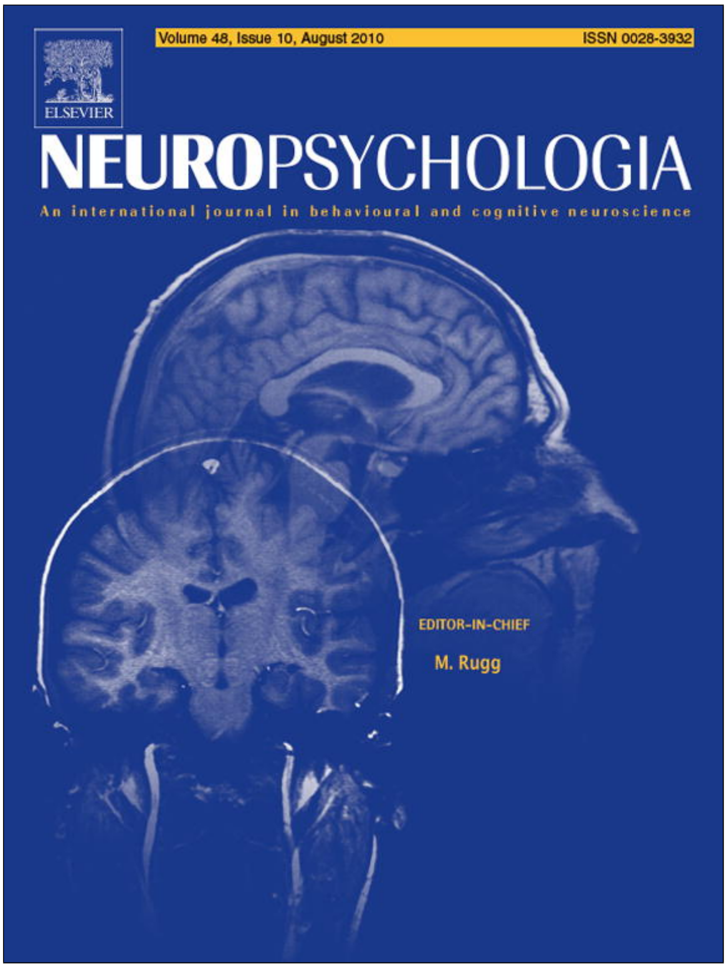
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Losing memories overnight: A unique form of human amnesia

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ABSTRACT

Since an automobile accident in 2005, patient FL has reported difficulty retaining information from one day to the next. During the course of any given day, she describes her memory as normal. However, memory for each day disappears during a night of sleep. She reports good memory for events that occurred before the accident. Although this pattern of memory impairment is, to our knowledge, unique to the medical literature, it was depicted in the fictional film “50 First Dates”. On formal testing, FL performed moderately well when trying to remember material that she had learned during the same day, but she exhibited no memory at all for material that she knew had been presented on a previous day. For some tests, unbeknownst to FL, material learned on the previous day was intermixed with material learned on the same day as the test. On these occasions, FL’s memory was good. Thus, she was able to remember events from earlier days when memory was tested covertly. FL performed differently in a number of ways from individuals who were instructed to consciously feign her pattern of memory impairment. It was also the impression of those who worked with FL that she believed she had the memory impairment that she described and that she was not intentionally feigning amnesia. On the basis of her neuropsychological findings, together with a normal neurological exam, normal MRI findings, and psychiatric evaluation, we suggest that FL exhibits a unique form of functional amnesia and that its characterization may have been influenced by knowledge of how amnesia was depicted in a popular film. She subsequently improved (and began retaining day-to-day memory) at Johns Hopkins University where she was in a supportive in-patient environment and was shown how to take control of her condition by interrupting her sleep at 4-h intervals.

Amnesia can present itself in two fundamentally different ways. In neurological amnesia, there is bilateral damage to structures of the medial temporal lobe or midline diencephalon and a characteristic pattern of impairment. The hallmark of the condition is an impaired capacity for new learning (anterograde amnesia), which occurs together with variable loss of information acquired before the onset of impairment (retrograde amnesia) (Gabrieli, 1998; Kopelman, 2002; Squire, Stark, & Clark, 2004). The impairment affects declarative memory, that is, conscious memory for facts and events regardless of sensory modality or type of material (for example, names, places, faces, objects, odors, and sounds). Other forms of memory that are not accessible to conscious recollection remain intact (e.g., skills, habits, and simple forms of conditioning), and these nondeclarative forms of memory depend on brain systems outside the medial temporal lobe and midline diencephalon.

In the other kind of amnesia, memory is impaired in the absence of structural damage due to brain injury or disease. This condition has been termed functional amnesia, psychogenic amnesia, hysterical amnesia, or dissociative amnesia (American Psychiatric Association, 1994; McHugh, 2008). Here, we use the term functional amnesia. Although functional amnesia is not associated with structural brain damage, there is evidence of hypometabolism, especially in the frontal lobe as measured by neuroimaging (Brand et al., 2009; Reinhold, Kuehnel, Brand, & Markowitsch, 2006). Similar findings have also been observed in other psychiatric and neurological conditions (i.e., transient global amnesia, Eustache, Desgranges, Aupee, Guillery, & Baron, 2000; bipolar and major depressive disorder, Savitz & Drevets, 2009; schizophrenia, Wolkin et al., 1992).

The pattern of impairment in functional amnesia is variable, though it typically presents as severe retrograde amnesia (sometimes including loss of personal identity) in the absence

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of anterograde amnesia (Brandt & Van Gorp, 2006). In a study of 10 patients with functional amnesia (Kritchevsky, Chang, & Squire, 2004), performance was largely intact on tests of anterograde memory, and none of the patients had difficulty learning and remembering day-to-day events after the onset of their amnesia. In contrast, all the patients had difficulty recollecting autobiographical memories of specific events from their past. In addition, most (but not all) of the patients were impaired on tests involving past news events or famous faces. Lastly, 8 of the 10 patients variously exhibited anomia, some loss of vocabulary, or difficulty performing previously familiar activities. This pattern of impairment, as well as its variability, is in line with the available single-case reports of functional amnesia (e.g., Compodonico & Rediess, 1996; Kopelman, Christensen, Puffett, & Stanhope, 1994; Schacter, Wang, Tulving, & Freedman, 1982).

We now report a case of apparent functional amnesia markedly different from any cases known to us. Since an automobile accident in 2005, involving minor injury and a brief loss of consciousness, FL has reported difficulty retaining information from one day to the next. During the course of any given day, she describes her memory as normal. However, memory for each day disappears during a night of sleep. She does not experience accelerated forgetting during the day as reported in some other cases of functional amnesia (Kessler et al., 1997; Kumar, Rao, Sunny, & Gangadhar, 2007; Markowitsch et al., 1998; Markowitsch, Kessler, Kalbe, & Herholz, 1999). In addition, unlike most cases of functional amnesia, FL does not complain of retrograde amnesia for events that occurred before the accident. This pattern of memory impairment is, so far as we know, unique to the medical literature and bears no relation to any known neurological or psychiatric condition (Baxendale, 2004). However, FL's condition was depicted in the fictional film "50 First Dates" (Segal, 2004; and also has some resemblance to an earlier film "Clean Slate", Jackson, 1994). In "50 First Dates", the central character is involved in a car accident. After the accident, she accumulates memories normally during each day, but forgets the events of the day after a night of sleep. Upon awakening each morning, she has no memories since the accident and believes she has awoken on the day of the accident.

In 2008, FL, three controls, and two simulators (volunteers asked to simulate her pattern of memory impairment) were given six standard neuropsychological tests, a specially constructed test of recognition memory for scenes, two motor skill tests, and three tests of retrograde memory. The tests were intended to assess FL's anterograde and retrograde memory abilities and to make comparisons between memories acquired within a given day and memories acquired on a previous day. In addition, the patient was evaluated independently by a neurologist and a psychiatrist, and high-resolution anatomical MRI scans of her brain were obtained.

1. Materials and methods

1.1. Case history: patient FL

FL was a 51-year-old woman with 15 years of education. Her full-scale IQ was 100 (the Wechsler Adult Intelligence Scale-III was administered by an independent neuropsychologist in July, 2005). She had been married for 27 years, had 3 children, and had worked for the same employer for 10 years. FL reported no personal or family psychiatric history. She and her husband were seeking consultation for her severe memory impairment, and she was evaluated in the Squire laboratory (September 29 to October 3, 2008).

In May 2005, FL was involved in a motor vehicle accident in which her car was struck from behind. She hit the left side of her head and briefly lost consciousness. She was treated and released from the emergency room, but upon awakening the next morning, she had no memory for the previous day and believed that the accident had just occurred. Every morning since has been similar. She awakens with anxiety, believes it to be the day of the accident, and states that she has no memory for anything that has occurred since the accident. Each morning her husband orients her to time and place and provides her with her journal where she has recorded salient events from previous days and weeks. During the course of the day, she describes her memory as normal, but states that memory for each day is lost at night during sleep. FL was able to return to her previous employment after some accommodations were made at work. She explained that she is able to work because she had the same job before the accident, and her responsibilities are similar each day.

Each day when FL arrived for testing, we introduced ourselves, reviewed the purpose of her visit, and repeated the informed consent procedure. We administered a variety of neuropsychological tests and also obtained high-resolution magnetic resonance images of her brain. Quantitative analysis of the MRI revealed no evidence of volume loss, tumor, hemorrhage, or infarction, and the MRI was read as normal by our neuroradiological consultant (G. Press, M.D.). FL was also evaluated independently by a psychiatrist and a neurologist during the week. The neurological examination (M. Kritchevsky, M.D.) was negative. Dr. Kritchevsky suggested a diagnosis of functional amnesia. On the basis of our neuropsychological findings (see below), a normal MRI scan, absence of neurological findings, and his own clinical interview, the psychiatrist who examined her (D. Kripke, M.D.) diagnosed FL as having psychogenic amnesia. The psychiatrist also attempted to perform hypnosis on the final day of FL's visit to try to recover memories from the time since the accident. FL did not recover any memories.

After the week-long evaluation in California, FL and her husband returned home where they sought help from mental health professionals in their area. In February 2009, at the suggestion of Dr. Squire, FL and her husband visited the Pain Treatment Center at Johns Hopkins University for 2 weeks.

At admission she was diagnosed as having depression, and the treatment team assured her that she was likely to recover with treatment. Her husband was asked whether she lost her memory if she took a nap during the day. He stated that she did not. Initially, she was placed on a sleep deprivation protocol and remained awake for 36 h. There was no loss of memory during this period. The following day the treatment team initiated a regimen in which she was awakened after longer and longer periods of sleep each night. After 1, 2, 3, or 4 h of sleep she retained all memories, but after 6 h of sleep she had recurrence of her memory loss. Thus, she was able to tolerate up to 4 h of continuous sleep without memory loss for the previous day's events.

She was treated for depression during her admission with escitalopram in escalating doses to a final dose of 30 mg/day. She was given positive reinforcement for her memory retention and increasingly independent function. On the day of discharge, she exhibited a full range of affect and stated that she was hopeful for the future. In April 2009, 2 months after FL returned home, her husband reported that she awakens 3.5 h into each night's sleep and has been able to retain her memory for successive days with this regimen. At our most recent contact (March 2010), she and her husband reported that she continues to use this regimen successfully.

1.2. Controls

Three volunteers served as controls (all female; mean age = 57.0 ± 1.0 years; mean education = 15.0 ± 1.7 years). Two additional volunteers were asked to simulate FL's memory disorder (simulators) (1 female; mean age = 57.5 ± 2.5 years; mean education = 15.5 ± 0.5 years). The simulators were read the following instructions each morning before testing:

> The idea is that you have a memory impairment with the following characteristics: You had an accident on May 5th, 2005. Since that day, you have good memory for things that happen to you during each separate day, but you forget everything from each day when you go to sleep. Therefore, when you wake up the next morning you do not remember anything that has happened the previous day.
>
> We would like you to respond on the following tests as if you have no memory for material that was presented prior to today. That is, you should perform as you normally would and do your best when it comes to material that was given today. However, for any material that was not given today you should respond as if you have no memory for it.
>
> You believe you have this memory problem and you want others to believe you have this memory problem as well.

For the News Events Test, the simulators were given a note card with the date of the patient's accident were read the following instructions:

> For this test, it is important to remember to answer the questions as if you have no memory for events that occurred between May 5, 2005 until today.

1.3. Volumetric measurement of the medial temporal lobe

Estimates of medial temporal lobe volume were based on quantitative analysis of magnetic resonance images (MRI) compared to data for four female controls (mean age ± SEM, 53.3 ± 1.3 years). The volumes of the full anterior-posterior length of the hippocampus and the parahippocampal gyrus were measured using criteria based on histological analysis of healthy brains (Amaral & Insausti, 1990; Insausti, Insausti, Sobreviela, Salinas, & Martinez-Penuela, 1998a; Insausti et al., 1998b). For FL and the four controls, the hippocampal and parahippocampal gyrus volumes were divided by the intracranial volume (ICV normalized) to correct for brain size (Gold & Squire, 2005).

Table 1
Recognition memory for scenes: sequence of study and test sessions.

Day 1	Day 2	Day 3	Day 4	Day 5
Study A Test A[b]	Test A[a] Study B Test B[b,c]	Test B[a]	Study B Test B[b]	Test B[a] Study A Test A[b,c]

Note: A and B refer to different study lists of 160 scenes. Within each day, the study and test sessions are listed in the order they were given.

[a] Overt measure of next-day memory for 40 scenes studied on the previous day and tested 24 h later.

[b] Overt measure of same-day memory for scenes studied and then tested 0, 2, or 8 h later on the same day (40 old scenes were presented on each test).

[c] Unbeknownst to participants, these tests allowed a covert measure of next-day memory because items were included that had been encountered previously but not on the same day as the test.

1.4. Standard neuropsychological tests

Materials and procedure: all participants (FL, controls, and simulators) were given five neuropsychological tests across a 5-day period. FL was also given two tests that other participants were not given.

Prose recall: subjects were read a short prose passage containing 21 segments. Recall was tested immediately and 12 min after presentation (Squire & Chace, 1975).

Paired-associate learning: ten noun-noun word pairs were presented on each of three study trials. After each study trial, participants were shown the first word of each pair and asked to recall the second word.

Recall of complex design: participants copied the Rey-Osterrieth figure (Osterrieth, 1944) and were asked to reproduce it from memory after a 12–15 min delay.

Two-choice recognition memory for words and faces (Warrington, 1984): participants saw 50 words one at a time and immediately thereafter were given a two-alternative, forced-choice recognition test for all 50 words. The same procedure was then used with 50 photographs of unfamiliar faces. A second version of the same two tests was also given with new materials and a 24-h retention interval.

Wechsler memory scale-revised (WMS-R) (Wechsler, 1987): the WMS-R is a standardized test of memory for verbal and figural material. Controls and simulators were not tested.

1.5. Recognition memory for photographs of scenes

Materials and procedure: testing took place during a 5-day period (Table 1). The purpose was to test material on both the same day it was studied and on the next day. In one condition, memory was tested after material had been studied on only one occasion. In a second condition, memory was tested after material had been studied multiple times across several days.

Nine hundred and twenty photographs of indoor and outdoor scenes were used to construct 160-item study lists and 80-item test lists given at one of four different times after study. Each 80-item test consisted of 40 studied scenes and 40 novel scenes. At each study session, participants viewed each scene for 3 s and were instructed to attend so that they might be able to recognize the scenes later. At each test session, participants viewed old, previously studied scenes intermixed with new scenes. For each scene, participants made a recognition memory judgment on a 1–6 scale (1 = “definitely new”, 2 = “probably new”, 3 = “maybe new”, 4 = “maybe old”, 5 = “probably old”, and 6 = “definitely old”). No time limit was imposed for the recognition judgment, and participants were encouraged to use the full range of confidence ratings.

Same-day and next-day tests for scenes studied one time: on Day 1, participants studied one list of 160 scenes. Four memory tests were then given, three on the same day (immediately, 2 h and 8 h after study) and one on the next day (24 h after study). Each test consisted of 40 old scenes and 40 new scenes. The same procedure was then initiated on Day 2 with another 160-item study list. However, in this case both the 2 and 8-h tests on Day 2 included not only 40 scenes that had been studied earlier that day (and 40 new scenes), but also 24 additional scenes that, unbeknownst to the participant, had been encountered only on the previous day (Day 1). In this way, it was possible to obtain an overt measure of next-day memory (i.e., from scenes that participants correctly understood to have been studied the previous day) as well as a covert measure of next-day memory (i.e., from scenes that participants did not know had been studied the previous day because they were intermixed with scenes studied earlier on the test day).

Same-day and next-day tests for scenes presented multiple times: to assess the ability to remember material presented multiple times, the entire procedure from Days 1 and 2 was repeated on Days 4 and 5. That is, the same materials and the same study-test intervals that were used on Days 1 and 2 were used again on Days 4 and 5 (though the foil items on the recognition tests were always novel). In this way, participants received same-day tests for scenes they had studied on the same day (and that had been presented on a previous day as well). In addition, participants on Day 5 also received an overt test of next-day memory for scenes they had studied on the previous day (and that had also been presented on 2 previous days). Lastly, participants received a covert test of next-day memory for scenes they had studied on the previous day (and that had also been presented on another previous day).

1.6. Motor skill learning

Mirror drawing: participants traced an outline of a 6-pointed star while looking at the reflection of the star and their hand in a mirror (Lafayette Instrument Co., Lafayette, IN). The star was composed of an inner and an outer line (separation, 0.6 cm). Participants completed 10 trials on Day 1 and 10 more trials on Day 2 with instructions to perform as accurately and quickly as possible. The scores were the number of errors (touching a line or crossing a line) and the time needed to complete each tracing.

Rotary pursuit: participants completed 16 trials of a rotary pursuit task (eight 20-s trials on Day 1 and eight 20-s trials on Day 2; Model 30010A; Lafayette Instrument Co., Lafayette, IN). Participants attempted to hold a flexible, L-shaped stylus in contact with the target on a rotating disk (25.5 cm diameter; 60 rotations per minute). The target (2 cm × 2 cm) was located 7.8 cm from the center the disk. A 20-s rest intervened between each trial (except trials 4 and 5, which were separated by 2 min). The score was the total time on each trial that the stylus maintained contact with the target.

1.7. Retrograde memory tests

Autobiographical Memory Index (AMI): the AMI is a standardized test (Kopelman, Wilson, & Baddeley, 1989) that quantifies the recall of personal semantic facts and autobiographical incidents using a structured interview. For each of three time periods, childhood (until 18 years old), early adulthood (19–29 years old), and recent (within the last year) personal semantic facts and autobiographical incidents are scored (personal semantic facts max score = 21; autobiographical incidents max score = 9). FL was asked to provide information from the three different time periods. Controls and simulators were not tested.

News events test: this test was modified from an earlier version (Bayley, Hopkins, & Squire, 2006). Tests of past public events, like this one, are sufficiently specific that it is difficult to answer the questions correctly unless an individual has lived through the time period in question (Squire, 1974; Warrington & Silberstein, 1970). The test included 266 questions about news events that had occurred between 1975 and 2008 (e.g., Which state's contested electoral votes were the deciding factors in George W. Bush's controversial win of the presidency? (Florida); What tire manufacturer recalled thousands of tires? (Firestone); What happened at Virginia Tech? (Shooting massacre)). The questions from different time periods were intermixed so that it would be difficult for participants to know exactly what time periods were being tested. Testing proceeded first in a free-recall format and then in a four-alternative, multiple-choice format. The data for FL, the controls, and the simulators were analyzed according to the date on which FL developed memory impairment (i.e., May 5th, 2005). In this way, a score for each participant was calculated for the period of anterograde amnesia and in 5-year intervals across 30 years of retrograde amnesia. Forty-one questions assessed her anterograde time period (May 5th, 2005–2008), and 225 questions assessed her retrograde time period (1975–May 4th, 2005). In this way, her memory was sampled from the 3 years since she developed memory impairment and up to 26–30 years before its onset, at a time when she was 17–21 years old.

Cities test: FL was read the names of 16 real and 16 plausible U.S. cities and associated states (e.g., Phoenix, Arizona, or Nelander, Michigan), and asked whether each city name was real or fabricated. The score was the number of cities correctly identified.

2. Results

The findings for controls are reported as means and standard errors of the mean. The results were very similar when medians were used instead of means.

2.1. Volumetric measurement of the medial temporal lobe

The MRI of FL's brain was read as normal by a neuroradiologist. On measurement, her hippocampal volume bilaterally was 6.8% below the mean of four age-matched controls, and the volume of her parahippocampal gyrus was 1.8% below the control mean (Fig. 1). Both values are well within 1 SD of the control mean.

2.2. Standard neuropsychological tests

Table 2 shows performance of patient FL, controls, and simulators on the neuropsychological tests. As expected, FL's scores for material tested 24 h after study were impaired relative to control

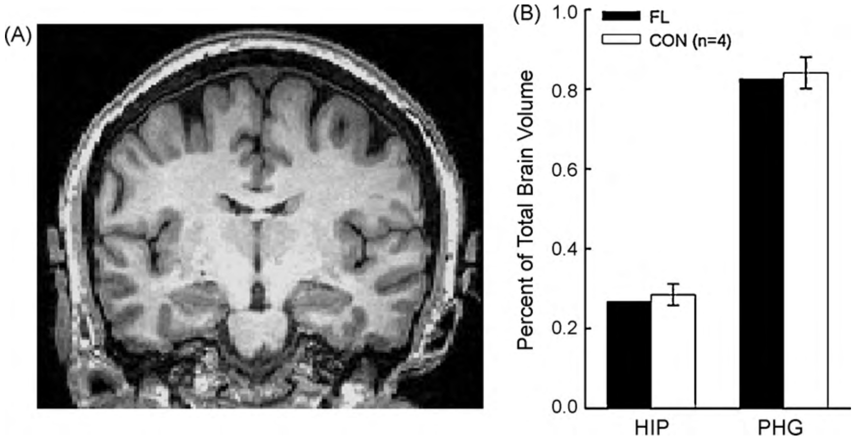

Fig. 1. (A) A T1-weighted coronal MRI image from FL. The left side of the brain is on the left side of the image. (B) The volume of bilateral hippocampus (HIP) and parahippocampal gyrus (PHG) were similar for FL and controls (n = 4). The volumes are expressed as a percentage of the whole-brain volume for each participant.

Table 2
Neuropsychological tests.

	Paragraph recall		Rey-O		Paired associates			Words	Faces	Words	Faces
	Immed	Delay	Copy	Delay	1	2	3	Immed	Immed	24 h	24 h
FL	8	5	27	18	2	7	7	41	37	25	20
Controls	9.3	9.7	28.7	20.3	6.7	10.0	10.0	49.7	47.7	43.7	40.3
Simulators	7.0	6.5	30.0	16.5	5.5	7.0	10.0	49.0	43.5	27.5	22.0

subjects. Specifically, she scored near chance levels on the 24-h test for words and the 24-h test for faces (chance performance = 25/50). The simulators also scored near chance levels on these same two tests. Though FL reports good memory for material learned within each day, she nevertheless performed a little poorer than expected on several tests of this ability (delayed recall of paragraph; paired-associate learning; immediate recognition of words and faces; but see Rey-O diagram recall). The simulators performed a little better than FL on all these tests and a little poorer than controls. FL also had mildly depressed scores across three indexes of the WMS-R: Attention and Concentration (83), Verbal Memory (99), Nonverbal Memory (108), General Memory (80), and Delayed Memory (85). The normal score for each index is 100 (SD = 15).

2.3. Recognition memory for photographs of scenes

In all cases, the results were averaged across the 0, 2, and 8-h retention intervals and across the same conditions from different days. It is important to emphasize that FL did not exhibit accelerated forgetting during the course of a day. Specifically, her percent correct score decreased 1.9% from the immediate tests to the 8-h tests (compare with a 10.4% decrease for controls and an 8.1% decrease for simulators).

Same-day and next-day tests for scenes studied one time (Fig. 2): after a single presentation, FL was able to remember scenes studied earlier on the same day, albeit not at the level of controls (d' = 1.2, 70.2% correct vs. d' = 2.6, 88.1% correct). In contrast, she exhibited no memory at all for scenes that she knew had been studied on the previous day (d' = 0.0, 50.0% correct). Indeed, for these tests, FL indicated that she was definitely sure that all the scenes were new (i.e., the old and new scenes were all rated as new and given a rating of 1). Despite this poor performance, FL did exhibit memory for scenes studied on the previous day when memory was tested covertly by intermixing the previous day's scenes with scenes studied earlier on the same day (d' = 0.9, 64.8% correct; chance performance = 50%).

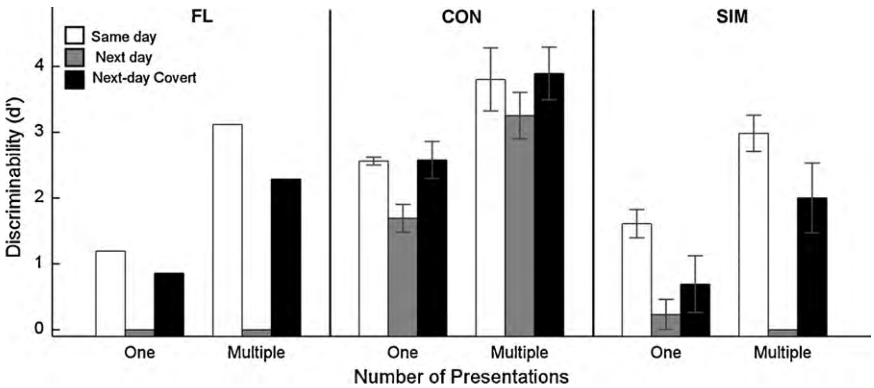

Fig. 2. Recognition memory for color photographs of scenes. One presentation: FL, Controls (n = 3), and Simulators (n = 2) saw 160 scenes once each and then took recognition memory tests later on the same day (Same day) as well as on the morning of the next day (Next day). After the Next-day test, participants studied 160 new scenes and then took recognition memory tests later on the same day. In this case, unbeknownst to the participants, the retention tests included scenes that had been studied and tested on the previous day (Next-day Covert). Multiple Presentations: the same scenes that had been studied and tested during the first 2 days were studied an additional time. As above, testing was done in three ways (Same day, Next day, and Next-day Covert). FL exhibited evidence of day-to-day memory in the Next-day covert tests (black bars) and in her improved performance when the same scenes had been viewed across multiple days (compare the two white bars and the two black bars in the left panel). Brackets show SEM.

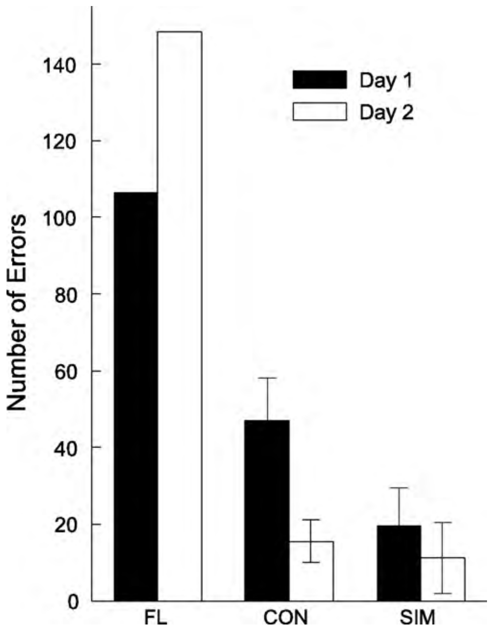

Fig. 3. Mirror drawing. FL, Controls (CON; n = 3), and Simulators (SIM; n = 2) traced the outline of a double-contoured star 10 times on Day 1 and 10 times on Day 2. For each day, the number of errors was averaged across the 10 trials. Unlike every control and simulator, FL performed poorly and scored worse on the second day than on the first.

Same-day and next-day tests for scenes presented multiple times (Fig. 2): FL exhibited no memory for scenes that she knew had been presented previously, even when the scenes had been presented on three separate days (d' = 0.0, 50.0% correct). Nevertheless, she demonstrated evidence of day-to-day memory on other tests. First, when scenes had been presented on a previous day as well as studied on the test day, FL's memory performance was much better than when scenes had been studied only on the test day (d' = 3.1 vs. d' = 1.2; 87.5% vs. 70.2% correct; compare the two white bars, Fig. 2, left panel). Because the advantage of multiple presentations depends on accumulating information across days, this finding provides additional evidence that FL was able to retain information from day to day. Still more evidence for day-to-day memory comes from the finding that FL could remember scenes that had been presented on 2 previous days and which were tested covertly by intermixing them with scenes studied on the same day as the test (d' = 2.3, 78.1% correct). This score was noticeably better than the score obtained on the covert test given after only one presentation (d' = 0.9, 64.8% correct; compare the two black bars, Fig. 2, left panel).

When accuracy noticeably improved after multiple presentations of the scenes (two white bars and two black bars in each panel; Fig. 2), it was expected that confidence in correct recognition judgments would increase correspondingly. However, confidence increased only for simulators and controls (the combined rating increased from 5.5 on the 6-point scale to 5.7, p < .01). Every control and simulator expressed increased confidence in their judgments when scenes were tested that had been presented multiple times instead of only once. In contrast, FL expressed lower confidence in these conditions (5.5 for scenes studied once and 5.2 for scenes presented multiple times).

2.4. Motor skill learning

Mirror drawing: FL's performance was much poorer than controls and simulators (Fig. 3). On Day 1, FL made more than twice as many errors as either the controls or the simulators. She did exhibit some learning across the 10 trials of Day 1 (50 fewer errors on last trial than on the first trial), but whatever learning occurred was not retained from one day to the next. In fact, FL performed worse on Day 2 than she did on Day 1 (41 more errors on Day 2 than on Day 1). In contrast, controls and simulators made fewer errors on Day 2 than on Day 1 (mean = 31 and 9 errors, respectively).

Measurement of the time needed to complete each trial yielded the same pattern of results as did the measurement of errors. That is, FL needed much more time on Day 1 to complete the tracings than did controls or simulators (FL = 292 s; controls = 133 s; simulators = 88 s; mean for all 10 trials). She did exhibit some learning on Day 1 (368 s faster on the last trial than on the first trial), but again, she exhibited no retention of the task from one day to the next (61 s slower on Day 2).

Rotary pursuit: the findings for the rotary pursuit task were largely the same as for the mirror drawing task. Overall, FL performed worse than either controls or simulators. Specifically, on Day 1 FL maintained contact with the target for less time than did controls or simulators (FL = 12.6 s; controls = 14.6 s; simulators = 14.5 s). FL was the only participant who exhibited no learning on Day 1 (last trial vs. first trial: FL = 0.3 s less contact; all other participants = 8.8 s more contact). FL also exhibited no improvement from one day to the next (mean 12.6 s on Day 1 and 12.7 s on Day 2). In contrast, all controls and one simulator exhibited improvement from Day 1 to Day 2 (mean = 1.9 s). The other simulator approached this task as a memory task and simulated forgetting overnight.

2.5. Retrograde memory tests

Autobiographical Memory Index (AMI): for the test of autobiographical memory, FL obtained nearly perfect scores on the Childhood and Young Adult sections of the AMI. For the Recent Life time period, FL obtained a score of 19.5 out of 21 for personal semantic facts and a score of 6 out of 9 for autobiographical incidents (lower scores than for her other periods). We expected her scores to be even poorer for the Recent Life time period, because these questions covered a time period well after her memory complaints began. When asked, she stated that many of the facts and events that she reported were recalled from her journal that she reviews each morning.

News events test: for notable news events that occurred after the onset of amnesia, both FL and the simulators exhibited poor memory (recall and recognition), relative to controls (Fig. 4). For news events that occurred before the onset of amnesia, FL also exhibited poor memory. Her difficulty extended across the 30 previous years covered by the test. It appears that the simulators conformed more exactly than did FL to the pattern of memory loss she reported (i.e., poor memory for events after the accident but good memory for events prior to the accident).

Cities test: FL exhibited normal performance on the cities test, scoring 84% correct. FL's controls and simulators were not tested; however, a previously tested group of controls (Kritchevsky et al., 2004) scored 90% (range: 80–100%).

3. Discussion

We carried out a neuropsychological and neuroradiological examination of a patient (FL) who has a memory impairment that, to our knowledge, is unique in the medical literature. She reported that she accumulates normal memories for the events of each day but that, ever since a minor (but stressful) vehicle accident 3 years earlier, she loses each day's memories during a night of sleep. Her husband likened her condition to the memory impairment depicted in the film "50 First Dates". Although FL stated that she had not seen the film before her accident, the film was released in 2004,

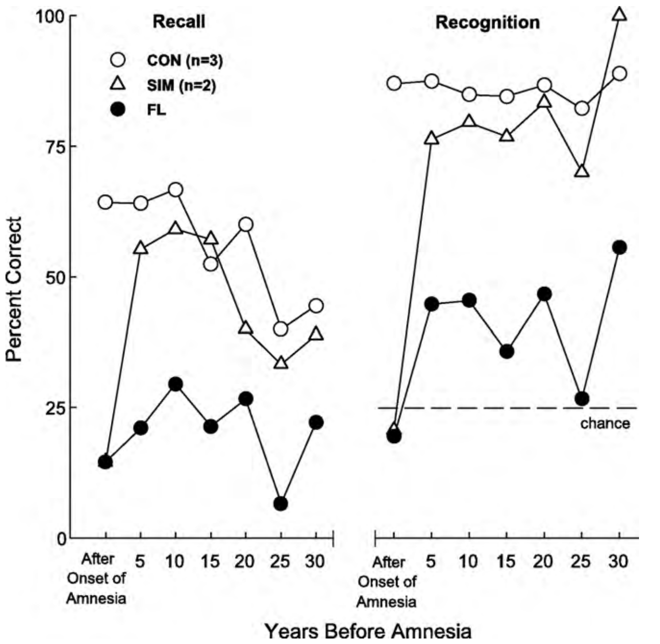

Fig. 4. Recall and recognition performance on a test of news events that occurred from 1975 to 2008. The scores for controls (CON; $n = 3$) and simulators (SIM; $n = 2$) have been aligned relative to the onset of amnesia in FL (2005). Performance is shown for the time period after the onset of amnesia and for 5-year intervals before the onset of amnesia. The data point 5 represents 1–5 years before amnesia, the point 10 represents 6–10 years before amnesia, and so on. After the recall test (left), participants completed a 4-alternative recognition test for the same material (right). Chance performance on the recognition test was 25%.

15 months before the onset of her condition. FL also stated that the film's central character is her favorite actress. Accordingly, it is possible that FL had knowledge of the film's plot before she developed memory impairment. FL's knowledge of how memory impairment was depicted in the film could have influenced her idea of how memory could fail after a car accident. Since the accident, her husband reported that she has viewed the film several times (though she forgets it after a night of sleep).

For the most part, formal testing documented FL's own description of her memory impairment. Thus, on five different tests of verbal and nonverbal memory, FL performed moderately well when trying to remember material that she had learned during the same day, but she exhibited no memory at all for material that she knew had been presented on a previous day (Table 2; Fig. 2). Additional tests, however, revealed that FL's memory loss for material learned earlier was not absolute, but could be revealed under certain conditions. First, for some tests, unbeknownst to FL, material learned on the previous day was intermixed with material learned on the day of the test. On these occasions, FL's memory for material learned the day before was nearly as good as her memory for material learned a few hours earlier (Fig. 2). Second, when the same material was presented multiple times across several days, FL performed considerably better than when the material was studied only once a few hours earlier (Fig. 2). That is, she exhibited the normal benefit of repetition on memory, in this case a benefit that required her to retain information across several days. Thus, FL's memory was not limited to the events of the current day. She could in fact remember events from earlier days but only under conditions where she believed she was being tested for material learned earlier on the same day.

FL performed very poorly on two motor skills tasks during both the first and second days of testing, and in addition exhibited no improvement from the first day to the second day (Fig. 3). Indeed, she performed more poorly on the second day than the first day. It is notable that patients with severe amnesia due to medial temporal lobe damage are quite capable of learning and remembering motor skills (Corkin, 1968; Milner, 1962). Thus, impaired learning and memory of motor skills is not observed in neurological amnesia.

FL had no difficulty recollecting autobiographical events from the time before the accident. She also recalled some autobiographical events from after the accident and explained that she knew about these events because she had read about them in the journal that she reads each morning. FL also identified the names of US cities as well as controls. In contrast, FL exhibited poor memory for news events whether they had occurred before or after the accident. The news events test was constructed such that material she was expected to know (events that occurred before the accident) was intermixed with material she was expected not to know (events that occurred after the accident). Performance may have been affected across all time periods if she had difficulty discriminating between these two kinds of material. Alternatively, it is possible that FL does not follow current events and had never learned about many of the events on the test. Indeed, she later noted that she "does not pay much attention" to current events.

On the basis of FL's neuropsychological findings, together with a normal neurological exam and normal MRI findings, we suggest that FL exhibits a form of functional amnesia. Nonetheless, her case is distinctly different from all other cases of functional amnesia known to us (e.g., Compodonico & Rediess, 1996; Kopelman et al., 1994; Kritchevsky et al., 2004; Schacter et al., 1982). First, as assessed by formal tests, patients with functional amnesia typically exhibit significant retrograde amnesia (especially for autobiographical information) in the absence of anterograde amnesia. However, FL has no difficulty remembering her past from before the accident. Second, most patients with functional amnesia do not report difficulty with everyday functioning. In contrast, FL has grave problems with everyday functioning because she does not remember from one day to the next. She accumulates memories during each day, but then the memories are lost after a night of sleep. Third, while most functional amnesic patients have premorbid psychiatric histories (Kritchevsky et al., 2004), we did not identify a significant psychiatric history for FL.

Despite these marked differences between FL's memory impairment and the typical pattern of impairment associated with functional amnesia, FL did share some characteristics with other cases (see Brandt & Van Gorp, 2006). Her amnesia was precipitated by a stressful event, she sustained mild head trauma at the time of the event, and there was involvement with the legal system after the accident.

In cases of functional amnesia, the question inevitably arises whether the impairment might reflect a conscious feigning or exaggerating of symptoms, either to achieve some psychological benefit from disability (Factitious Disorder) or in pursuit of some external incentive such as financial compensation (Malingering) (American Psychiatric Association, 1994). One test of malingering, in the case of memory impairment (TOMM; Tombaugh, 1996), measures memory only for material studied and tested on the same day. This test would not be able to detect malingering in FL, because she reported no difficulty remembering information learned earlier on the same day. In order to explore the possibility of malingering, we examined data from two volunteers who had been instructed to consciously simulate FL's memory impairment. Although simulators mimicked FL's condition on many tests, there were notable exceptions where FL and the two simulators performed differently.

First, on the memory test for scenes, simulators (and controls) expressed stronger confidence in their memory judgments when they were tested on material multiple times (instead of just once). In contrast, FL exhibited improved memory scores under the same conditions, but her confidence in her memory judgments decreased rather than increased.

Second, on tests of motor skill learning FL exhibited poor performance overall on each day and also exhibited little or no retention of the motor skill from one day to the next (Fig. 3). In comparison, simulators performed as well as or better than controls on these tests and exhibited retention of the skill from one day to the next. It is noteworthy that FL's poor performance on these tasks within each test day indicates that her impairment extended to areas where she should have been able to perform well (i.e., learning a motor skill during a single day). To some degree, the same observation can be made about her performance on standard tests of new learning (Table 2). She performed moderately well but appeared to fall short of what controls and simulators achieved. Perhaps an experience of disability creates tentativeness, anxiety, and a sense of helplessness that can affect test performance rather broadly.

Third, although both the simulators and FL recalled few news events from after the accident, they differed markedly in their memory for more remote events. Whereas the simulators did as well as controls at remembering news events from the time before the accident, FL did poorly across the entire 30 years covered by the test (Fig. 4).

In sum, FL performed differently in a number of ways from individuals who were consciously feigning memory impairment. Indeed, it was the impression of those who worked with FL during her visit to San Diego that she believed she had the memory impairment that she described. On the basis of these observations, we believe that FL was not consciously simulating a memory disorder. Instead, we suggest that the difficulties she exhibited with her memory involve processes not readily accessible to conscious awareness. It is notable that FL's condition did not improve when she was informed that she was in fact able to retain information from one day to the next (as our tests demonstrated). Rather, her condition improved (i.e., she became able to retain memories from one day to the next) when she was shown how to take control of her condition by interrupting her sleep at 4-h intervals. These observations are consistent with the suggestion that she did not have full conscious control over her condition. Rewarding her for improved function allowed her to alter her behavior.

Many writers have commented about how difficult it can be for either the patient or the clinician to know whether a particular behavior should be attributed to conscious or unconscious processes (Barbarotto, Laiacona, & Cocchini, 1996; Brandt & Van Gorp, 2006; Delis & Wetter, 2007; Kopelman et al., 1994). In addition, behavior may be guided by different degrees of conscious and unconscious control (Delis & Wetter, 2007; Hilgard, 1986; Kopelman et al., 1994). Certainly, determining to what extent a condition is under conscious control remains a formidable challenge. As suggested by McHugh (2008), conditions like functional amnesia may reflect vivid self-deception in the absence of any awareness of intent to mislead. The patient believes that he/she has a memory impairment and acts on the belief.

As suggested by Kritchevsky et al. (2004), patients with functional amnesia may perform poorly on tests in relation to how directly the test appears to assess a patient's commonsense concept of memory. Thus, the variability evident in different patterns of functional amnesia illustrates the various ways that lay people conceive of memory and memory impairment. The fact that FL's memory impairment is unique means that the variability with which memory impairment can be expressed is even greater than has been appreciated. In this sense, FL's case broadens the concept of functional amnesia. The idea that memories can disappear overnight became popularized by a fictional film and may have influenced FL's concept of how memory could fail after a car accident. The brain uses preexisting concepts of memory and through altered brain function creates a particular constellation of symptoms.

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