

ACQUISITION OF DOMAIN-SPECIFIC KNOWLEDGE IN ORGANIC AMNESIA: TRAINING FOR COMPUTER-RELATED WORK*

ELIZABETH L. GLISKY† and DANIEL L. SCHACTER

Department of Psychology, University of Toronto, Toronto, Ontario, Canada M5S 1A1

(Received 9 December 1986; accepted 4 February 1987)

Abstract—In previous research we demonstrated that memory-impaired patients can acquire some forms of complex domain-specific knowledge in the laboratory. The present study explored further the kind of complex knowledge that amnesic patients can acquire in the laboratory, and examined whether such knowledge could be applied in an important domain of everyday life. A severely amnesic patient was taught, in the laboratory, the knowledge and skills needed to perform a complex computer data-entry job. Subsequently, she was able to perform the job in the real-world work environment as quickly and as accurately as experienced data-entry employees. Successful job training appeared to depend on (a) the use of a training technique, *the method of vanishing cues*, that engaged the patient's preserved learning abilities, (b) extensive repetition of all procedures, and (c) explicit and direct training of all components of the job.

INTRODUCTION

It is widely recognized that organic memory disorders interfere with many different aspects of everyday functioning [24]. However, there is as yet little evidence that neuropsychological interventions can have a significant positive impact on the day-to-day lives of patients with serious memory problems. Although a large number of studies have been concerned with remediation of memory disorders, they have generally lacked ecological validity and have therefore failed to demonstrate significant transfer of training from the laboratory to the real world. This article describes a case study in which we attempted to teach a memory-impaired patient knowledge and skills that had to be applied in an important domain of everyday life: the workplace. The patient was a young woman whose continued employment in a large corporation depended on her ability to learn a complex computer data-entry job. She was initially taught the job in our laboratory using experimentally developed techniques, and then performed her duties flawlessly in the actual work environment. Before describing further the nature of the job, the details of the training procedure, and the data that were obtained, we will first outline the rationale underlying our approach and review earlier research that provided an impetus for the present study.

*This research was supported by a Special Research Program Grant from the Connaught Fund, University of Toronto, and by the Natural Sciences and Engineering Research Council of Canada, Grant No. UO361 to Daniel L. Schacter.

†Address correspondence to either Elizabeth L. Glisky or Daniel L. Schacter, now at Department of Psychology, University of Arizona, Tucson, AZ 85721, U.S.A.

Background and rationale

During the past decade, a growing number of studies have explored whether effective methods of memory remediation or rehabilitation can be developed (for review, see [5, 10, 17, 23, 28]). The general approach taken by most investigators has been to try to improve patients' mnemonic function in some general sense and thereby lessen the impact of memory disorder on everyday life. Two different manifestations of this orientation can be distinguished. First, several investigators have reported attempts to restore memory function by having patients perform repetitive drills or exercise (e.g. [8, 19]). Second, a larger number of studies have examined whether patients can learn mnemonic strategies, such as imagery (e.g. [3, 12, 18]), organization (e.g. [4]), and rehearsal (e.g. [25]), which are potentially applicable to numerous situations in everyday life that place demands on memory. Unfortunately, the results to date have been decidedly disappointing. Although it has been demonstrated that memory-impaired patients can learn specific pieces of information and even some mnemonic strategies, there is as yet no empirical evidence that the memory function of brain-damaged patients can be improved by drills or exercises; nor is there convincing evidence that patients actually use mnemonic strategies on an ongoing basis in their everyday lives (cf. [17, 20, 23]).

As an alternative to restoration oriented approaches, SCHACTER and GLISKY [23] suggested that it may be more productive to attempt to teach memory-disordered patients *domain-specific knowledge*: knowledge and skills that can help patients to perform a specific task that is important for everyday functioning (see also [13, 27]). An important empirical observation that motivates this approach is the finding that even severely amnesic patients have some *preserved* learning abilities. Such patients can acquire various perceptual and motor skills in a normal or near-normal manner (e.g. [2, 14–16]) and show substantial performance facilitations on tests such as word-fragment completion and word identification (e.g. [1, 9, 15, 22, 26]). SCHACTER and GLISKY [23] suggested that it would be worthwhile to explore whether patients' preserved learning abilities could be used in the acquisition of knowledge and skills that are useful in everyday life.

To examine this idea, GLISKY *et al.* [6, 7] attempted to teach a group of memory-disordered patients how to operate and interact with a microcomputer. They reasoned that if patients could learn to operate a microcomputer, they might be able to use it as an external memory aid (cf. [11]) in everyday life. In order to teach patients the necessary vocabulary, commands, and operations, Glisky *et al.* devised a technique, referred to as the *method of vanishing cues*, that taps patients' preserved learning abilities—specifically, their demonstrated ability to successfully complete graphemic fragments of recently presented words (e.g. [9, 15, 26]). With the method of vanishing cues, patients are initially given as many letters of a target response as they need in order to identify it; the size of the letter fragment is then reduced across learning trials until the patient can produce the desired response in the absence of any target letters. For example, to teach the patient that the computer command “SAVE” means *to store information on a disk*, the definition would first be provided together with as many letters of the target response as the patient needed in order to guess it (e.g. SAV). The number of letters would then be reduced across trials (e.g. SA—, S—) until the patient could produce the target to the definition without any letter cueing.

Using this basic technique, GLISKY *et al.* [7] successfully taught memory-disordered patients a small computer vocabulary and showed that they could retain it across a 6-week delay. In a subsequent study, GLISKY *et al.* [6] found that patients could learn to write simple

programs, edit them, and use a variety of disk storage and retrieval operations. Moreover, even severely amnesic patients retained this complex knowledge over delays of up to several months. Glisky *et al.* did not, however, evaluate whether patients could actually use their acquired knowledge to perform computer tasks in everyday life.

In the present study, we examine whether the method of vanishing cues can be used to teach a severely amnesic patient to perform a complex task involving data entry into a computer in a real-life work environment. The first main part of the study entailed training the patient with the method of vanishing cues in our laboratory, where we constructed a detailed simulation of the actual job. In the second major part of the study, the patient attempted to do the job in the workplace, and we recorded on-line measurements of her performance in this real-world environment. Description of the job requirements and the various training procedures that we used requires a somewhat lengthy and detailed exposition. Accordingly, we have organized our reporting of method and results so as to avoid overloading the reader with excessive procedural detail. In the General Method section, we present the case history and provide an overview of the job requirements. We then divide the report into four separate sections corresponding to the four major phases of the study, which we refer to as Knowledge Acquisition, Skill Acquisition, Special Procedures, and Performance in the Workplace. Method and results are presented together for each of the four different phases.

GENERAL METHOD

Case history

H.D. is a 32-yr old female with a Grade 12 education who became amnesic after contracting herpes simplex encephalitis in June 1980. At that time, she had been employed for 9 yr in a clerical position at a major corporation in Toronto for which her husband also worked. Following her illness, H.D. was unable to perform her old job and was subsequently assigned to a lower-level clerical position that placed minimal demands on her memory. H.D. lives with her husband who is extremely supportive. He accompanies her wherever she goes outside of the home, brings her to and from work, and in addition performs virtually all household chores. H.D. is almost totally dependent upon him.

In April 1982, H.D. was referred to the Unit for Memory Disorders by the company physician for evaluation of memory and other cognitive functions. Since that time, she has been assessed repeatedly with standard neuropsychological tests and has participated in a number of experimental studies of memory. Her neuropsychological test performance, depicted in Table 1, has remained stable since her initial referral to our unit. On the WAIS-R, H.D. achieved a full-scale IQ of 84; her Verbal IQ of 79, however, was considerably lower than her Performance score of 95. She also had some problems on the Benton Visual Naming Test that were indicative of dysnomia. Her performance on the Token Test showed no signs of verbal comprehension difficulties and her digit span of six forward and five backward was in the normal range. As indicated in Table 1, the only other cognitive impairment was a severe memory disorder that was the most striking feature of this patient's profile. Her performance on the Wechsler Memory Scale (WMS) was extremely poor (MQ = 65); in addition she was unable to recall anything of the stories, line drawings, or hard associates from the WMS after a 30-min delay. On a delayed test of recognition memory for complex scenes, she performed at a chance level.

Despite her severe memory problem, H.D. is capable of some forms of learning. In our earlier research concerning acquisition of computer-related knowledge [6, 7], H.D. was able to acquire 30 new definitions of computer terms and her vocabulary learning was greatly facilitated by the vanishing cues technique described earlier. She also learned to interact independently with a microcomputer, to perform a variety of disk storage and retrieval operations, and to write simple computer programs. In addition, she demonstrated long-term retention of this material across an interval of 7-8 months.

In February 1986, we were informed by H.D.'s employer that the clerical job that she had been doing for the past few years was going to be terminated in the near future. Her employer realized that serious psychological and financial consequences would likely follow from her job loss, and wished to consult with us concerning any possibilities for training H.D. for a new job within the corporation.

From our prior experience with H.D., we knew that she was able to learn even quite complex material, although the learning process was slow. We also knew that the method of vanishing cues was an effective training procedure for H.D. In view of her previous computer training in our laboratory and the fact that she possessed excellent

Table 1. Patient characteristics

Patient H.D., 32-yr old, F, Grade 12, Encephalitis (1980)				
WAIS-R		VIQ	PIQ	
84		79	95	
WMS		Log Mem	Vis Repro	Hard Assoc
65	Imm	5	4	0
	Del	0	0	0
Picture Recognition (/16) Hits = 9				
FA = 9				
Token Test (normal > 29) = 34.5				
Benton Visual Naming (normal > 50) = 40				
Digit Span = 6 forward, 5 backward				

keyboard skills, we recommended that a computer data-entry job would be well-suited to her talents and would be amenable to laboratory training. We agreed to explore the possibilities for employing H.D. in this area by conducting a "pilot" training program for a part-time job within the company. Training for full-time employment would await the outcome of the pilot study. This paper reports the results of the part-time job training program.

For a number of reasons, no control subjects participated in this study. First, the major purpose of the research was to determine whether the patient could learn to perform a complex task in a real-world situation. Because we knew from previous studies [6, 7] that H.D.'s learning of complex materials was slower than normal, and had every reason to believe that her learning of this complex job would likewise be impaired relative to a non-amnesic subject, it is unlikely that a control subject would have provided much critical information. Second, because of H.D.'s special background, an appropriate control was difficult to find. Although the patient had no premorbid experience with microcomputers and had no prior exposure to the particular job, she possessed some general knowledge pertaining to the company for which she had worked for 15 yr. In addition, H.D.'s keyboard skills and her prior exposure to computer training in our laboratory contributed to her unique status. Third, and most important, the company information to which H.D. was exposed during training was confidential and could not be made available to other persons. Thus, even if appropriate control subjects would have been useful and could have been found, we could not have trained them on the same task that H.D. had to learn. Finally, on-the-job performance measures could not be obtained for a control subject.

Job description

The job was defined as a computer filing job. Information that appeared on company documents was to be entered into a computer display according to a set of rules. The computer display consisted of nine columns with coded headings, and the operator's task was to extract required information from a large stack of documents called *meter cards*, and enter it into the appropriate columns. Meter cards are used by the company's customers to record meter readings from rented copy machines, and large numbers of them are returned to the company on a regular monthly basis. They are all similar in physical appearance, and the information to be entered into the computer is printed in the same location on all cards. However, the mapping between the cards and the column headings is not straightforward and the cards often contain irrelevant information that has to be ignored.

For this job to be performed adequately, the following knowledge, facts and skills have to be acquired: (1) the general terminology associated with the job, (2) the meaning of each of the nine coded column headings in the computer display, (3) the additional codes that defined the operation being performed and the document being entered, (4) the location and the meaning of the information on the cards, (5) the mapping between cards and display, (6) the use of specific data-entry and cursor control keys on the computer keyboard, (7) the meaning of error messages or other computer queries and how to respond to them, and (8) the final integration of all of these components into a skilled sequence of operations.

Table 2 shows the nine headings of the computer display along with appropriate entries from the meter card that is illustrated in Fig. 1. The job proceeds as follows: In the first column of the display under the

Table 2. Headings of the computer display with appropriate entries from meter card in Fig. 1

ACD	CUST #	TYPE	DOC #	FRAME	O INV #	DOC YMD	ROLL	N CUST #
A	223776	MC	004220	2242		85 12 20	186076	

heading ACD, the letter "A" is typed, indicating that new information is being added to the file. In column 2, the customer number must be entered. On the computer display, the customer number is represented by the abbreviation CUST #; on the card, the heading for the same number is CUST.NO. In the example provided, the customer number 223776 is entered into the second column of the computer display. The next column heading is TYPE, which requires identification of the type of document being entered. The letters "MC" indicate that the document is a meter card. (The alphabetic entries in the first and third columns do not appear on the cards.) The fourth column of the display is headed DOC #, which corresponds to the card's SERIAL NO. In this case, there is no overlap between the headings on the display and on the card; furthermore, of the eight digits appearing on the card only the last six are entered into the computer display. The column headings FRAME and ROLL refer to segments of microfilm where permanent copies of each are stored. These numbers are stamped at the top of each card during microfilming. The frame number is always four digits and the roll number has six digits. In the column headed

186076 2242		DATE METERS READ		
SERIAL NO. 01004220	CUST. NO. 223776	DAY	MO.	YR.
		20	12	85
REPLENISHMENT DATE <u>12/85</u>				
METER A	METER B	METER C		
484844	210479	362919		
DATE	METER A	CREDITS		
Dec 6/85	298347	9.99		
"	"	9.99		
"	"	5.00		
		(24.98)		

FIG. 1. A schematic representation of a meter card showing key features. On an actual meter card, additional irrelevant information fills the blank space on the left.

DOC YMD, the date from the top right corner of the card has to be entered. Note that the numbers of the date have to be typed in reverse order to the way in which they appear on the card. The other two columns of the display remain blank and all other information on the card is ignored.

Apparatus

At the company, the job was performed on an IBM 3278 terminal that was connected to a mainframe computer. The keyboard was a special data-entry model with a numeric keypad that was embedded in the alphabetic keys; it also contained an ENTER key in addition to the standard line feed or RETURN key, both forward and backward TAB keys as well as cursor control keys allowing movement one space in any direction, and a number of special function keys. For purposes of laboratory training, an Apple IIe microcomputer was modified to simulate the company's IBM system. The numerics were embedded at the right end of the alphabetic keyboard and the computer was programmed to display and record either alphabetic or numeric characters depending on the display field. Other keys were programmed to perform other necessary functions. The standard numeric keys in the top row of the keyboard were covered so that only the shifted characters were visible.

Overview of procedure

The first three phases of the study involved training in the laboratory; the fourth concerned performance in the workplace. Each phase of laboratory training was designed to address one or more components of the overall task, and to guide the patient gradually closer to the real job situation. The first phase of training, referred to as Knowledge Acquisition, was concerned with the basic facts needed to perform the task accurately—general terminology, meanings of the display codes, meaning and location of information on the cards, and the relation between cards and display. The second phase was devoted to Skill Acquisition—gaining and improving speed and efficiency of data entry. The third phase was directed towards the use of Special Procedures, such as error handling routines. The training technique used for the acquisition of the basic facts and knowledge was the method of vanishing cues, and the patient worked at the computer independently at her own pace. In the fourth phase of the

study, *Performance in the Workplace*, we assessed whether laboratory training transferred to the work environment.

KNOWLEDGE ACQUISITION

Method

Explanations concerning the meaning and use of each of the pertinent concepts were presented on the computer screen as incomplete sentences with the final key word omitted. The subject was required to type the correct completion on the keyboard. For example, *The display is divided into nine columns or (blank)* was to be completed with the word FIELDS. If the subject did not know the answer or typed an incorrect completion, cues in the form of initial letters of the target word were added until the correct response was given (i.e. F, FI, FIE, . . . "FIELDS"). On succeeding learning trials, sentences were presented with a fragment of the target word, which contained one less letter than had been needed for correct responding on the previous trial (e.g. "The display is divided into nine columns or FI"). Thus letter cues were gradually "vanished" across trials. If on any trial the patient failed to type the right answer, letters were again added until the correct response was given. Perfect performance required the completion of all sentences without any letter cues.

At the beginning of each learning trial, the display, illustrated at the top of Table 2, appeared on the computer screen and the patient was handed a meter card such as the one shown in Fig. 1. The incomplete sentences explaining the task were presented on the screen one at a time below the display. In the first part of the knowledge acquisition phase, 28 sentences were presented on each trial. Three of the sentences referred to general terminology (as above); either three or four sentences pertained to each of the seven fields into which information had to be entered; and two sentences explained the fields to be ignored and the keys for tabbing over those fields.

Each of the sentences concerning a particular field provided a different piece of information about that field and attempted to guide the subject towards the relevant datum on the meter card. For example, the following four incomplete sentences pertained to the column headed DOC # (see Fig. 1).

- (1) DOC # stands for
- (2) The document number appears on the card under the printed heading
- (3) Although this number has eight digits, you should enter only the last
- (4) The DOC # for this card is

Note that correct completion of sentences 2 and 3 would accurately define the answer for sentence 4. The completion of the final sentence in each group was always the target piece of information for that particular field and, when typed correctly, it was automatically entered under the appropriate column heading. By the end of each trial, one complete record (i.e. data from one meter card) had been entered into the computer display. There were five trials (or cards) per session and training sessions were conducted twice weekly until performance was essentially perfect. Unique cards were used on every trial. (The company provided us with approximately 1200 different cards, which were not repeated until the final stages of training.)

In the second part of the knowledge acquisition phase, the explanatory sentences for each field were withdrawn. In the example for DOC # described previously, sentences 2 and 3 were removed. The patient therefore had to specify the meaning of the column heading and go directly to the target information on the meter card. Seventeen sentences comprised this part of training, three referring to general terms and two for each of the relevant seven fields. For the two blank fields, the subject had to use the TAB key and the RETURN key respectively. Cues in the form of initial letters of target responses were again provided if necessary. There were two sessions, spaced 3 days apart, and the number of cards to be entered was increased from five to ten per session.

RESULTS

Two major dependent measures were used: (1) the number of hints required, and (2) time. As indicated in Table 3, the number of hints per trial and the time taken per trial decreased dramatically both within and across the six training sessions of the first part of knowledge acquisition, indicating that considerable learning was achieved. In the early trials of the first session, the patient needed as many as 60 hints to complete the 28 sentences correctly and required as long as 55 min for one trial. By the end of the sixth session, performance was perfect (i.e. 0 hints) and time per trial had reached a low of 8.9 min.

In the second part of knowledge acquisition (sessions 7 and 8 in Table 3), when the explanatory sentences were withdrawn, accuracy of sentence completion on the remaining 17 sentences remained virtually perfect, although time to complete the task initially increased.

Table 3. Number of hints and time taken to complete one trial (or card) in the knowledge acquisition phase of laboratory training. Sessions were conducted twice weekly

Session	Trials	Range of hints	Mean hints per trial	Range of times (in mins)	Mean times per trial
Part 1: 5 trials/session, 28 entries/trial					
1	1-5	60-49	53.0	55.5-25.1	35.3
2	6-10	47-29	36.2	28.5-19.3	24.0
3	11-15	35-11	19.6	20.2-13.8	17.6
4	16-20	7-0	3.2	18.4-11.4	15.0
5	21-25	3-0	1.4	10.7-8.9	9.9
6	26-30	1-0	0.4	*	*
Part 2: 10 trials/session, 17 entries/trial					
7	31-40	2-0	0.4	9.4-6.2	7.2
8	41-50	1-0	0.1	8.2-5.5	6.5

*Times were inaccurate because of program interruptions in session 6.

By the end of 20 trials, however, the patient was performing about as fast as at the end of the first six sessions.

SKILL ACQUISITION

Method

Successful completion of the first phase of laboratory training indicated that the patient had acquired the knowledge needed for the job. However, she had not yet performed the actual task. The next steps of the training procedure were designed to help the patient to develop speed and efficiency of data entry. In this skill-acquisition phase of training, the patient was simply handed a stack of cards and instructed to enter the appropriate data into the computer. There were no sentences to be completed and no explanatory information was provided. Sixteen sessions were conducted at 2-3 day intervals over a 2-month period. Each session lasted 1-2 hr with additional cards being added as speed and efficiency improved. Training was divided into four parts, based on attained skill.

In the first part, H.D. was required to enter data from 10 cards on each trial. There were seven entries per card plus TAB and RETURN for the two empty fields. Letter cues were still available if needed. Six trials (or 60 cards) were completed per session and four sessions were conducted in a 2-week period. At the end of these four sessions, it appeared that the basic data-entry skill had been acquired, and so some additional keyboard functions were introduced. H.D. was given practice in cursor control movements and in the use of a special ENTER key. In addition, an optional but more efficient method of entering the ROLL number was explained. Because the roll number is the same for all records entered on a given day, it can be entered just once in a special location at the bottom of the computer screen instead of being part of each individual record. Practice in the use of these additional operations was provided on an informal basis.

In the second part of skill acquisition, the new functions that had been introduced to increase efficiency of data entry were incorporated into the overall procedure. After 10 cards were entered into the display, the patient was required to use the cursor control keys to move to the bottom of the computer screen and to tab across to the location for the single ROLL entry. After entering the ROLL number for the entire screen, the subject pressed the ENTER key to complete the trial. Any errors in the placement of the roll number or in the use of the ENTER key were handled by providing direct prompts concerning the correct procedures. All other errors were cued as in the earlier phases with initial letters of the correct responses. Ten trials of 10 cards comprised a session (i.e. 100 cards were entered per session) and there were two sessions, 3 days apart.

In the third part of skill learning, 20 cards were entered on each trial. This comprised a full screen or 20 rows of data, and no hints were provided. The patient was simply handed 20 cards and instructed to enter them. The purpose of this training was simply to provide extensive practice in order to increase speed of data-entry. In each session, data from 200 cards (10 trials) were entered. Training continued for five sessions, followed by a 2½ week break. After the delay, a single 10-trial session was conducted.

The fourth and last segment of skill training was designed to be as close to the actual job situation as possible. Rather than working in separate 20-card or single screen trials as previously, with a short break between trials, the patient was given a stack of 200 cards to enter. Performance was thus continuous for 10 screens with no forced break between trials. Pressing the ENTER key at the completion of one screen cleared all data from the screen and presented a blank display for continued entry. Four sessions were conducted over a 2-week period.

RESULTS

Relevant data are displayed in Table 4. Mean times per card were obtained by dividing the total time per trial by the number of cards entered on that trial. Error rates represent mean hints per card in Parts 1 and 2; in Parts 3 and 4, where no hints were provided, errors were simply counted. At the beginning of skill learning, the mean time required to enter information from a single card was 63.4 sec. By the end of the skill acquisition phase of training, speed had increased substantially: the mean time to enter data from one card was approx. 14 sec. This time was comparable to the time taken by experienced data-entry clerks at the company—10 to 15 sec per card. In addition, accuracy was relatively high throughout all parts of skill acquisition with the patient committing only one or two typographical errors per 100 cards. The marked increase in entry times between the first and second parts of skill development is attributable to the introduction into the procedure of the new keyboard operations (i.e. ENTER and ROLL). Time to enter one card increased from about 33 sec at the end of part 1 to 60 sec at the beginning of part 2. However, after 20 trials of practice in use of the new procedures, time per card again decreased to about 30 sec, and continued to decline steadily across the next five sessions (or 1000 cards) in part 3. Note also the complete absence of any decrements in performance in either speed or accuracy across the 2½-week delay.

In the final segment of skill acquisition, errors and times were not recorded after each screen but only after 200 cards had been entered; the time required to switch between screens was thus included in the mean time per card. This probably accounts for the slightly longer times per card at the beginning of part 4. However, speed once again increased rapidly with practice and seemed to asymptote around a level of 14 sec per card.

Table 4. Error rates and mean times to enter each card in the skill acquisition phase of laboratory training. Number of cards entered was 60, 100, 200 and 200 per session in parts 1-4 respectively. Sessions were held at 2-3 day intervals

Session	Error rate	Range of mean times per card (in secs)	Mean of mean times per card (in secs)
Part 1: 10 cards/trial, 6 trials/session			
1	0.13	63.4 48.0	54.5
2	0.09	46.4 42.9	44.7
3	0.02	41.8 34.1	36.9
4	0.02	44.2 32.7	38.0
Part 2: 10 cards/trial, 10 trials/session			
5	0.10	60.0 33.7	42.4
6	0.04	44.2 29.6	36.4
Page 3: 20 cards/trial, 10 trials/session			
7	0.005	34.6 27.4	30.9
8	0.01	33.1 24.0	27.0
9	0.005	26.0 19.9	22.2
10	0.02	20.3 15.4	17.6
11	0.015	17.5 12.9	14.6
Delayed	0.015	14.5 13.0	13.8
Part 4: 200 cards/session			
12	0.015		15.4
13	0.025		14.2
14	0.01		13.8
15	0.01		14.0

SPECIAL PROCEDURES

Method

The final phase of laboratory training concerned the learning of special error-handling routines. The company's computer system had built-in error detectors that were activated when the ENTER key was pressed. Handling of the two most frequent errors was taught independently of the basic data-entry procedures to allow for some degree of experimental control. Use of the error routines was never integrated into the data-entry procedure during laboratory training.

On each trial of phase 3, pre-entered data for 20 cards were displayed on the computer screen. The subject pressed the ENTER key and one of two messages appeared at the bottom of the display: *correct highlighted error* or *record exists-invalid add*. The patient was required to carry out the appropriate procedures in each case. To correct a highlighted error the following steps were necessary: (a) find the highlighted error on the computer screen, (b) find the meter card that corresponds to the incorrect computer entry, (c) correct the error, and (d) press ENTER. An invalid add message required the following responses: (a) find the highlighted record on the computer screen, (b) find the corresponding meter card, (c) type I for inquiry, (d) press ENTER, (e) copy the new roll and frame numbers that appear on the screen onto the meter card, and (f) place the specially-marked card in a box labelled "Record Exists".

In two preliminary 20-trial sessions, detailed verbal instructions concerning the error messages were given to the patient and she was verbally prompted throughout execution of the procedures. Six training sessions were then conducted without verbal prompting. In each session, the two error messages were randomly mixed across 20 trials, with 10 of each type. Time to respond completely and correctly to the messages was the dependent measure.

RESULTS

The results concerning the acquisition of the two special procedures for handling errors appear in Table 5. Times required to carry out both error-handling routines declined steadily across sessions, reaching an asymptotic level by about the fifth session.

Table 5. Mean times (in secs) across 10 trials to complete error-handling procedures

	Session					
	1	2	3	4	5	6
Error 1	71.6	69.0	48.8	50.6	48.9	48.5
Error 2	61.5	48.2	35.5	30.8	25.9	25.9

PERFORMANCE IN THE WORKPLACE

Method

Following completion of laboratory training, H.D. began the job in the company's filing department. She was accompanied by one of the experimenters who monitored her performance, was prepared to deal with any problems that arose, and ensured that the task was performed correctly.

The patient was seated in front of a computer terminal on which appeared a display very similar to the one on which she had been trained. She was given stacks of meter cards to be entered but was given no special instructions. The experimenter sat next to her with a stopwatch to record the time taken to enter each full screen of 20 cards. Four other people were working in the same room doing similar computer filing jobs, including one supervisor who was available to answer questions. H.D. worked at this job on consecutive mornings until all cards for the month had been entered. In the afternoons, she returned to her regular department in another section of the company, where she performed her other clerical duties. Each month thereafter, when meter cards again were available for computer entry, H.D. returned to the filing department to enter the new data into the computer. No intervening training was given.

When this phase of training began, several differences between our laboratory simulation and the actual task were noted. One difference was that the zero on the Apple was located one key to the left of where it was on the IBM keyboard. The IBM keyboard also contained a number of function keys that were not available on the Apple. For example, the IBM machine had two different ERASE keys on a separate function keypad. One was used to erase information from a field and the other erased all input from the screen. The Apple keyboard had no such keys; the space bar performed a simple erase operation. The space bar on the company's computer locked the keyboard

completely; unlocking required the use of a RESET key. There was also a special numeric lock key on the company terminal which, if accidentally pressed, prevented alphabetic entry. To return to normal entry mode, the numeric lock key had to be pressed a second time. The experimenter was made aware of some of these special function keys before the patient began the job, and verbally prompted the patient when problems arose. The times taken to perform these functions were included in the patient's times per screen. Other special functions, however, were discovered in the course of the patient's performance. In these cases, time was stopped while the supervisor was queried and was re-started after the problem was solved.

RESULTS

On-the-job results are shown in Table 6. Mean times per card were based on the times recorded at the end of each 20-card screen. During the first session, the patient entered a total of 1670 cards in $7\frac{3}{4}$ hr over 3 days. Mean times per card decreased from a high of 26.6 sec on the first screen of Day 1 to a low of 11.0 sec on Day 3. This mean time was lower than any achieved in laboratory training.

Table 6. Performance in the workplace: mean times to enter each card during monthly sessions on the job

Monthly sessions	Day	Number of cards entered	Total time required (hr)	Range of mean times per card (sec)	Mean time per card (sec)
1	1	540	2.8	26.6-13.4	16.1
	2	655	2.8	16.2-11.5	13.9
	3	475	2.2	15.1-11.0	13.0
Total		1670	7.8		
2	1	754	3.0	18.8-10.2	12.9
	2	1261	4.5	13.8-9.8	11.1
Total		2015	7.5		
3	1	659	2.4	12.3-9.7	10.8
	2	1237	4.1	11.4-9.0	9.9
Total		1896	6.5		
4	1	760	2.8	13.2-9.5	10.7
	2	1002	3.3	10.9-8.7	9.9
Total		1762	6.1		

The slow times in the beginning stages of the job were partly attributable to the minor differences, which were discussed in the Method section, between our laboratory simulation of the job and the actual task. For example, the fact that the zero on our Apple computer was located one key to the left of where it was on the company's IBM initially caused errors and slowing, which, however, declined with practice. In addition, the patient occasionally had to use ERASE and RESET keys as well as a special numeric lock key. Use of special function keys was required on 17 different occasions during the first on-the-job session. By the end of Day 3, the patient was using the RESET key on her own without instruction, and she had completely adapted to the different placement of the zero key. However, she had been unable to learn the ERASE operations or the problems involved in a numeric lock.

Both of the detectable errors that the patient had been trained to handle in the laboratory were encountered in the first work session and were dealt with correctly. On six occasions, the patient responded to a "correct highlighted error" message and four times she made the appropriate inquiries following the message, "record exists—invalid add". The screen-clearing procedures that were required after an invalid add had not been pre-learned because they required the use of special function keys. Verbal instructions for these operations were provided when necessary.

Results of subsequent monthly sessions on the job are also shown in Table 6. Data entry speed continued to improve over the next 2 months with the time to enter each card decreasing to an average of 9 to 11 sec per card. By the end of the second monthly session H.D. had also learned how to use one of the ERASE keys and continued to use the RESET key correctly. However, three other special functions still required verbal prompting in the second and third months because their use was so infrequent (i.e. 1–4 times per session). Between the third and fourth monthly sessions, an additional program was developed to teach H.D. information about these special functions. Because the laboratory computer did not possess the special keys required, H.D. was unable to perform the actual functions. However, again using the method of vanishing cues, she acquired the information necessary for the use of those keys. In the fourth on-the-job session, H.D. performed completely on her own, without any prompting or instruction from the experimenter who simply acted as an observer. Mean time to enter a card appeared to have reached asymptote around the 10 sec mark. Only one of the recently-learned special functions was required during this session and H.D. performed it without help. For the fifth session in the workplace, the experimenter was not present. The supervisor reported that H.D. performed the job independently without difficulty; she asked only two questions, both of which were appropriate queries of the supervisor.

Qualitative observations

Although H.D. learned to perform the task quickly and correctly both in the laboratory and in the workplace, she remained unable, when asked, to recount the specific details of the procedure. On a few occasions during laboratory training, the patient was queried by one of the experimenters as to the nature of her visits to the Unit. H.D. was able to say that she was learning a job that required typing on a computer, but she could provide only a sketchy description of the procedures or materials. Similarly, the patient herself reported that when she left the laboratory, she was unable to remember exactly what she had been doing except that it had involved data entry from cards into a computer. Her husband noted that when friends or co-workers questioned her about the nature of the training, H.D. became somewhat embarrassed because she could say no more than that she was doing something that involved a computer. Towards the end of laboratory training, H.D. was able to provide some additional bits and pieces of information regarding the job. For example, when interviewed by one of the experimenters at the beginning of the final skill acquisition phase, she was able to recall accurately two of the column headings from the computer display. However, H.D.'s difficulty recalling details of her job persisted in the workplace. For instance, it was observed during an "on-the-job" lunch break that H.D. could not respond informatively to a fellow employee who asked her in what department she was working. Again, she offered only the general information that she was doing a job on a computer.

H.D.'s perception of her own performance and progress both in the laboratory and in the workplace was very positive. During training, the vanishing cues procedure allowed her to work independently at her own pace. The task could always be accomplished, initially with many hints but with increasingly fewer hints across trials. H.D. was aware that her performance was improving and was satisfied with her progress. In the workplace, she was pleased to be able to do a job that was complex and demanding, and that had a "high-tech" image. She was also sensitive to and pleased by the appreciation expressed by her co-workers for her contribution.

DISCUSSION

In this article we have demonstrated that a severely amnesic patient can acquire the knowledge and skills needed to perform a complex computer entry job. More importantly, we have also shown that the patient could perform the job on her own and without error in the actual work environment. As far as we know, this case study represents the first systematic empirical demonstration that laboratory training of an amnesic patient can have a significant impact on the patient's ability to perform a complex task in an important domain of everyday life.

One question raised by our research is whether the positive results that we obtained could also be observed with other amnesic patients. We cannot, of course, be certain that this type of training would produce a similar outcome in other cases, but there is at least some reason for expressing optimism in this regard. H.D. is a severely amnesic patient who in addition possesses a relatively low verbal IQ (79). If such a seriously impaired patient can successfully master a complex task and perform it well in everyday life, it seems reasonable to suggest that other patients with similar or milder intellectual and memory impairments could also do so. However, one important characteristic of H.D. that contributed to her success concerns her excellent ability to maintain sustained attention to a task and to monitor carefully the appropriateness of her responses. This capacity is reflected by H.D.'s superior performance on tests that are sensitive to frontal lobe dysfunction. For example, she achieved six categories on the Wisconsin Card Sort and showed little evidence of perseveration. Many memory-disordered patients, particularly those with frontal lobe damage, lack the attention and concentration skills exhibited by H.D. It remains to be determined whether such patients could also learn complex new skills and apply them successfully in an actual job environment.

Although the generalizability of our data must remain uncertain, the present results extend our previous observations on learning of complex knowledge in memory-disordered patients [6] and provide further evidence that the method of vanishing cues is a useful technique. It should be emphasized, however, that H.D. learned slowly and initially required large numbers of hints in order to perform the task. Indeed, H.D. performed so poorly on the first trial of the initial session, when she required almost 1 hr to enter a single card, that we had serious doubts as to whether we should continue with training. We proceeded largely because of our previous research with H.D. and other amnesic patients which indicated that patients could eventually learn complex tasks even when they performed disastrously in the first few sessions. We think that this is an important point for other investigators to bear in mind should they attempt to teach complex tasks to memory-disordered patients.

Despite the initial difficulties, the demonstration that H.D. was able to acquire, retain, and use a great deal of new knowledge highlights the fact that we have not yet observed any limit on the amount of new knowledge that amnesic patients can acquire. It is entirely conceivable that with sufficient repetition and use of the vanishing cues procedure, it will prove possible to teach patients even larger amounts of knowledge. One limitation on learning that we have observed in previous research, however, concerns the *quality* of the knowledge that amnesic patients can acquire. It appears to be rather rigidly organized and accessible only under a narrow range of test conditions—which we have referred to as *hyperspecific* knowledge [6, 21]. The fact that the knowledge acquired by amnesic patients in complex tasks can have a hyperspecific quality was taken into account when we selected the computer entry job as our target task and when we constructed our training regime. We deliberately chose a job that did not require problem-solving, hypothesis testing, access to information in the

presence of cues different from the precise cues that were used in training, or any other functions that would demand flexible use of acquired knowledge. In addition, we were careful to teach H.D. *explicitly* and *directly* each and every discrete operation or bit of information that was required to perform the job, because we assumed that she would be unable to make any generalizations or inferences on her own.

The foregoing considerations may be important to take into account in future attempts to train amnesic patients to perform complex jobs in the real world. The jobs that will likely prove most amenable to training are ones in which (a) an effective technique such as the method of vanishing cues can be used, (b) extensive repetition can lead to mastery of all job requirements, and (c) all procedures can be taught explicitly so that flexible use of acquired knowledge is not required. Jobs involving data entry into computers would thus appear to be excellent targets for training: Once mastered, learned procedures can be executed repeatedly with few demands made on memory or high level cognitive processes. In addition, the "high-tech" image of computer-related work is likely to appeal to patients and foster self esteem, as was observed with H.D. More generally, the positive outcome of the present study provides empirical support for SCHACTER and GLISKY's [23] suggestion that training amnesic patients for gainful employment represents a fruitful direction for memory remediation research with a domain-specific orientation. Of course, we do not expect that training an amnesic patient to perform a job will improve or restore memory function in any general sense. We certainly observed no evidence of restoration or generalized memory improvement in H.D.'s case. For example, her post-training MQ on the WMS (63) was no better than her pre-training MQ (65). Nevertheless, domain-specific training can have a major impact on the quality of the patient's everyday life. As we have argued previously [5, 23], restoration-oriented approaches have yet to provide such evidence.

The extent to which H.D.'s everyday life will be affected by the present intervention remains to be determined. As noted earlier, our agreement with the company was to try to train H.D. for part-time work, and if we achieved our goals, to go on and attempt to train her for a full-time job. Since the first phase of training has succeeded, we are now in the process of training H.D. for full-time employment. The results of this next stage of our research will not only determine whether H.D. can remain gainfully employed, but will also provide further information concerning the type of knowledge an amnesic patient can acquire and the extent to which it can be used in everyday life.

Acknowledgements—We thank C. A. Gordon Hayman for programming assistance, Peter Graf for useful comments on an earlier draft of the manuscript, and Carol A. Macdonald for help with preparation of the manuscript.

REFERENCES

1. CERMAK, L. S., TALBOT, N., CHANDLER, K. and WOLBARST, L. R. The perceptual priming phenomenon in amnesia. *Neuropsychologia* **23**, 615-622, 1985.
2. COHEN, N. J. and SQUIRE, L. R. Preserved learning and retention of pattern-analyzing skill in amnesia: dissociation of "knowing how" and "knowing that". *Science* **210**, 207-209, 1980.
3. CROVITZ, H. F., HARVEY, M. T. and HORN, R. W. Problems in the acquisition of imagery mnemonics: three brain-damaged cases. *Cortex* **15**, 225-234, 1979.
4. GIANUTSOS, R. and GIANUTSOS, J. Rehabilitating the verbal recall of brain-damaged patients by mnemonic training: an experimental demonstration using single-case methodology. *J. clin. Neuropsychol.* **1**, 117-135, 1979.
5. GLISKY, E. L. and SCHACTER, D. L. Remediation of organic memory disorders: current status and future prospects. *J. Head Trauma Rehabil.* **1**, 54-63, 1986.

6. GLISKY, E. L., SCHACTER, D. L. and TULVING, E. Computer learning by memory-impaired patients: acquisition and retention of complex knowledge. *Neuropsychologia* **24**, 313–328, 1986.
7. GLISKY, E. L., SCHACTER, D. L. and TULVING, E. Learning and retention of computer-related vocabulary in amnesic patients: method of vanishing cues. *J. clin. exp. Neuropsychol.* **8**, 292–312, 1986.
8. GODFREY, H. P. D. and KNIGHT, R. G. Cognitive rehabilitation of memory functioning in amnesiac alcoholics. *J. consult. clin. Psychol.* **53**, 555–557, 1985.
9. GRAF, P., SQUIRE, L. R. and MANDLER, G. The information that amnesic patients do not forget. *J. exp. Psychol., Learn., Mem. Cognit.* **10**, 164–178, 1984.
10. GRAFMAN, J. Memory assessment and remediation in brain-injured patients: from theory to practice. In *Behavioral Assessment and Rehabilitation of the Traumatically Brain-Damaged*, B. A. EDELSTEIN and E. T. COUTURE (Editors). Plenum, New York, 1984.
11. HARRIS, J. Methods of improving memory. In *Clinical Management of Memory Problems*, B. A. WILSON and N. MOFFAT (Editors). Aspen, Rockville, MD, 1984.
12. JONES, M. Imagery as a mnemonic aid after left temporal lobectomy: contrast between material specific and generalized memory disorders. *Neuropsychologia* **12**, 21–30, 1974.
13. MAYER, N. H., KEATING, D. J. and RAPP, D. Skills, routines, and activity patterns of daily living: a functional nested approach. In *Clinical Neuropsychology of Intervention*, B. UZZELL and Y. GROSS (Editors). Martinus Nijhoff, Boston, 1986.
14. MILNER, B., CORKIN, S. and TUBER, H. L. Further analysis of the hippocampal amnesic syndrome: 14-year follow-up study of H.M. *Neuropsychologia* **6**, 215–234, 1968.
15. MOSCOVITCH, M. Multiple dissociations of function in amnesia. In *Human Memory and Amnesia*, L. S. CERMAK (Editor). Erlbaum, Hillsdale, NJ, 1982.
16. NISSEN, M. J. and BULLEMER, P. Attentional requirements of learning: Evidence from performance measures. *Cognit. Psychol.*, **19**, 1–32.
17. O'CONNOR, M. and CERMAK, L. S. Rehabilitation of organic memory disorders. In *Neuropsychological Rehabilitation*, M. MEIER, L. DILLER and A. BENTON (Editors). Guilford Press, New York, 1987.
18. PATTEN, B. M. The ancient art of memory. *Archs. Neurol.* **26**, 25–31, 1972.
19. PRIGATANO, G. P., FORDYCE, D. J., ZEINER, H. K., ROUCHE, J. R., PEPPING, M. and WOOD, B. C. Neuropsychological rehabilitation after closed head injury in young adults. *J. Neurol. Neurosurg. Psychiat.* **47**, 505–513, 1984.
20. SCHACTER, D. L. Imagery mnemonics, retrieval mnemonics, and the closed head injury patient. Presented to *International Neuropsychological Society*, San Francisco, January 1980.
21. SCHACTER, D. L. Multiple forms of memory in humans and animals. In *Memory Systems of the Brain: Animal and Human Cognitive Processes*, N. WEINBERGER, J. MCGAUGH and G. LYNCH (Editors). Guilford Press, New York, 1985.
22. SCHACTER, D. L. Priming of old and new knowledge in amnesic patients and normal subjects. *Ann. N.Y. Acad. Sci.* **144**, 41–53, 1985.
23. SCHACTER, D. L. and GLISKY, E. L. Memory remediation: restoration, alleviation, and the acquisition of domain-specific knowledge. In *Clinical Neuropsychology of Intervention*, B. UZZELL and Y. GROSS (Editors). Martinus Nijhoff, Boston, 1986.
24. SCHACTER, D. L., GLISKY, E. L. and MCGLYNN, J. M. Impact of memory disorder on everyday life: awareness of deficits and return to work. In *The Neuropsychology of Everyday Life*, Vol. I, D. TUPPER and K. CICERONE (Editors). Martinus Nijhoff, Boston, in press.
25. SCHACTER, D. L., RICH, S. A. and STAMPP, M. S. Remediation of memory disorders: Experimental evaluation of the spaced retrieval technique. *J. clin. exp. Neuropsychol.* **7**, 79–96, 1985.
26. WARRINGTON, E. K. and WEISKRANTZ, L. The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia* **12**, 419–428, 1974.
27. WILSON, B. Memory therapy in practice. In *Clinical Management of Memory Problems*, B. A. WILSON and N. MOFFAT (Editors). Aspen, Rockville, MD, 1984.
28. WILSON, B. and MOFFAT, N. Rehabilitation of memory for everyday life. In *Everyday Memory: Actions and Absent-Mindedness*, J. E. HARRIS and P. MORRIS (Editors). Academic Press, London, 1984.