groups 2 and 3. Two control groups (CON-DELAY2 and CON-DELAY3) were tested in an attempt to match the score obtained by the amnesic group on the transfer test. CON-DELAY2 was given Session 1 of learning and then tested after 3–5 days. CON-DELAY3 was given Session 1 of learning and then tested after 2 weeks. The question of interest was how well performance would transfer from the original cues to synonyms when the overall level of performance was equated for the AMN and control groups.

Delayed-Control Group 4. A final control group (CON-DELAY4) was given Session 1 of learning and then after a delay of 4 weeks was given the events test and two more trials of learning of the 40 sentences that had been trained with the study–test and study-only procedures. At this delay, the performance level achieved by CON-DELAY4 on the events test matched the level achieved by the AMN group after 1 week. The question of interest was what relationship would be observed in each group between the event and fact memory scores.

Results

Several analyses were conducted to compare the performance of amnesic patients and controls during the training sessions (i.e., on the items trained using the study–test procedure), on the subsequent test of the items trained using both the study–test and study-only procedures, and on the transfer test from original cues to synonyms. In addition, performance on the events test was compared with performance on the sentences test. For each analysis, comparisons between the AMN and CON groups were followed by additional comparisons between the AMN group and the CON-DELAY groups.

Pretest and Training Sessions

Only a small number of two-word sentence-frame cues were completed with the correct target words prior to training (mean proportion correct on the pretest was .02 for the AMN group and .01 for all the control groups, including CON and CON-DELAY1–4). For participants who completed sentence frames correctly on the pretest, the correctly completed sentences were excluded from further analysis. No participant answered more than three sentence frames correctly out of 40 on the pretest.

Figure 1 shows the performance of the AMN and CON groups during the weekly training sessions. The learning rate was much faster for the CON group than for the AMN group. The CON group approached perfect performance on the second test of Session 2, whereas performance of the AMN group was still low after Session 4. Nevertheless, the amnesic patients did exhibit gradual improvement with increasing numbers of training trials. Moreover, the increase in performance between the two tests within each session was greater with each succeeding session. This facilitation of learning within each session presumably reflected a savings in relearning (Ebbinghaus, 1885) of sentences that had been learned during previous sessions but that had been forgotten over the intervening delay.

Test of Study–Test and Study-Only Learning

Figure 2 shows performance on the test of study–test and study-only learning for the AMN, CON, and CON-DELAY1 groups. A 2 (group: AMN vs. CON) × 2 (learning procedure:

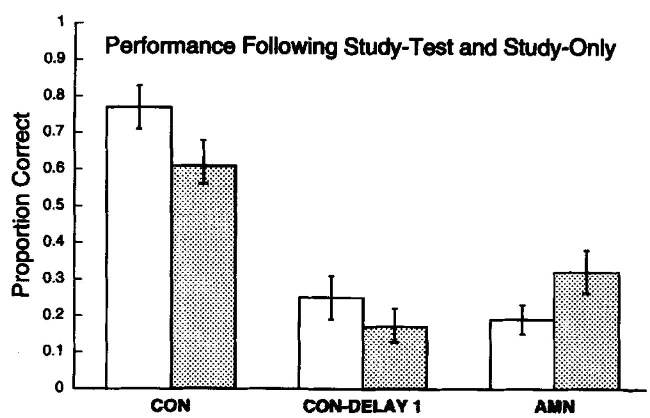

Figure 2. Experiment 1. Performance on tests of the study–test (open bars) and the study-only (shaded bars) procedure, which was given after 2 weeks of training in the case of controls (CON), after 4 weeks of training in the case of amnesic patients (AMN), and after 2 weeks after one session of training in the case of delayed controls (CON-DELAY1). Error bars indicate the standard error of the mean.

study–test vs. study-only) mixed-factorial analysis of variance (ANOVA) was conducted to compare the efficacy of the study–test and study-only learning procedures. The overall level of learning was higher in the CON group than the AMN group, $F(1, 18) = 27.67$, MSE = .07, $p < .001$. In addition, there was no overall effect of learning procedure, $F(1, 18) < 1$, and there was a crossover interaction between group and learning procedure, $F(1, 18) = 21.52$, MSE = .01, $p < .001$. Planned comparisons showed that, whereas the CON group completed correctly more sentence frames that had been trained with the study–test procedure than with the study-only procedure, $t(10) = 3.71, p < .01$, the AMN group exhibited the opposite pattern and benefited more from the study–test procedure than the study-only procedure, $t(8) = 2.92, p < .02$.

To determine whether the efficacy of the study–test and study-only learning procedures might have differed because the overall level of learning was different for the AMN and CON groups, the same analysis was repeated for the AMN group and the CON-DELAY1 group. The CON-DELAY1 group had been trained for two trials in Session 1 and was then tested 2 weeks later with the intention of matching the performance of this group to the overall performance of the AMN group on the first test of the study-only/study–test procedure. The analysis confirmed that the overall level of learning did not differ between the two groups, .25 ± .04 for the AMN group (hereinafter, values following the ± symbol indicate the standard error of the mean) versus .21 ± .04 for the CON-DELAY1 group, $F(1, 19) < 1$. In addition, there was no overall effect of learning procedure, $F(1, 19) = 1.31$, MSE = .006, $p > .27$, and there was again a crossover interaction between group and learning procedure, $F(1, 19) = 18.12$, MSE = .006, $p < .001$. Planned comparisons showed that the CON-DELAY1 group completed more sentence frames that had been trained with the study–test procedure than with the study-only procedure, $t(11) = 2.98, p < .02$; the same pattern obtained for the CON group. Thus, the difference in efficacy of the learning procedures between the amnesic patients and controls remained when the overall level of performance was equated.

As described in the *Procedure* section, a second study–test/study-only test was given in the same session following an additional trial of learning (see Table 5). For both the CON and CON-DELAY1 groups, the additional learning trial resulted in near-ceiling levels of performance (proportion correct with the study–test learning procedure = .96 ± .02 and .93 ± .02 for the CON and CON-DELAY1 groups, respectively, and .94 ± .03 and .89 ± .03 for the study-only procedure). For the amnesic patients, performance on the second test improved considerably from performance on the first test, but the advantage of the study-only learning procedure remained; proportion correct with the study–test learning procedure = .41 ± .04, with the study-only procedure = .59 ± .08; planned comparison between the study–test and study-only procedures, $t(8) = 3.93, p < .01$.

Long-Delayed Study–Test/Study-Only Test

When the amnesic patients were tested on one final occasion (Session 7 on Week 10), they continued to exhibit an advantage of the study-only learning procedure. The patients completed correctly more sentences that had been studied with the study-only learning procedure (.29 ± .07) than with the study–test learning procedure (.16 ± .05); paired two-tailed t test between the study–test and study-only learning procedures, $t(8) = 3.85, p < .01$. These results indicate significant retention by amnesic patients of information acquired during training (compare performance on Week 10 to performance on the first and second tests of study–test and study-only learning given during Week 5; first test: study-only = .32 ± .06, study–test = .19 ± .04; second test: study-only = .59 ± .08, study–test = .41 ± .04). Note also that during the 5-week interval between Week 5 and Week 10, the 40 sentences also appeared in two more tests (Session 6). The fact that overall level of performance did not greatly decrease and that the advantage of study-only learning remained across a 5-week interval indicates that the information acquired during the training sessions was substantially resistant to forgetting and interference.

Correlational Analysis

To determine what factors contributed to the advantage of the study-only procedure for the amnesic patients, a correla-

Table 5
Individual Scores of Amnesic Patients on the Two Kinds of Tests in Experiment 1

	Week 5 (Test 1)		Week 5 (Test 2)		Week 10	
Patient	Study–test	Study-only	Study–test	Study-only	Study–test	Study-only
N.C.	.10	.50	.45	.75	.10	.20
R.C.	.05	.30	.25	.55	.00	.25
N.F.	.05	.15	.30	.25	.05	.15
P.N.	.15	.20	.30	.50	.10	.20
V.F.	.25	.26	.40	.53	.15	.25
J.W.	.35	.58	.65	.95	.35	.55
A.B.	.10	.05	.35	.32	.00	.00
L.J.	.21	.30	.42	.65	.35	.70
N.A.	.42	.55	.58	.80	.30	.35
M	.19	.32	.41	.59	.16	.29

Note. Test 1 on Week 5 refers to the data from Figure 2. The test on Week 10 refers to the long-delayed test (see text).

tional analysis was conducted. Two factors were considered: performance scores on tests of memory function (Wechsler Memory Scale—Revised [WMS-R; Wechsler, 1987], General and Delayed indexes); and performance scores on tests of frontal lobe function (number of categories correct on the Wisconsin Card Sorting Test [WCST; Nelson, 1976], the DRS [Mattis, 1976], initiation–perseveration subscale, and the California Card Sorting Test [CCST; Delis, Squire, Bihrle, & Massman, 1992], percentage of correct sorts on Condition 1. Performance scores on the events test were considered separately, because the events test was expected to be sensitive to both memory and frontal lobe factors).

To calculate pooled estimates for each factor, scores on each test were first converted into ranked scores. The ranked scores for each participant were then summed across the two tests comprising the memory factor and across the three tests comprising the frontal lobe function factor (i.e., for each participant a sum was calculated for the ranked scores on the two memory tests, and a separate sum was calculated for the ranked scores on the three tests that assessed frontal lobe function). These two sums from each participant were then ranked to reflect pooled estimates for each participant of performance on the memory and frontal lobe function tests, respectively. Finally, the events test scores were also converted into ranked scores. Correlations were then calculated between these three ranked scores and a score representing the advantage of the study-only procedure. Specifically, the study-only advantage was calculated according to the following formula: (proportion correct score for the 20 sentences trained with the study-only procedure) − (proportion correct score for the 20 sentences trained with the study–test procedure). This difference score was calculated for each amnesic patient from the first test of all 40 sentences on Session 5, because this was the first test of the items trained with the study-only procedure.

It should be noted that correlational analyses conducted with a small sample should be interpreted cautiously because of low power and the possibility of spurious results. Nevertheless, we present the findings from our correlational analysis because of the relevance of correlational data to current thinking about the relationship of degree of memory impairment and frontal lobe dysfunction to the study-only advantage in amnesia (Baddeley & Wilson, 1994; Hayman et al., 1993; Squire, Knowlton, & Musen, 1993).

The pooled estimator of frontal lobe function correlated (negatively) with degree of study-only advantage ($r = -.64$, $p < .06$), as did performance on the events test ($r = -.58$, $p = .10$). In each case, lower performance on these tests (i.e., greater dysfunction) was associated with increased benefit from the study-only procedure. In contrast, the pooled estimator of severity of memory deficit was not highly correlated with the study-only advantage ($r = .30, p > .10$).

These simple correlations indicated that patients with low scores on the frontal lobe tests and on the events test benefited more from the study-only procedure. Thus, patients who had frontal lobe deficits and who also had difficulty recollecting the context of prior learning sessions (which has been linked to frontal lobe dysfunction; Janowsky, Shimamura, & Squire, 1989) benefited the most from the study-only procedure. The question therefore arises whether the advantage of the study-only procedure is entirely a consequence of frontal lobe dysfunction.

To address this question, we examined the data from the three non-Korsakoff amnesic patients (A.B., L.J., and N.A.). These patients have no detectable frontal lobe deficits. A 2 (group: non-Korsakoff amnesic patients vs. CON-DELAY 1) × 2 (learning procedure: study–test vs. study-only) mixed-design factorial ANOVA found no effect of group, $F < 1$, no overall effect of learning procedure, $F < 1$, and a crossover interaction between group and learning procedure, $F = 5.23$, $MSE = .004$, $p < .04$. This interaction indicated that the non-Korsakoff amnesic patients learned more with the study-only procedure than the study–test procedure (.30 ± .14 vs. .24 ± .09, respectively). The CON-DELAY1 participants exhibited the opposite pattern, learning more with the study–test procedure than the study-only procedure (.25 ± .06 vs. .17 ± .05, respectively). The crossover interaction between the non-Korsakoff amnesic patient group and the CON-DELAY1 group suggests that memory impairment by itself is sufficient to produce a pattern opposite to what is observed with controls. However, this conclusion must be tentative because (a) only 3 non-Korsakoff patients were available and (b) the study-only advantage for these 3 patients (6%) was not itself significant, $t(2) = 1.04, p > .10$.

Original Cues Versus Synonyms

Figure 3 shows the results for the transfer test in which the sentence frames consisted of either the original cues or synonyms. A 2 (group: AMN vs. CON) × 2 (cue: original vs. synonym) × 2 (learning procedure: study–test vs. study-only) mixed-factorial ANOVA was conducted to compare the degree of transfer to synonym cues (i.e., the difference between performance with original cues vs. synonym cues) by controls and amnesic patients and to determine whether transfer was

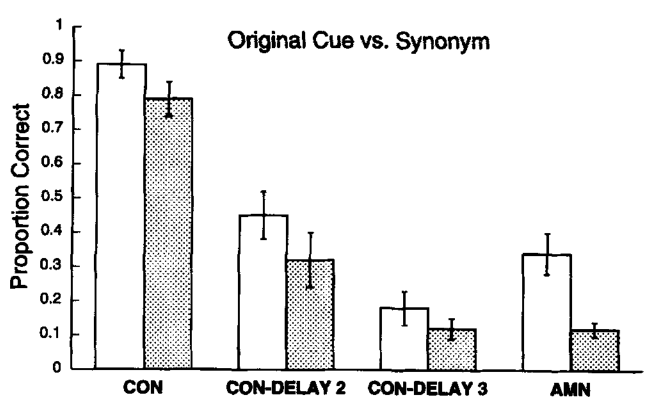

Figure 3. Experiment 1. Performance when the sentence frames were presented in their original form (open bars) or when the original cue words were replaced by synonyms (shaded bars). Testing was scheduled on the week after the study–test/study-only tests (presented in Figure 2) for both the controls (CON) and the amnesic patients (AMN). Delayed controls were given Session 1 of training with the sentences and then tested after 3–5 days (CON-DELAY2) or after 2 weeks (CON-DELAY3). Error bars indicate the standard error of the mean.

affected by the procedure used to learn the sentences. The CON group had higher overall performance than the AMN group, $F(1, 17) = 77.80$, MSE = .09, $p < .001$, and in both groups more original cues were completed correctly than synonyms, $F(1, 17) = 45.72$, MSE = .01, $p < .001$. There was also a significant interaction between group and type of cue, indicating that there was a smaller difference between performance with original cues versus synonym cues in the CON group than in the AMN group, and suggesting that greater transfer of learning to synonym cues occurred in the CON group, $F(1, 17) = 5.51$, MSE = .01, $p < .03$.

A comparison was also conducted between those cues on the transfer test that had been trained with the study–test procedure (10 original cues and 10 synonyms) and those that had been trained with the study-only procedure (10 original cues and 10 synonyms). The findings were the same as for the preceding analysis of learning with both the study–test and study-only procedures. There was a (now marginal) crossover interaction between group and learning procedure, $F(1, 17) = 3.24$, MSE = .02, $p < .09$. The AMN group completed more sentence frames on the transfer test for sentences trained with the study-only procedure (proportion completed for the study–test procedure = .19 ± .04; study-only procedure = .27 ± .05), whereas the CON group exhibited the opposite pattern (proportion completed for the study–test procedure = .86 ± .05; study-only procedure = .82 ± .05). The magnitude of this interaction was likely constrained by a ceiling effect in the CON group. The crossover interaction resulted in no main effect of learning procedure, $F(1, 17) < 1$, overall proportion of sentence frames completed on the transfer test that followed the study–test procedure = .54 ± .06; study-only procedure = .56 ± .06.

Because the greater transfer (i.e., lesser difference between performance with original cues vs. synonym cues) exhibited by the CON group compared with the AMN group might have resulted from overall differences in group performance (including the possibility of ceiling effects in the CON group), two additional control groups were tested in an attempt to match the overall performance level of the amnesic patients on the transfer test. The CON-DELAY2 group was tested 3–5 days after Session 1 of training, which resulted in an overall level of performance that was nonsignificantly higher than that of the AMN group (CON-DELAY2 = .38, AMN = .23) $F(1, 19) = 3.77$, MSE = .13, $p < .07$. The CON-DELAY3 group was tested 2 weeks after Session 1 of training, which resulted in an overall level of performance that was nonsignificantly lower than that of the AMN group (CON-DELAY3 = .15, AMN = .23) $F(1, 19) = 1.77$, MSE = .08, $p < .20$.

The same analysis that had been performed with the CON group and the AMN group was first carried out with the CON-DELAY2 group and the AMN group. For both groups, more targets were recalled to the original cues than to synonym cues, $F(1, 19) = 29.41$, MSE = .02, $p < .001$. In contrast to the results obtained with the AMN and CON groups, there was no greater difference between performance with original cues versus synonym cues in the AMN group than in the CON-DELAY2 group, $F(1, 19) = 2.09$, MSE = .02, $p > .10$. It should be noted that the power for this interaction was low, however (power values of .44, .20, and .05 for large, medium, and small effect sizes; Cohen, 1988).

A comparison was also conducted with the AMN and CON-DELAY2 groups between those cues on the transfer test that had been trained with the study–test procedure (10 original cues and 10 synonyms) and those that had been trained with the study-only procedure (10 original cues and 10 synonyms). There was a crossover interaction between group and learning procedure, $F(1, 19) = 25.26$, MSE = .02, $p < .001$; the AMN group completed more sentence frames on the transfer test for sentences trained with the study-only procedure (proportion completed for the study–test procedure = .19 ± .04; study-only procedure = .27 ± .05), whereas the CON-DELAY2 group exhibited the opposite pattern (proportion completed for the study–test procedure = .50 ± .05; study-only procedure = .27 ± .05). There was a main effect of learning procedure, $F(1, 19) = 6.66$, MSE = .02, $p < .02$. The overall proportion of sentence frames completed on the transfer test following the study–test procedure = .37 ± .04; study-only procedure = .27 ± .03.

The results for the CON-DELAY3 group were less easy to interpret. In both the CON-DELAY3 group and the AMN group, more sentences were completed correctly in response to the original cues than to synonym cues, $F(1, 19) = 29.70$, MSE = .01, $p < .001$. There was also a significant interaction between group and performance on original cues versus synonyms, with the AMN group exhibiting a greater difference between performance with original cues versus synonym cues than the CON-DELAY3 group, $F(1, 19) = 10.09$, MSE = .01, $p < .01$. However, the level of transfer in the CON-DELAY3 group may have been influenced by a floor effect in the original cue condition. The level of performance with original cues in this group was only 18%, a level that left little room for a decrement when transfer to synonym cues was assessed. Indeed, of the 12 participants in this group, 3 scored 0% correct when tested with original cues and 2 scored only 5%. Thus, 5 of the 12 control participants were at the lowest range of the performance scale. In contrast, the lowest level of performance in the original cues condition by an amnesic patient was 10%, and all the other amnesic patients performed above this level.

A comparison was also conducted with the AMN and CON-DELAY3 groups between those cues on the transfer test that had been trained with the study–test procedure (10 original cues and 10 synonyms) and those that had been trained with the study-only procedure (10 original cues and 10 synonyms). There was a crossover interaction between group and learning procedure, $F(1, 19) = 11.33$, MSE = .17, $p < .01$. The AMN group completed more sentence frames on the transfer test for sentences trained with the study–test procedure (proportion completed for the study–test procedure = .19 ± .04; study-only procedure = .27 ± .05), whereas the CON-DELAY3 group exhibited the opposite pattern (proportion completed for the study–test procedure = .20 ± .05; study-only procedure = .09 ± .03). The crossover interaction resulted in no main effect of learning procedure, $F(1, 19) < 1$, overall proportion of sentence frames completed on the transfer test following the study–test procedure = .20 ± .03; study-only procedure = .17 ± .03.

Event and Fact Memory

Figure 4 shows performance on the events test and the sentences test in Session 2 (Week 2) by the AMN and CON groups, and by the CON-DELAY4 group (tested 4 weeks after Session 1). Performance on these tests was above chance for each group; for the events test, t test against .50 (chance), $t(8) = 4.66, p < .01$; $t(10) = 8.52, p < .01$; $t(10) = 5.74, p < .01$, for the AMN, CON, and CON-DELAY4 groups, respectively; for the sentences test, t test against 0 (chance), $t(8) = 6.00, p < .01$; $t(10) = 4.76, p < .01$; $t(10) = 4.00, p < .01$, for the AMN, CON, and CON-DELAY4 groups, respectively. Performance of the AMN group on the events test was bimodal. Patients with Korsakoff's syndrome ($n = 6$) performed worse than the other patients ($n = 3$), $t(7) = 2.71, p < .03$, unpaired two-tailed t test; mean performance was .61 ± .04 for the Korsakoff patient group and .76 ± .02 for the other patients. These two subgroups performed similarly on the sentences test, $t(7) = 1.53, p > .10$, unpaired two-tailed t test.

A 2 (group: AMN vs. CON) × 2 (test: events vs. sentences) mixed-factorial ANOVA was conducted to compare the two groups with respect to event and fact memory. The analysis showed that the CON group had better performance overall on both tests than the AMN group, $F(1, 18) = 18.17$, MSE = .03, $p < .001$, and that there was a marginal interaction between group and test, $F(1, 18) = 3.38$, MSE = .02, $p < .08$. Specifically, there was a greater difference between performance in the events and sentences tests in the AMN group than in the CON group.

Because differences between the AMN and CON groups on the two tests may have been due to the difference in overall performance, a second control group (CON-DELAY4) was tested after a long delay (4 weeks) in an attempt to match the level of performance of the AMN group on the events test. The result was that the AMN and CON-DELAY4 groups did not differ in their performance on the events test, $t(18) = .73, p > .10$, two-tailed unpaired t test. Moreover, the finding of particular interest was that, having matched the overall level of performance, there was now no interaction between group and test type, $F(1, 18) = 1.34$, MSE = .008, $p > .10$. Thus, for the amnesic patients there was no evidence for a disproportionately severe deficit in event memory compared with fact memory. In fact, the fact memory score obtained by the amnesic patients was slightly below that obtained by the CON-DELAY4 group; .05 ± .01 for the AMN group, .15 ± .04 for the CON-DELAY4 group, $t(18) = 2.36, p < .03$. Thus, the level of fact memory ability in amnesic patients was lower than what it should have been given the level of event memory.

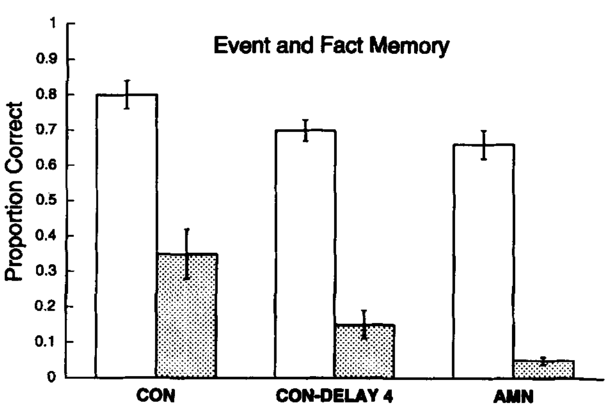

Figure 4. Experiment 1. Performance on the events test (open bars), which was given at the beginning of Session 2, and in the sentences test (shaded bars) that was given in the same session (study–test procedure only). CON = controls; AMN = amnesic patients; CON-DELAY4 = delayed controls given Session 1 of training and then given both the events test and sentences test after 4 weeks. Error bars indicate the standard error of the mean.

Discussion

The main findings of Experiment 1 are considered in the General Discussion. Experiment 2 was motivated by three possible concerns about Experiment 1 that complicated the comparison between event memory and fact memory. First, fact memory in Experiment 1 was assessed during the test phase of the study–test procedure, during the second weekly session. However, the study–test procedure disadvantaged the fact learning of amnesic patients and benefited the fact learning of controls. Thus, the estimate of fact memory for the amnesic patients, which was used in the comparison between event memory and fact memory in Experiment 1, was obtained under conditions (i.e., the study–test procedure) that probably underestimated the capacity for fact learning. Accordingly, in Experiment 2 all sentences were trained with the study-only procedure. The idea was that this procedure should provide a higher estimate of the capacity of amnesic patients to accomplish fact learning, and we could then ask whether the same relationship between event memory and fact memory would be found as was found in Experiment 1.

Another concern was that the overall level of fact memory was low (close to floor) in both the amnesic patients and delayed controls at the point at which it was sampled. In Experiment 2, the procedure was modified to increase the level of fact memory. Specifically, four training trials were presented in a single session (only two trials were presented in Experiment 1), and memory was assessed after only 1 day (instead of 1 week).

A final concern about Experiment 1 was that the format of the event test and the fact memory test differed. The event test was a test of recognition memory, and the fact test was a test of cued recall. Thus, difference in test format was confounded with the event versus fact memory comparison. In Experiment 2 we assessed fact memory in two ways, first with a cued-recall test (as in Experiment 1) and then with a two-alternative, forced-choice recognition-memory test (to match the format of the event test).

Experiment 2

Method

Amnesic Patients

Ten amnesic patients (see Tables 1 and 2) participated in Experiment 2 (except for N.C., who only participated in

Experiment 1). Of the 2 patients who had not participated in Experiment 1, 1 patient (H.W., male) had alcoholic Korsakoff's syndrome. The other patient (M.G., female) became amnesic following a bilateral thalamic infarction confirmed by MRI (Squire, Amaral, & Press, unpublished observations).

These 10 patients averaged 63.0 years of age and 12.5 years of education. Immediate and delayed (12-min) recall of a short prose passage averaged 4.5 and 0 segments, respectively. Scores on other memory tests appear in Table 2. The mean score on the DRS (Mattis, 1976) was 131.0 (range = 125–143). Most of the points were lost on the memory subportion of the test (mean points lost = 6.1). The mean score on the Boston Naming Test was 56.2 (range = 54–59).

Control Groups

The principal group of controls (CON2) and the delayed-control group (CON2-DELAY) consisted of new participants from the same pool described in Experiment 1 (Table 3). The participants in each group matched the amnesic patients with respect to the same criteria used in Experiment 1.

Materials

The materials consisted of 20 new three-word sentences constructed as described in Experiment 1. The third word of each sentence (the target) was difficult to guess from the first two words (e.g., JAPANESE welcomed AMBASSADOR). The words in the 20 sentences had the same average length and frequency as the words in the sentences used in Experiment 1. Words similar in meaning to words used in Experiment 1 were avoided to minimize the possibility of interference.

For each of the 20 sentences, an alternative word was selected as a foil for the recognition memory test (e.g., BUSINESSMAN instead of AMBASSADOR). The target words and the foils were selected on the basis of a study with 10 pilot participants such that participants were equally likely to guess the primary or the alternative target in the absence of prior study.

Procedure

Overview. The experiment was conducted in two sessions. Session 1 consisted of a pretest and four training trials with the study-only procedure. In Session 2, three memory tests were given in the following order: a 20-item event recognition test that assessed memory for events that had occurred during Session 1, a fact recall test for the sentences trained in Session 1, and a 20-item fact recognition test for the same sentences. Sessions 1 and 2 occurred on successive days for the AMN and CON2 groups. For the CON2-DELAY group the interval between Sessions 1 and 2 ranged from 3 to 6 weeks (4 participants at 3 weeks, 6 participants at 5 weeks, and 2 participants at 6 weeks; M = 4.5 weeks). This range of delays for the CON2-DELAY group reflected the fact that we combined participants from three different delay intervals to construct a control group whose average score matched the score of the AMN group on the fact recognition test. (The fact recognition test was used to match the CON2-DELAY and AMN groups in order to equate overall performance level between groups). Except for retention interval the AMN, CON2, and CON2-DELAY groups were tested identically. The AMN and CON2 groups were tested during the same time period. The CON2-DELAY group was tested after all testing of the AMN and CON2 groups had been completed.

Pretest. Before training began, a pretest was administered to determine the probability of completing sentence frames with the correct target word in the absence of prior study. The procedure was the same as in Experiment 1, with one exception. If a participant produced the correct target to a sentence frame on the pretest, that sentence was replaced with an alternate sentence that had been selected according to the same criteria as was used for the other 20 sentences.

Training trials. Immediately after the pretest had been administered, the training trials began. Each participant received four trials of training on the 20 sentences using the study-only procedure, as described in Experiment 1. Thus, on each trial the first two words of each sentence appeared, followed a moment later by the target word that completed the sentence. The participant read the sentence aloud and rated the sentence according to how much sense the sentence made and according to how many people could have guessed the target word from the other two words. The four training trials proceeded without a break between trials. After the fourth trial of training, a short three-item questionnaire was given. The purpose of the questionnaire was to introduce a unique event into Session 1 for purposes of the event recognition test given on Session 2.

Event recognition test. At the start of Session 2, a test was administered to assess retention of specific events that had occurred during Session 1. The experimenter first reminded the participant of the previous session and informed the participant that the questions would refer only to that session. Each test question was read aloud. The test consisted of 20 two-alternative, forced-choice questions about information such as the duration of the previous session, the stimuli that had been used, the presence or absence of objects such as a stopwatch and a calculator, and two unique events that had been introduced arbitrarily into the first training session (a questionnaire and one trial of the WAIS–R digit span subtest). The test was similar to the events test given in Experiment 1. However, for questions that were retained from Experiment 1, the correct answer was changed (e.g., in Experiment 1 the correct answer to the question "Was a calculator on the table next to the computer?" was "no"; in Experiment 2 the correct answer was "yes"). Immediately after the event recognition test, the fact recall test was given.

Fact recall test. The fact recall test was conducted in the same way as in Experiment 1. The sentence frames for all 20 sentences were presented in a random order, and participants were allowed 15 s to recall the correct target that had been studied with each cue. Two different random orders were used for presentation of cues during the test. Each random order was used equally often across participants.

Fact recognition test. Immediately after completing the fact recall test, participants were given the 20-item fact recognition test. Each cue was presented for 15 s together with two alternatives that appeared one above the other and to the right of the cue. The correct and incorrect alternatives appeared equally often above and below the cue. Participants were asked to choose the alternative they remembered having studied with the cue. Participants who were unsure were asked to guess. Two different random orders were used for presentation of cues during the test, and each random order was used equally often across participants.

Results

Pretest

As in Experiment 1, only a small number of two-word sentence-frame cues were completed with the correct target words prior to training (mean proportion correct on the pretest was .02 for the AMN and CON2-DELAY group and .01 for the CON2 group). No participant answered more than two sentence frames correctly out of the 20 presented.

Event and Fact Memory

Figure 5 shows performance in Session 2 on the event recognition test, the fact recognition test, and the fact recall test for the AMN, CON2, and CON2-DELAY groups. Two individuals, the amnesic patient H.W. and 1 control participant in the CON2-DELAY group, were excluded. H.W. exhibited a bias on the fact recognition test, always choosing the upper alternative. (The results did not noticeably change when H.W.'s data were included in the analysis. All obtained p values for effects and interactions remained the same.) The CON2-DELAY participant was excluded because she reported that she had rehearsed the studied material frequently during the retention interval.

The amnesic patients were impaired relative to the CON2 group. A 2 (group: AMN vs. CON2) × 3 (task: event recognition vs. fact recognition vs. fact recall) mixed-factorial ANOVA found a main effect of group, $F(1, 18) = 139.29$, MSe = .01, $p < .0001$, and an interaction between group and task, $F(2, 36) = 95.88$, MSe = .01, $p < .0001$. The finding of interest was the main effect of group. The interaction likely resulted from ceiling effects that were present in the CON2 group.

By testing after a longer delay, we matched the performance of the CON2-DELAY group on the fact recognition test to the level of performance of the amnesic patients on the same test. The question of interest was whether performance levels on all the tests would match or not after the two groups had been equated on the fact recognition test. A 2 (group: AMN vs. CON2-DELAY) × 3 (task: event recognition vs. fact recognition vs. fact recall) mixed-factorial ANOVA found no effect of group, $F(1, 19) < 1$, and no interaction between group and task, $F(2, 38) < 1$. (The power for this interaction was .61, .27, and .06 for large, medium, and small effect sizes, respectively; Cohen, 1977.) Thus, the groups performed similarly on all three tests. The amnesic patients were not disproportionately deficient in event memory. Finally, as would be expected, the CON2-DELAY group was impaired relative to the CON2 group on all three memory tests. A 2 (group: CON2-DELAY vs. CON2) × 3 (task: event recognition vs. fact recognition vs. fact recall) mixed-factorial ANOVA found a main effect of group, $F(1, 19) = 72.28$, MSe = .02, $p < .0001$, and an interaction between group and task, $F(2,38) = 41.59$, MSe = .01, $p < .0001$. Again, the finding of interest was the main effect of group. The interaction probably resulted from ceiling effects in the CON2 group.

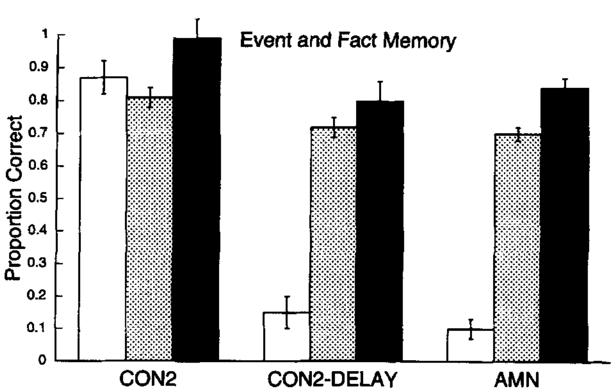

Figure 5. Experiment 2. Performance on the fact recall test (open bars), event recognition test (shaded bars), and fact recognition test (solid bars) that were given in Session 2. CON2 = controls, CON2-DELAY = delayed controls who were tested 3–6 weeks after Session 1; AMN = amnesic patients. Error bars indicate the standard error of the mean

Discussion

The results of Experiment 2 provided additional evidence that fact memory ability and event memory are similarly affected in amnesia. The event recognition test and the two tests of fact memory were all equivalently impaired in the amnesic patients. This result was obtained even when the sentences had been trained with the study-only procedure, which should have advantaged the learning of the amnesic patients.

In the comparison between event memory and fact memory in Experiment 1, the amnesic patients were slightly but significantly impaired on the fact memory test, even though they matched the CON-DELAY4 group on the event memory test. Because impaired fact memory was not found in Experiment 2, it is likely that the impairment observed in Experiment 1 was due to the difference in training procedures between the two experiments. Specifically, the study–test procedure in Experiment 1 was likely to have disadvantaged the factual learning of the amnesic patients.

General Discussion

In this study, we addressed two main questions concerning the acquisition of new factual knowledge in amnesia. The first question was whether the acquisition of new factual knowledge by amnesic patients can be accelerated by a special learning procedure (the study-only procedure) and if so, whether the effectiveness of this procedure is more related to the medial temporal lobe and diencephalic damage that causes amnesia or to the frontal lobe damage that sometimes occurs with amnesia. The second main question concerned whether the factual knowledge acquired by amnesic patients is qualitatively similar to the knowledge acquired by unimpaired individuals. The qualitative nature of the acquired knowledge was assessed by three tests: one that measured the ability of the amnesic patients and control participants to transfer their learning to related cues, another that compared the capacity of amnesic patients and controls to acquire information about facts and events, and another that measured long-term retention of newly acquired factual knowledge.

The major findings were as follows: (a) Amnesic patients acquired more factual knowledge with the study-only procedure than with the study–test procedure; (b) controls who were matched to the same overall level of performance as the amnesic patients exhibited the opposite pattern, learning more with the study–test procedure than with the study-only procedure; (c) performance on the transfer test suggested that the information acquired by the amnesic patients could be used about as flexibly as the information acquired by controls; (d) the relative scores of amnesic patients on event and fact memory tests were proportional to the scores of controls who were matched to the level of performance of the amnesic patients; and (e) the amnesic patients retained factual knowledge to a high degree across a 1-month interval.

Advantage of the Study-Only Procedure for Amnesic Patients

The beneficial effect of the study-only learning procedure for the amnesic patients replicates earlier results with amnesic patient K.C., in which the same procedure was used (Hayman et al., 1993). The advantage of the study-only procedure was robust, appearing in the two tests of the 40 sentences that were given in Session 5, on the transfer test given in Session 6, and finally on the 1-month-delayed test of all 40 sentences given in Session 7.[1]

The crossover interaction between the AMN and CON groups (Figure 2) indicates that the AMN group benefited more from the study-only procedure than from the study–test procedure, whereas the CON group exhibited the opposite pattern. Although Hayman et al. (1993) found greater efficacy for the study-only procedure with patient K.C., the 3 controls who received the same learning procedure as K.C. exhibited approximately equivalent performance with the study-only and study–test procedures (.85 for the study-only procedure and .83 for the study–test procedure). As noted earlier, several other studies have found the study–test procedure to improve learning in unimpaired individuals.

The study-only benefit for amnesic patients probably occurs because the procedure reduces the amount of interference encountered during learning (Hayman et al., 1993; Tulving et al., 1991). Specifically, by omitting testing during training, the study-only procedure prevents the production of erroneous responses and thus eliminates interference arising from such errors. For example, in an earlier study, Patient K.C.'s learning of factual information was facilitated by a procedure that included unique-completion, word-fragment cues to constrain his responses during training. This procedure eliminated the possibility of committing errors during training (Tulving et al., 1991). In another study, amnesic patients including patient K.C. were able to learn gradually new computer-related vocabulary that was trained with the method of vanishing cues (Glisky, Schacter, & Tulving, 1986b). This method constrains the participant's responses by providing some of the initial letters of the response word. Both the word-fragment-constrained learning method and the method of vanishing cues reduced or prevented the production of incorrect responses during training. In this respect, these two methods are similar to the study-only procedure used previously (Hayman et al., 1993) and in the present study. For each method, the common factor of interference reduction appears to underlie its efficacy.

If amnesic patients are vulnerable especially to the negative effects of interference, the pattern of errors exhibited during training with the study–test procedure should differ for the two groups. Specifically, greater vulnerability to interference should increase the probability that an incorrect response from earlier in training will be erroneously retrieved during subsequent retrieval attempts. As a result, the amnesic patients should generate more perseverative errors than controls. (An error was defined as perseverative if a participant had made the same error at least once in response to the same sentence-frame cue in an earlier training trial.) This prediction was confirmed. The amnesic patients committed more errors than the controls during the first two sessions of training with the study–test procedure. Across four training trials and 80 response opportunities the error rate was 77% errors for the AMN group vs. 46% for the CON group. For the AMN group, 34% of these errors were perseverative; for the CON group, only 15% of the errors were perseverative, $F(1, 18) = 23.36$, $p < .0001$. The greater frequency of perseverative responses in the amnesic patient group is consistent with earlier findings with Patient K.C., who made a large number of perseverative responses during training (Hayman et al., 1993).

Although the interference hypothesis can account for why the amnesic patients benefited from the study-only procedure, it does not account for why controls benefited from the study–test procedure. Earlier studies suggested several possibilities. First, the test in the study–test procedure may serve as another study episode that strengthens associations (Thompson et al., 1978). Second, the facilitative effect of testing might depend on (a) rehearsal of retrieval operations or (b) an opportunity during the test to use feedback about the efficacy of retrieval operations to develop more successful retrieval operations (Allen, Mahler, & Estes, 1969; Runquist, 1983).

Whatever aspects of the study–test procedure are responsible for the facilitation of learning by controls, it is difficult to know whether the same influences operate with the amnesic patients. Is the potentially beneficial effect of the study–test procedure simply overshadowed by the negative effects of interference caused by the study–test procedure? Or is the study–test procedure also ineffective for amnesic patients because of their memory impairment? One possibility is that the study–test procedure does not benefit amnesic patients because their slow learning rates and high error rates result in the learning of many incorrect responses. This possibility could be tested by matching the learning rate (and therefore the error rate) of the controls to the slow learning rate of the amnesic patients (e.g., by shallow encoding operations or limited study time) and seeing whether the study–test advantage then decreases or even reverses for the controls.

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[1] We also tested E. P., a 73-year-old male who developed profound amnesia in 1992 following herpes simplex encephalitis (Squire & Knowlton, in press). E. P. was tested with the same procedure used to test the amnesic patients in Experiment 1, with the exception that for E. P. the four training sessions were administered during a 2-week period (two sessions per week) rather than during 4 weeks (one session per week). In marked contrast to the other 9 amnesic patients, E. P. exhibited no learning at all, obtaining a score of zero on every test. This result suggests that very severely amnesic patients, who have little or no residual capacity for declarative memory, are unable to acquire new declarative knowledge even when given the potential benefit of the study-only procedure.

Nature of the Acquired Information

Transfer to Related Cues

The issue of flexibility concerns whether the factual knowledge that amnesic patients acquire is less flexible and more narrowly accessible than normally acquired information. This question is motivated by studies of both amnesic patients and animals with lesions to the hippocampus and related structures that have sometimes found acquired knowledge to be abnormally inflexible and bound to the original learning context (Eichenbaum, Mathews, & Cohen, 1989; Glisky et al., 1986a; Saunders & Weiskrantz, 1989). For example, in a study involving the learning of computer commands, amnesic patients were impaired at answering open-ended questions and were incapable of using their knowledge flexibly to write a program (Glisky et al., 1986a).

In the present study, although the delayed controls (Group CON-DELAY2) exhibited numerically more transfer to related cues than did the amnesic patients, the two groups did not differ significantly. These results are similar to Shimamura and Squire's (1988) finding that amnesic patients were no more disadvantaged than controls when they were cued indirectly by paraphrases of training sentences. Although the results of the transfer test are consistent with the conclusion that the amnesic patients and controls were similarly able to use their knowledge flexibly, this conclusion must remain tentative in light of the numerically lower transfer exhibited by the amnesic patients and the low power for the comparison between amnesic patients and controls. At the same time, the results of the transfer test provided no evidence for the extreme inflexibility that Glisky et al. (1986a) found in a different paradigm that assessed computer vocabulary learning in amnesic patients.

In the current study as well as in Hayman et al. (1993), the factual knowledge acquired by amnesic patients may reflect their residual capacity for acquiring declarative knowledge. By this view, whatever declarative knowledge can be acquired is as flexible and as accessible to indirect cues as the knowledge acquired by controls. Inflexibility should be observed only when the knowledge acquired by amnesic patients depends especially on nondeclarative knowledge, which is thought to be rigidly organized and to exhibit limited transfer to new contexts. In such a case, the knowledge gained by the amnesic patients would appear inflexible because the controls (but not the amnesic patients) would be successful in acquiring concomitantly some declarative knowledge about the task.

Event Memory and Fact Memory

Another question regarding the capacity for factual learning in amnesia is whether this capacity is proportional to the residual (but impaired) capacity for learning about specific events, or whether the capacity for learning in amnesia is better than it should be, given the capacity for event memory. This question is of theoretical interest, because there are at least two different views about the relationship between event and fact memory in amnesia.

One view proposes that amnesia can impair memory for events to a greater extent than memory for facts. By this view, some new factual knowledge can be acquired independently of the structures damaged in amnesia, even in the absence of any memory for specific events that occurred during learning (Tulving et al., 1991; Wood, Brown, & Felton, 1989). The other view is that both types of memory depend similarly on the integrity of the same medial temporal lobe and midline diencephalic structures (Ostergaard & Squire, 1990; Shimamura & Squire, 1989). This view predicts that amnesia should affect both event and fact memory to the same extent.

In the current study, a direct quantitative comparison was made between the event and fact memory capacities of amnesic patients and controls. In Experiment 1, event memory was assessed with a recognition test about the details of the initial training session. Memory for facts was tested in the same session as the test of sentences. To permit a valid comparison between amnesic patients and controls, the two groups were matched with respect to the level of event memory. Specifically, the control participants were tested at longer retention intervals than the amnesic patients (CON-DELAY4, CON2-DELAY).

The results were that, when the level of performance on the events memory test was equated between the amnesic patients and controls, fact memory was also equated. That is, the performance of the amnesic patients on the fact memory test was about what it should have been, given their performance on the events test. One possible difficulty with comparing event memory with fact memory is that uncertainty exists about the extent to which event memory might contribute to the recollection of recently learned facts, or indeed the extent to which event memory and fact memory interact. Nevertheless, our results raise the possibility that event and fact memory are similarly dependent on the medial temporal lobe and diencephalic structures damaged in amnesia. It should be noted that our finding is also consistent with the idea that the capacity for event memory depends additionally on the integrity of the frontal lobes (Shimamura & Squire, 1987; Tulving, 1989; Tulving et al., 1994).

In Experiment 2 we found further evidence for a proportional impairment of event memory and fact memory in amnesia and corrected two potential difficulties concerning the comparison between event and fact memory conducted in Experiment 1. In Experiment 1, the comparison between event and fact memory was made during the training phase, at a point when only the sentences being learned with the study–test procedure could be tested. Because the study–test procedure disadvantaged the learning of amnesic patients and benefited the learning of controls, the study–test procedure would have tended to underestimate the capacity of the amnesic patients for fact memory. In Experiment 2, factual sentences were trained with the study-only procedure, a procedure that should provide a more accurate estimate of the capacity for fact learning in amnesic patients. In addition, a fact recognition test was included in Experiment 2 to provide a second measure of the capacity for fact memory and one that was comparable to the recognition-test format of the event memory test. The CON2-DELAY group and amnesic patient group matched on all three measures: event recognition, fact recognition, and fact recall. This result provides additional evidence that fact and event memory are equivalently impaired in amnesic patients and that fact memory is not spared relative to event memory. A question for further study is whether event recall would exhibit the same relationship to fact recall and recognition that was found with event recognition in the current experiments.

Long-Term Retention

Although the amnesic patient group acquired new factual information abnormally slowly (see Figure 1), once this information had been acquired it was retained to a substantial degree over each weekly delay interval and across a delay of more than a month. Across the 1-month interval (from the first test of Session 6 for the 20 cues that were presented in their original form to the final test of Session 7), performance declined only 35%. These results replicate previous findings of substantial long-term retention of newly acquired factual knowledge in Patient K.C. (Hayman et al., 1993) across even longer intervals (14 and 30 months).

Conclusion

Amnesia severely impaired the acquisition of new factual knowledge. Nevertheless, factual knowledge was gradually acquired over repeated learning trials, especially when the traditional study–test method was replaced by a study-only procedure that eliminated the possibility of making errors during learning. The advantage of the study-only procedure for the amnesic patients was related to the degree of frontal lobe dysfunction, a possibility first raised by Hayman et al. (1993). In addition, the study-only advantage may be related to the severity of the memory impairment itself. All the amnesic patients acquired new factual knowledge to some degree, and the information that was acquired was qualitatively similar to that acquired by controls. First, the information could be used almost as flexibly by amnesic patients as by controls. Second, the capacity for acquiring new factual memory in amnesic patients was approximately what it should have been, given the residual capacity to acquire event memory. Thus, the capacity for factual learning in amnesia does not reflect some spared or partially spared ability, relative to the capacity for event memory. Third, the information that was acquired was long lasting, just as it is in controls.

The type of material to be learned may play a critical role in determining the efficacy of the study-only procedure. Baddeley and Wilson (1994) used a study-only and study–test procedure to train amnesic patients, elderly controls, and young controls to complete two-letter word stems with five-letter words (e.g., BR———; correct answer: *bread*). With these materials, all groups showed an advantage of the study-only procedure. Furthermore, this advantage was not associated with frontal lobe deficits in the amnesic patient group, and there was no difference in the proportion of perseverative errors between groups during training. Each of these findings contrasts with those of the current study. (It should be noted that one of the two tests of frontal lobe dysfunction considered by Baddeley and Wilson, the Wisconsin Card Sort Test (WCST), also had a low simple correlation in the current study with the study-only advantage, $r = .33$.) In addition, the effect of the study-only procedure may vary widely depending on the nature of the test material. In the case of the materials used by Baddeley and Wilson, implicit memory can support part of the performance measure (i.e., word-stem completion can be supported by implicit memory). They suggested that their training procedures had similar effects on amnesic patients and control participants (i.e., a study-only advantage was observed for both groups), because in both groups performance on the task relies in part on implicit memory (which they view as highly vulnerable to interference), which is intact in both groups.

The comparison that we have carried out between memory tests for facts and a memory test for events has potential relevance to the distinction between semantic and episodic memory (Tulving, 1983). Specifically, our finding that event memory and fact memory were proportionally impaired in amnesia is consistent with the view that semantic memory and episodic memory are proportionally impaired in amnesia. At the same time, it should be clear that our finding also supports the idea that a principled and useful distinction can be made between the capacity for semantic memory (factual information) and the capacity for episodic memory (specific events; Knowlton & Squire, 1995; Shimamura & Squire, 1987; Squire et al., 1993; Tulving, 1989). Memory for facts and events both depends on the integrity of medial temporal lobe and midline diencephalic structures. In addition, the frontal lobes are involved in the acquisition of event memory because of the importance of contextual information for the encoding of episodes that are specific to time and place.

Event memory also enables individuals to correct earlier errors during learning by permitting them to recollect prior learning episodes and thereby distinguish between correct and incorrect responses that have been made to the same cue. In this way, event memory can facilitate the acquisition of fact memory. Thus amnesic patients with frontal lobe dysfunction exhibited poor factual learning with the study–test procedure, a procedure that was associated with considerable interference from competing incorrect responses. These results suggest that a better understanding of how amnesic patients and unimpaired individuals acquire new factual knowledge depends on gaining more information about the ways in which declarative memory for facts and events interact.

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