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CASE STUDY

Acquired oral reading vocabulary following the onset of amnesia in childhood

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Abstract

While the neuropsychological literature includes few cases of child-onset amnesia, 2 previous case studies suggest that these patients may be able to learn new information of a semantic or academic nature. The previous studies were, in large part, based on neuropsychological testing performed during adulthood and a retrospective review of academic achievement test scores during childhood. We present patient A.C., who acquired severe anterograde amnesia at age 10 years but demonstrated average levels of performance on tests of reading, spelling and arithmetic upon examination at age 19 years. Episodic and semantic memory test scores were severely impaired, but near normal performances were found on tests of implicit and procedural memory. In a prospective study, A.C. learned to read new irregular and pseudowords and retained this learning over a 1-month period, similar to the performance of age-matched controls. This demonstration of postmorbid, acquired oral reading vocabulary supports a previous conclusion that oral reading can progress in childhood following the onset of severe anterograde amnesia. The data also suggest that this new learning probably reflects nondeclarative memory processes rather than preservation of semantic memory, as was proposed in an earlier case study. (*JINS*, 1998, *4*, 179–189.)

Keywords: Amnesia, Child, Reading vocabulary, Academic achievement

INTRODUCTION

Patients with focal and severe memory deficits have fascinated clinicians and neuroscientists for at least a century (Claparède, 1911; Ribot, 1882). Cumulative evidence from a growing body of case studies and controlled research has converged upon a definition of the amnesic syndrome as a severe defect in the conscious remembering of information with sparing of intelligence, language, and other higher cognitive functions (Cermak, 1982; Cohen, 1984; Hirst, 1982; Squire & Shimamura, 1986; Weiskrantz, 1987). Investigations of amnesic patients have demonstrated that under special circumstances, these patients can learn new motor or cognitive skills (e.g., Charness et al., 1988), perform normally on a wide range of priming tasks (e.g., Cermak et al., 1988), and even learn new associations (Glisky et al., 1986). These studies have contributed to the widely agreed position that declarative memory functions mediated by a hippocampal–neocortical system are impaired in amnesia, and nondeclarative learning mechanisms mediated by other neural networks are preserved (Bauer et al., 1993; Squire, 1987). While this conceptualization of the amnesic syndrome is widely accepted, it is noteworthy that it evolved exclusively out of the study of adult patients.

To the best of our knowledge, only 2 cases of child-onset amnesia have been reported in the literature. Wood and colleagues (Wood et al., 1982, 1989) presented patient T.C., a young girl who contracted herpes encephalitis at age 9, while in the fourth grade. Two years after her injury, a CT head scan and EEG were normal and she was reported to be alert and able to communicate effectively. At age 16 years, psychological testing revealed a Verbal IQ of 78, a Performance IQ of 91, and a Full Scale IQ of 83 based on the Wechsler Intelligence Scale for Children–Revised (Wechsler, 1974). Dense anterograde amnesia was firmly established at age 20 with standardized tests of recent episodic memory and new learning. Wood et al. (1989) noted that while T.C.'s Verbal IQ was below average, her score was actually higher than might have been expected for the se-

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verity of her amnesia, considering that at least some acquired semantic knowledge is necessary for a normal score on many of the subtests that comprise the VIQ. Indeed, had T.C. achieved raw scores consistent with a 9-year-old child, her age-based Verbal IQ would have been 50 to 60, rather than 78. With this intriguing observation, the authors went on to retrospectively review T.C.'s academic records. Not only had T.C. passed a high school competency examination that required at least a sixth-grade level of proficiency, but at age 20, her scores on the reading and spelling subtests of the Wide Range Achievement Test–Revised (WRAT–R; Jastak & Wilkinson, 1984) were at the eighth-grade level. Together, these findings were taken as evidence that T.C. had acquired a substantial base of postmorbid academic knowledge, and it was further proposed that semantic memory can be preserved in some amnesic patients.

These findings and interpretations were strongly challenged by Ostergaard (1987) who presented the only other child-onset amnesia case known to us. Patient C.C. developed severe anterograde amnesia when he was 10 years of age, following an anoxic episode. A CT head scan performed approximately 3 months later revealed damage in multiple areas of the brain including the left mesial temporal lobe, the right orbitofrontal white matter, and the right anterior hippocampus. At 6 months postinjury, his WISC–R Verbal IQ was 96 and his Performance IQ was 99 (Full Scale IQ not reported), scores that were regarded as consistent with his premorbid level of intelligence. About 6 years later, C.C. underwent extensive neuropsychological testing that demonstrated a severe, dense anterograde amnesia. He was then compared with 8 age-matched control participants on various implicit and procedural memory tasks. The results indicated that his nondeclarative memory task performances were within normal limits. Review of academic records revealed that at 6 months postinjury, C.C.'s reading age score on the Schonell Reading Test (Schonell & Schonell, 1960) was 9 years, 7 months, and his spelling age equivalent was 9 years, 2 months. By age 15, his age equivalent had progressed to the 11 year, 8 month level in reading, and to the 10 year, 8 month level in spelling.

In their commentary, Ostergaard and Squire (1990) pointed out that while T.C.'s academic achievement test scores suggested at least some degree of postmorbid academic learning, her progress had actually been quite slow. For example, between the ages of 14 and 20, she had progressed only two grade levels in reading. Ostergaard and Squire (1990) also questioned the severity of T.C.'s amnesia because she had demonstrated some preservation of episodic memory on a verbal learning test (she recalled 3/15 words after a 25-min delay). C.C.'s gain in academic performance was, on the other hand, considered quite modest, as his reading age was still well below his chronological age. Ostergaard and Squire (1990) continued by arguing that even if one concedes that some progression in academic performance had taken place in T.C. and C.C. after the onset of amnesia (and that T.C. was in fact amnesic), the observation could be explained by multiple factors other than preserved semantic memory, as was proposed by Wood et al. (1989). Ostergaard and Squire summarized their thoughts by pointing out that amnesic patients, regardless of age, have normal capacities for perceptual and motor skills, priming, and conditioning, in contrast to an impaired ability to "learn new vocabulary words, facts, and episodes."

These case reports raise questions about the presentation of child-onset amnesia and the degree to which such patients are capable of developing postmorbid academic or semantic knowledge. In this paper, we present patient A.C., who developed severe anterograde amnesia at age 10. She shares with T.C. both her gender and the etiology of her condition, and as with C.C., structural neuroimaging studies have demonstrated extensive mesial temporal lobe damage. The age of onset is almost identical in all 3 cases and all were at least average in intelligence prior to injury. Our first goal was to gather evidence for or against the hypothesis of preserved postmorbid semantic memory *via* comprehensive neuropsychological evaluation. We also endeavored to determine prospectively whether A.C. is capable of learning new vocabulary.

CASE HISTORY

In the spring of 1986, A.C., then a healthy, 10-year-old, right-handed White girl, was admitted to a university-affiliated hospital with acute fever and severe headache. She was disoriented, had problems recognizing family members, and evidenced auditory and visual hallucinations. Neurological examination and a CT head scan without contrast were normal. Analysis of the cerebrospinal fluid revealed a white cell count of 1410 and a glucose count of 70. Cell cultures were negative. A.C. was diagnosed with probable herpes encephalitis and begun on a 10-day course of acyclovir, which was followed by a second 10-day course, 12 days later. During the second week of hospitalization, her EEG tracing revealed diffuse slowing and she suffered a generalized seizure. Antiseizure and neuroleptic medications were then begun in varying combinations in an effort to control A.C.'s seizure activity and psychosis. By Day 40, her mental status was clear and she was discharged with a diagnosis of dementia secondary to herpes encephalitis. Soon after her return home all psychotropic medications were discontinued and she remained seizure-free until 1989 when she developed a generalized tonic–clonic seizure. An EEG revealed left temporal sharp and slow waves and she was begun on Tegretol. Her seizures have been well controlled since that time.

Two MRI head scans were performed in 1989 and 1991 (see Figures 1 and 2). In both studies, T_1 weighted images demonstrated large areas of low signal intensity in the temporal lobes (more severe on the right) and dilatation of the temporal horns. The low intensity signals were read as being consistent with encephalomalacia and atrophic change. On proton density images, abnormal signals were found in the same location revealing evidence of extensive gliosis. Abnormal high signal intensities were seen on T_2 images in

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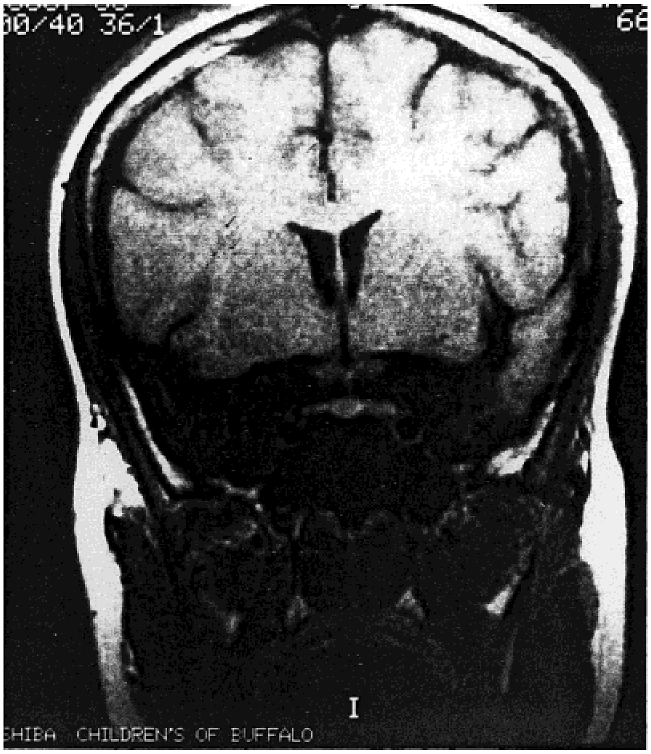

Fig. 1. T_1 weighted MRI head scan of patient A.C. demonstrating large areas of low signal intensity in the temporal lobes bilaterally in coronal section. The MRI scan shows infarction extending into the superior temporal gyrus on the right, and involvement of the middle temporal gyrus on the left. Both mesial temporal lobes are completely damaged.

the same location. As can be seen in Figures 1 and 2, the scans clearly demonstrate that the entire inferior surface of both temporal lobes are lesioned. On the right, the entire temporal lobe extending up through the middle temporal gyrus is involved. On the left, the lesion is less extensive at the level of the middle temporal gyrus, with less posterior involvement. The entire anterior and mesial temporal lobes are lesioned, bilaterally. Neither scan revealed evidence of damage to the frontal or parietal lobes.

Prior to the onset of her illness, A.C.'s only medical problems had been recurrent ear infections between the ages of 4 and 5 years, placement of bilateral tympanotomy tubes, and intermittent migraine headache. Her psychological functioning was described as excellent. She was born *via* cesarean section without complication and her developmental milestones were met at expected times. She was described as a happy third-grade student at the time of her illness. A.C. underwent two neuropsychological examinations between 1986 and 1992, but only a narrative report from one examination could be obtained.

Currently, A.C. resides with her parents but she is completely independent in personal hygiene and other physical self-maintenance skills. She is responsible for a few chores around her home such as washing dishes, mowing the lawn, and cleaning her room. She is very adept at computer video games. She has participated in special education and vocational rehabilitation since her injury and she recently graduated from a vocational training program. Her calculation skills were recognized as a relative strength a few years ago and she was given a trial as cashier in a school store. She did not do well, however, because she could not keep track of transactions. She has performed better in clerical positions requiring her to file papers, take messages, and so forth. A.C. has few friends and at times complains of feeling lonely. In the near future, she hopes to be placed in a supervised apartment complex for disabled adults.

STUDY 1: NEUROPSYCHOLOGICAL EXAMINATION

A.C. was examined in a university neuropsychology clinic, 9 years postinjury. She was alert and partially oriented to time and place. Her response latencies were long but her speech was normally articulated. There was no evidence of formal thought disorder or psychosis. Her affect was mildly blunted and symptoms of depression were denied by both her and her mother. A severe anterograde memory deficit was readily apparent on mental status exam as A.C. had great difficulty relating information concerning recent events. For example, she could not recall what she had had for dinner

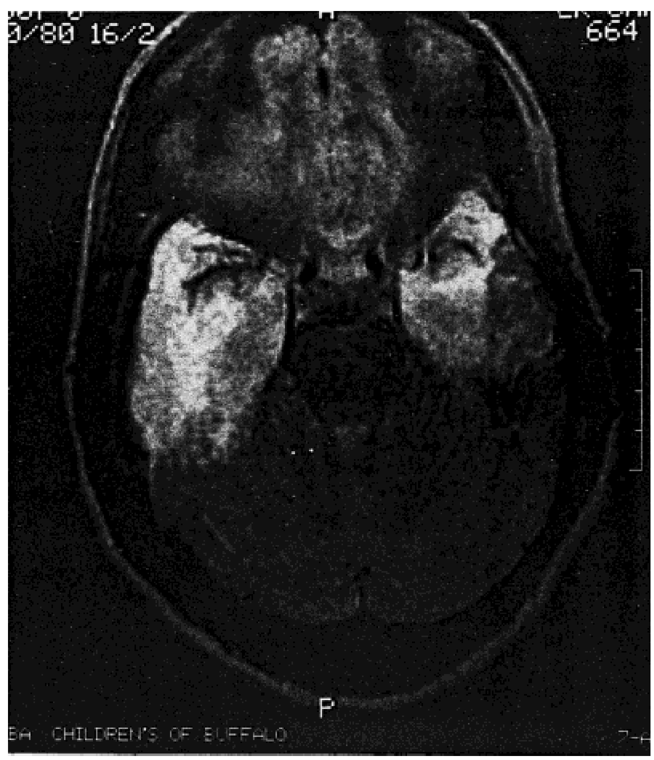

Fig. 2. T_2 weighted MRI head scan of patient A.C., in transverse plane, demonstrating large areas of high signal intensity in the temporal lobes bilaterally. The MRI scan shows infarction extending into the posterior temporal lobe on the right, with some sparing of the posterior mesial temporal lobe on the left.

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the night before her appointment, and her responses to questions regarding her journey to the hospital were vague. A.C.'s mother had not observed any symptoms of depression, save for occasional frustration at her lack of autonomy. Neuropsychological test scores were compared to normative samples published for each test, and A.C.'s age-based percentile equivalents are presented in Table 1. For tests where combined age- and education-based percentiles were available, an education level of 12 years was used to derive the percentile rank.

General Intelligence and Executive Control

A.C.'s IQ scores on the Wechsler Adult Intelligence Scale–Revised (WAIS–R; Wechsler, 1981) were Full Scale 85, Verbal 88, Performance 85. Performances on tests requiring the rapid processing of information, attention, and problem-solving were intact or above average. For example, on the Brief Test of Attention (Schretlen et al., 1996a, 1996b), a newly developed test of auditory divided attention, A.C.'s performance was above average for her age. On the Wisconsin Card Sorting Test (Heaton, 1981), she completed 6 categories while making only 12 errors. Her generation of word lists on the Controlled Oral Word Association Test (Benton & Hamsher, 1983) was superior and her reproduction of the Taylor figure (Taylor, 1969) was scored as only mildly deficient.

Declarative Memory

In contrast, A.C.'s performances on tests of recent, episodic memory were severely impaired. On the Wechsler Memory Scale–Revised (Wechsler, 1987), her memory index scores were all less than 50, while her Attention–Concentration Index was 100. A revised version of the Hopkins Verbal Learning Test (HVLT–R; Benedict et al., in press) was also administered. In completing this test, A.C. was presented with a 12-item word list on three successive learning trials. She was then asked to recall the list again 25 min later. The delayed free-recall trial was then followed by a yes–no recognition trial including the 12 target words and 12 nontargets. A.C. recalled 5, 5, and 6 words over the learning trials and her delayed recall was zero. On the delayed recognition task, she gave 8/12 true-positive and 7/12 false-positive responses. The Brief Visuospatial Memory Test–Revised (BVMT–R; Benedict, 1997) is a nonverbal analog to the HVLT–R, in which patients are asked to learn a matrix of six geometric designs (maximum score is 2 points per design). Again, A.C.'s learning curve was reduced relative to normal performance, and her delayed recall and recognition scores were severely impaired.

Nondeclarative Memory

Standardized testing of implicit and procedural memory ability was carried out using subtests from the Colorado Neuropsychology Tests battery (Davis et al., 1994). This package includes a range of declarative and nondeclarative memory tasks that are administered with a personal computer. While each test includes many administration options, only the standardized versions of the tests were employed here. A.C.'s performances were compared to a standardization sample of 30 persons with a mean age of 21.8 years (SD = 3.0) and 14.1 years (SD = 1.7) of education.

The Hanoi Test presents a five-ring, three-position version of the Tower of Hanoi puzzle. The task begins with five rings varying in size and color stacked on the right side position. A.C. was required to move the rings from their initial position to the same arrangement on the left side. Smaller rings were required to be placed on top of larger rings at all times. Each change of position constituted one move and A.C.'s goal was to change the position of the rings in the fewest number of moves possible. Four successive trials of the task were administered in a single session, followed by the same procedure 1 week later. In Session 1, the average number of moves per trial was impaired relative to controls (Table 1). But in Session 2, A.C.'s per-trial average improved to 71, which is within normal limits. While the test manual does not provide normative data for Session 1 to 2 change scores, the data do demonstrate improvement of 19.8 moves by controls. By comparison, A.C.'s improvement was 26.3 moves.

The Repeat Test is a serial reaction time task modeled after the procedures of Lewicki et al. (1988) and Nissen and Bullemer (1987). A.C. was asked to press a key on the numeric keypad (Key 1, 2, 4, or 5) corresponding to one of four quadrants on the computer screen. Whenever the target stimulus "X" appeared on the screen, her task was to press the corresponding key as quickly as possible. Unknown to A.C. a repeating sequence of stimuli was included in each of eight successive trials (100 stimuli per trial), administered in a single session. A.C. made two errors on Trial 1 and her mean response latency was .62 s. On Trial 8, she made no errors and her mean response latency was .46 s. Her improvement from Trials 1 to 8 was similar to that of the standardization sample (A.C. = .16; controls = .20).

The Priming Test was used to examine A.C.'s performance on word-stem completion, recall, and recognition tasks. In two successive word-stem completion tasks, administered in accordance with the procedure of Davis et al. (1990), A.C. was presented with a 15-item word list and asked to rate how much she liked each word on a 5-point scale. Then, the stems of 10 rated words and 10 new baseline words were presented and A.C. was asked to simply say the first word that comes to mind. A priming score was calculated as the percent of rated words completed correctly minus the percent of baseline words. On the first word-stem completion task, A.C. completed 60% of the rated words and 10% of the baseline words, resulting in a priming score of 50%. On the second task using a different word list, her priming score was 20%, resulting in a total priming score of 35%, which places her roughly .5 standard deviations below the mean for her age. Recall and recognition tasks were then presented in the same format such that A.C. was asked

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Table 1. Neuropsychological test results

Test	Score	Percentile
General intelligence		
Wechsler Adult Intelligence Scale–Revised		
Information	5	5
Digit Span	11	63
Vocabulary	7	16
Arithmetic	13	84
Comprehension	7	16
Similarities	9	37
Picture Completion	7	16
Picture Arrangement	8	25
Block Design	12	75
Digit Symbol	7	16
Verbal IQ	84	16
Performance IQ	85	16
Full Scale IQ	84	16
Executive and visuospatial functions		
Controlled Oral Word Association Test	44	85
Brief Test of Attention	18	75
WAIS–R Digit Span	11	63
Trail Making Test		
Part A	32	25
Part B	51	84
Complex Figure Test copy	30	10
WAIS–R Block Design	12	75
Wisconsin Card Sorting Test		
Categories	6	>75
Total # errors	12	>75
WMS–R Attention–Concentration Index	100	50
Declarative memory		
Wechsler Memory Scale–Revised		
Logical Memory I	6	1
Logical Memory II	0	1
Visual Reproduction I	23	3
Visual Reproduction II	0	1
Verbal Memory Index	<50	<1
Visual Memory Index	50	<1
General Memory Index	<50	<1
Delayed Recall Index	<50	<1
Hopkins Verbal Learning Test–Revised		
Trials 1 to 3	16	2
Delayed Recall	0	<1
Recognition Hits/False-Positives	8, 7	<1
Brief Visuospatial Memory Test–Revised		
Trials 1 to 3	6	<1
Delayed Recall	0	<1
Recognition Hits/False-Positives	6, 3	<1
Warrington Recognition Memory Test		
Words	27	<5
Faces	25	<5
Nondeclarative memory		
Colorado Neuropsychology Tests		
Tower of Hanoi, mean # of moves Week 1	97.8	2
Tower of Hanoi, mean # of moves Week 2	71.5	16
Pattern Repeat reaction time, Trial 1	.62	50
Pattern Repeat reaction time, Trial 8	.46	16
Priming Test, priming score	35.0	25
Priming Test, recall score	0	<1
Priming Test, recognition score	55.0	<1

continued

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Table 1. *Continued*

Test	Score	Percentile
Language and academic ability		
WAIS–R Arithmetic	11	84
Wide Range Achievement Test–R[2]		
Reading	64	50
Spelling	29	32
Arithmetic	37	53
Gray Oral Reading Tests–Third Edition		
Passage Score	83	25
Comprehension Score	19	<1
Boston Naming Test	35	<1
Peabody Picture Vocabulary Test–Revised	97	<1
WAIS–R Information	4	2
WAIS–R Vocabulary	5	5

to first rate words and then asked to recall them. Her recall score was 0/10. On the yes–no recognition task, she gave 9 true-positive and 8 false-positive responses, a severely deficient performance (recognition score calculated as number correct/number incorrect).

Language and Academic Achievement

The profile of WAIS–R subtest scores included a significant degree of variability, especially on the verbal scale. Relatively high scores were found on Digit Span (age-corrected scale score = 11) and Arithmetic (age-corrected scale score = 13) consistent with her preserved capacity for attention and immediate memory. The superior score on the WAIS–R Arithmetic subtest also implies that A.C., despite her amnesia, has acquired new information pertaining to mathematical problem-solving. On the WRAT–R, her grade equivalents were Reading 12E, Spelling 9E, and Arithmetic 11E. She read correctly the words *deteriorate*, *protuberance*, and *abysmal*. On the other hand, scores on tests highly dependent upon the knowledge of word meaning were far below average. A.C.'s Boston Naming Test (Kaplan et al., 1983) score was severely impaired, and on the Peabody Picture Vocabulary Test–Revised (PPVT–R; Dunn, 1981) her score was below the 1st percentile.

Summary

The neuropsychological test data indicate that this child-onset amnesic patient has severe deficits in recent declarative memory, with relatively preserved abilities in verbal fluency, attention, problem-solving, procedural learning, and implicit memory. Like patient T.C., her scores are higher than we would expect on tests emphasizing academic-based knowledge, particularly in the areas of arithmetic and oral reading. At the same time, her performances on tests that emphasize the semantic meaning of words (BNT, PPVT–R, WAIS–R Information and Vocabulary) are severely impaired.

STUDY 2: ACQUISITION OF READING VOCABULARY

Research Participants

In addition to A.C., the participants included 7 sex- and age-matched, healthy participants, recruited from an introductory psychology class at a large metropolitan university in the northeast United States. Each volunteer received class credit and a payment of $30 in U.S. currency in exchange for participating. Their average age was 18.4 years (*SD* = 0.5, range = 18–19). All were White, right-handed, speakers of English. Six of the students were college freshmen, and one was a sophomore. Exclusion criteria for the control group included history of neurologic or psychiatric illness, learning disability, attention deficit disorder, and substance or alcohol abuse.

Materials

A reading vocabulary test was developed that included 25 real words (nouns) and 25 pseudowords, all with irregular spelling–pronunciation correspondences. The irregular real words were selected from the Oxford Psycholinguistic Database (Quinlan, 1992) using the following selection criteria: Kucera-Francis frequency = 1, familiarity rating = 0, imagery rating = 0. These criteria produced a list of infrequent, unfamiliar, and low imagery nouns from which 25 words were selected based on unusual spelling-to-sound correspondences. The selected words were from five to eight letters in length and contained two or three syllables. The pseudowords were composed by a linguist (J.J.) and were also five to eight letters and two or three syllables in length; while they were all possible English words, they contained the same types of unusual spelling-to-sound correspon-

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dences found in the irregular real words. Definitions for the pseudowords were created by selecting noun definitions at random from a standard English dictionary (e.g., *thorzue* = long flowing skirt, *bognach* = large waterfall). The final result was a list of 50 irregular words and definitions that were not likely to be read or defined correctly by either A.C. or controls.

Procedure

The reading vocabulary experiment was divided into three sessions, conducted at 1-week intervals.

Session 1: Pretraining vocabulary tasks

Three pretraining vocabulary tasks were administered to each participant: (1) *oral reading*, (2) *definition recall*, (3) *definition recognition*. The tasks were administered individually to each participant. In the *oral reading task*, a 22 × 28 cm sheet of paper containing the 50, randomly arranged, irregular words was presented to each participant. Using instructions similar to the North American Adult Reading Test (Blair & Spreen, 1989) the participants were instructed to simply read each word aloud and to guess at the pronunciation of words they did not know. The participants were permitted to change a response provided they decided on a final pronunciation for each word. The *definition recall task* was administered in a format similar to the Vocabulary subtest from the WAIS–R, except that the stimuli were presented visually and the responses were scored as either *correct* (1 point) or *incorrect* (0 points). Even vague approximations of the target definitions (e.g., a 1-point response on the WAIS–R Vocabulary test) were scored as correct. Using the same stimulus sheet as in the oral reading task, the participants were asked to provide the best definition for each word. Finally, a multiple-choice recognition task was presented in the visual modality. This *definition recognition task* consisted of a booklet with the 50 irregular words, each followed by its correct definition and five foils. Participants were told to simply circle the correct definition for each word. One of the six choices for each word was "I do not recognize the definition." The position of the correct answer in the list was randomized across items. The reading vocabulary tasks were administered by a clinical psychology graduate student who was familiar with A.C. and the purpose of the experiment.

We anticipated that the participants might pronounce, recall, or recognize some of the real words in the list, and by chance alone respond correctly to a few pseudowords. Any word correctly pronounced or defined by any subject during the recall or recognition task in Session 1 was removed from the experiment. Twenty-six words were eliminated on this basis, leaving 6 irregular real words and 18 pseudowords that were unfamiliar to all subjects (Appendix A). Of the remaining 24 words, 12 (3 real words, 9 pseudowords) were selected randomly for the vocabulary training intervention (hereafter referred to as trained words) leaving 12 words for the control condition (control words).

Session 2: Vocabulary training

The vocabulary training intervention was designed to train participants to read and define the 12 trained words to a criterion of 100% correct. Participants were told that the purpose of the study was to see how quickly people can learn new words and their definitions. The intervention began with the oral reading phase in which the experimenter presented each correct pronunciation aloud. Participants were instructed to practice saying the words by simple repetition, with errors being corrected by the experimenter. The participants were not permitted to write notes, use visual imagery, or any other compensatory or mnemonic strategy during this phase of training. The experimenter made periodic checks on progress by asking the participant to read the list of trained words.

Once a participant demonstrated correct pronunciation of all 12 words, the experimenter began the definition phase of the intervention. Participants were given a sheet of paper on which the correct definition for each word was printed, as well as examples of mnemonic strategies that might be used to help them remember the definitions. They were instructed to learn the definitions, by employing one of the mnemonic strategies. Again, the experimenter made periodic checks on progress in definition learning, while continuing to insure proficiency in oral reading. Participants were excused from the training session after they were able to read and define each of the 12 words. To discourage the participants from practicing the words between Sessions 2 and 3, they were told that they had completed the vocabulary part of the experiment and that the final session would be devoted entirely to debriefing and other cognitive tests.

The healthy participants were trained in two groups of 3 and 4, seated far enough away from one another to prevent distraction. All of the healthy participants completed the training session in 1 hr or less. A.C., as expected, had much more difficulty with vocabulary training. As a result, four successive training sessions, conducted at 1-week intervals, were employed in her case. A.C. also had the benefit of being trained individually. She reached criterion for oral reading, but after nearly 2 hr of practice with the word definitions, the definition phase was terminated due to her increasing frustration with the task.

Session 3: Posttraining vocabulary tasks

One week following Session 2, a revised version of the reading vocabulary assessment task, including only the 24 trained and control words, was administered. For all participants, the administration and scoring of the tasks was conducted by a new experimenter who was blind to the identity of the trained and nontrained words, as well as pretraining performance. As in Session 1, the tasks were administered individually, along with standardized tests of cognitive function (HVLT–R, BVMT–R).

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Results

As can be seen in Table 2, A.C. performed well outside the range of controls on the HVLT–R and BVMT–R, despite the fact that she had been exposed to the same tests about 18 months earlier. As a group, controls retained 100% of what was initially recalled on these tests 25 min later, whereas A.C.'s retention was nil. The recognition discrimination index scores (true-positives minus false-positives) also demonstrate a severe deficit in delayed recognition memory. These repeated declarative memory tests confirmed that A.C. was still severely amnesic at the time of the reading vocabulary experiment.

During training, controls required an average of 15 min to reach criterion during the oral reading phase, and 23 min to learn the definitions for each of the trained words. A.C.'s ability to learn the new word pronunciations was deficient, as she required 78 min to attain the criterion level of performance. As noted above, 112 min were devoted to learning of definitions, but A.C. learned only 8/12 trained words during that time period. These observations demonstrate that A.C. is deficient in the acquisition of both oral reading vocabulary and word meanings.

Nontrained words were not read correctly, by either A.C. or controls, 1 week after training. In addition, participants demonstrated very little knowledge of the nontrained word definitions by either recall or recognition tests. Control participants did retain the ability to read the trained words 1 week after training, as demonstrated by a mean correct score of 11.1 (*SD* = 1.1). In comparison, A.C. read 8 of 12 words correctly, a level of performance that falls outside of the normal range. Definitions of trained words were easily recalled and recognized by the control group, but A.C. had no declarative memory for these definitions. The reading vocabulary test was readministered to A.C. in a 1-month follow-up session. As would be expected, her recall and recognition performances were again at or near zero, but she again read correctly 8 of the 12 words that she had been trained to read 5 weeks earlier. Thus, there was no loss of oral reading vocabulary knowledge over a 5-week interval.

DISCUSSION

Two previous case studies of child-onset amnesia generated debate about the degree to which a patient who acquires amnesia in childhood can develop postmorbid academic knowledge (Ostergaard, 1987; Ostergaard & Squire, 1990; Wood et al., 1982, 1989). In our opinion, patient A.C. has higher scores on standardized tests of academic knowledge than would be expected given that she acquired severe anterograde amnesia during the third grade. While the results of nondeclarative memory tests were either normal or equivocal, very severe impairments were found on all tests of episodic and semantic memory. In a prospective study, A.C. learned to read eight pseudowords that she had failed to either read or define at baseline. This unequivocal dem-

Table 2. Reading vocabulary results

Measure	A.C.	Max	Control group *M*	Control group *SD*	Control group Range
Hopkins Verbal Learning Test–Revised					
Total immediate recall, Trials 1–3	16	36	30.0	2.9	25–33
Delayed recall	0	12	11.3	0.8	10–12
Percent retained	0	100	100	7.0	92–110
Delayed recognition discrimination	1	12	11.7	0.5	11–12
Brief Visuospatial Memory Test–Revised					
Total immediate recall, Trials 1–3	6	36	31.4	2.5	28–35
Delayed recall	0	12	11.7	0.5	11–12
Percent retained	0	100	98	3.0	92–100
Delayed recognition discrimination	3	6	6.0	—	6–6
Training time (min)					
Pronunciation	78	—	15.0	6.6	7–25
Learn definition	112	—	22.7	4.4	18–30
Posttraining Reading Vocabulary Task					
Pronunciation—trained words	8; 8	12	11.1	1.1	9–12
Pronunciation—control words	0; 0	12	0.3	0.5	0–1
Recall definition—trained words	0; 0	12	9.7	1.8	7–12
Recall definition—control words	0; 0	12	0	—	0–0
Recognize definition–trained words	1; 2	12	11.9	0.4	11–12
Recognize definition–control words	0; 0	12	0	—	0–0

Max = maximum score on task. The two scores recorded for A.C. on the Posttraining Reading Vocabulary Task refer to the score 1 week following training, and follow-up 5 weeks after training. Delayed Recognition Discrimination scores calculated as true- minus false-positives.

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onstration of postmorbid, acquired oral reading vocabulary supports Wood et al.'s conclusion that oral reading skills can progress in child-onset amnesia.

At the same time, our findings do not support a previous argument that this finding demonstrates that semantic memory is spared in amnesia (Wood et al., 1989). Neuropsychological testing revealed failures on all tests that require the use and understanding of word definitions, and A.C. failed to recall or recognize a single word definition in the prospective study, despite nearly 2 hr of practice. Unfortunately, the design of our study does not permit us to identify the cognitive process that underlies A.C.'s acquisition of new oral reading vocabulary. We did not administer a lexical decision task (cf. Verfaellie et al., 1995) that would have helped distinguish between lexical and procedural learning skills in this patient, nor did we test whether A.C. could read other new words that follow the same unusual spelling–pronunciation correspondences found in the trained words. As a result, this phenomenon could be explained by preserved lexical processing, the learning of specific grapheme-to-phoneme transformations, or more simple motor learning with repetition. Nevertheless, the majority of our data would seem to support Ostergaard and Squire's (1990) more general contention that nondeclarative memory plays a substantial role in the unexpectedly strong academic performances of the child-onset amnesics studied to date. This hypothesis is supported by the relatively strong procedural and implicit memory abilities found in patients A.C. and C.C.

Our conclusions are, of course, limited by the problems encountered in any single-case study. Unique characteristics of T.C., C.C., and A.C. limit the degree to which we can generalize the findings to the population of child-onset amnesia patients. While all 3 patients have severe anterograde amnesia, their brain damage is not restricted to the hippocampus and related mesial-temporal structures, unlike some adult bitemporal amnesia patients (Benedict et al., 1993; Cermak & O'Connor, 1983; Gabrieli et al., 1988; Zola-Morgan et al., 1986). A.C. suffered damage to the lateral aspect of the temporal lobes and this extensive injury could have contributed to her inability to learn new word definitions. Therefore, while we offer a preliminary conclusion that child-onset bitemporal amnesics can learn to read new words, we do not claim that another child-onset amnesic with more focal brain damage could not learn new word definitions with the proper form of training. Indeed, other research has demonstrated the development of vocabulary and factual knowledge in amnesic patients when the information is acquired and tested implicitly and with few incorrect responses (Glisky et al., 1986; Van der Linden et al., 1994).

Our clinical interactions with A.C. suggest other ways in which the child-onset amnesic may differ from adult-onset patients. In spontaneous conversation, A.C. demonstrated some retention of recent events even though she could answer few direct questions about recent activity during the clinical interview. It was our impression that A.C. often had a vague awareness of recent events, although the information was not integrated into a conscious, temporal schema. For example, while she could not list what she had eaten for breakfast the morning of her appointment, she later stated (correctly) that it was a warm sunny day and that she had stopped to eat on her way to the hospital. Similar observations have been made by other amnesia researchers (e.g., Verfaellie & Cermak, 1994), but such an observation in this patient with such extensive temporal lobe damage is remarkable. One might speculate that when amnesia is acquired at an early age, patients may develop exceptional skill in the use of nonconscious or automatic memory mechanisms in their efforts to adapt to their environment. Alternatively, unlike the adult-onset amnesic, child-onset patients are likely to be inundated with special education and vocational rehabilitation interventions after the onset of their injury. Combined with a greater degree of neural plasticity that is likely present in a younger patient, these factors may all contribute to a less severe amnesic syndrome in the child-onset patient.

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Appendix A

Word type	Orthography	Pronunciation	Definition
Trained words			
Real words	AEGIS	[í-dʒəs]	"heavy shield or breastplate"
	SCION	[sáʲ-jən]	"bud of a plant"
	VERMEIL	[vɚ-méʲ]	"metal coated with gold"
Pseudowords	BOGNACH	[bág-ni-jǽk]	"large waterfall"
	CHEILAS	[tʃéʲ-laz]	"great disaster"
	CURINGE	[kʰjɚ́-ɪŋ]	"something that holds a variety of odds and ends"
	DEARTIAN	[dɚ́-ʃən]	"worm-like insect"
	GEBBET	[dʒə-béʲ]	"tree found in the rain forest"
	JALIGHT	[dʒǽ-laʲt]	"verse of a poem"
	KIEZE	[kʰi-jɛ́ʃ]	"isolated island"
	QUESIUR	[kʰeʲ-ʃɚ́]	"alphabet used by ancient people"
	THORZUE	[θor-swéʲ]	"long flowing skirt"
Nontrained words			
Real words	CORTEGE	[kʰor-tʰáʒ]	"group of followers"
	GHAZAL	[gá-zal]	"long poem"
	METIER	[mèʲ-ti-jéʲ]	"advanced trade or profession"
Pseudowords	CHYDON	[kʰí-dən]	"small songbird"
	FLIVAGE	[flɪ-váʒ]	"harsh cry"
	GNACE	[néʲ-si]	"small room or compartment"
	PHEATUM	[fɛ́-ɾəm]	"metal used in the construction of a ship"
	PRIUN	[pʰraʲ-jún]	"disease resulting from poor nutrition"
	SOUGHER	[sóʷ-gɚ]	"artwork found in a museum"
	TROTER	[troʷ-tʰéʲ]	"small red home plant"
	XONGIPE	[zɔ́ŋ-gɪp]	"person who lives in the jungle"
	ZOTHER	[zə-tʰɛ́r]	"harsh, blowing wind"

Pronunciations are given in the International Phonetic Alphabet; hyphens indicate syllable boundaries, and accent marks indicate stress.

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