EXTENDING THE LIMITS OF COMPLEX LEARNING IN ORGANIC AMNESIA: COMPUTER TRAINING IN A VOCATIONAL DOMAIN*

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Abstract—This study explored the limits of learning that could be achieved by an amnesic patient in a complex real-world domain. Using a cuing procedure known as the method of vanishing cues, a severely amnesic encephalitic patient was taught over 250 discrete pieces of new information concerning the rules and procedures for performing a task involving data entry into a computer. Subsequently, she was able to use this acquired knowledge to perform the task accurately and efficiently in the workplace. These results suggest that amnesic patients' preserved learning abilities can be extended well beyond what has been reported previously.

PATIENTS with organic memory disorders are typically characterized by an inability to remember recent experiences and learn new information. Nevertheless, it has been recognized since the earliest clinical descriptions of memory loss that even severely amnesic patients have some *preserved* learning and memory abilities: the behavior and performance of such patients can be influenced by recent experiences, despite patients' lack of conscious or explicit recollection of those experiences (e.g. [4, 8, 18]; for review, see [23, 26, 27]). In recent years, studies of the preserved learning abilities of patients with memory disorders have occupied an increasingly prominent place in neuropsychological research.

Two different but related lines of research on preserved learning can be distinguished. The first has focussed on analysis of the conditions under which amnesic patients show *normal* learning and memory performance. A number of studies have documented normal acquisition of various perceptual, motor and cognitive skills that are learned gradually across trials and sessions (e.g. [1, 3, 6, 19–21]); other experiments have demonstrated that amnesics show intact priming effects following one or two study trials on such tests as word completion [15, 30, 37], perceptual identification [2], and free association [25, 32]. These studies have played an important role in shaping theorizing about a host of important issues, including multiple memory and learning systems (e.g. [5, 7, 17, 27, 31, 33, 35, 38, 39]) and the relation between memory and consciousness [16, 28, 36].

A second type of research on preserved learning has been less concerned with determining when amnesic patients show normal memory performance, and has focussed instead on (a)

assessing the amount and complexity of new information that can be acquired by memory-impaired patients, and (b) ascertaining whether preserved learning abilities provide a basis for teaching patients new knowledge that may be useful to them in their everyday lives.

This latter approach is illustrated by a series of studies in which we have assessed whether amnesic patients can learn to operate, interact with and program a microcomputer [12–14]. Because learning about computers entails the acquisition of many different kinds of new knowledge—vocabulary, programming skills, editing commands and disk operations to name just a few—it represents a rich domain in which to examine the nature and extent of amnesic patients' preserved learning abilities. In an initial study, we examined whether amnesic patients with lesions of varying etiology could learn a small vocabulary of new computer terms [14]. This study made use of a technique, referred to as the *method of vanishing cues*, that taps patients' preserved abilities to show priming effects when tested with word-fragment cues (e.g. [15, 37]). Definitions of to-be-learned items (e.g. *to store a program on a disk*) were presented together with letter fragments of the targets (e.g. S— for SAVE); an increasing number of letters were presented until the patient guessed the response. On subsequent trials, letters were gradually withdrawn from the target item until the patient could retrieve it without any letter cues. Using this procedure, four patients with memory disorders of varying severity were able to learn, and retain across a 6-week delay, approximately 15 new computer terms. Subsequent studies using the vanishing-cues procedure showed that both mildly and severely amnesic patients could learn to write simple computer programs, edit them, and perform disk storage and retrieval operations [12, 13]. Moreover, there was little loss of learning over delays of 7–9 months [12].

The vanishing-cues technique was also used in a recent case study in which we explored further the amount of new knowledge that can be acquired by an amnesic patient, and evaluated whether such knowledge could be used in the performance of a real-world job [10]. The patient was a 32-yr old woman, H.D., who became severely amnesic after a bout of encephalitis in 1980. She had been working in a clerical position at a major corporation for several years prior to her illness, and continued working in a lower level position thereafter. When this position was eliminated from the company, H.D.'s future employment became contingent on her ability to learn a new job. Working in co-operation with the company, we attempted to train H.D. for a part-time job that involved extracting information from company documents called "meter cards" and entering it into coded columns of a computer display. Learning the job required the acquisition of a considerable amount and variety of knowledge: new terminology, meanings of various codes, location of critical information on company documents, mappings between the documents and the computer display, and error-handling routines and other special procedures. The job was simulated on a computer in our laboratory, and training sessions were conducted two to three times a week over a period of several months. Results indicated that in the early stages of training, H.D. performed poorly: she was extremely slow and required numerous letter hints for successful responding. With practice, however, H.D. eventually learned to perform this complex task rapidly and without error. Most importantly, she was then able to carry out the job competently in the actual work environment, performing it accurately and at a speed comparable to that of experienced employees [10].

The foregoing studies indicate clearly that amnesic patients can acquire some forms of complex knowledge. However, it should be emphasized that patients' rate of learning in these studies was far from normal, and that their acquired knowledge was somewhat inflexible or *hyperspecific* [13, 24]; performance deteriorated substantially when even small changes

between training and test were introduced. Nevertheless, the empirical fact that amnesic patients can show robust retention of a good deal of new computer learning encourages further examination of the amount and kind of complex knowledge that patients can learn, and exploration of the situations in which such knowledge can be applied.

The purpose of the present study is to advance our understanding of the limits of amnesic patients' preserved learning abilities. To accomplish this objective, we examined whether the encephalitic patient H.D. could learn a computer-entry job that is several orders of magnitude more complex than the job that she had learned previously [10]. Whereas the earlier job involved entering information from a single document type into the computer, the present task entails entering information from 11 different document types, many of which have multiple variations. Successful performance requires learning the properties and codes for each document type, cues for discriminating among document types, a set of rules for identifying information on different documents, and mappings between each document and the computer display. Approximately 250 discrete items of new information, many of which are rather complex, must be acquired and linked together appropriately so that a smooth integrated sequence of data-entry operations can be performed. Furthermore, because of the endless number of exemplars of each document type, transfer to the workplace requires that learning be applicable to situations and documents never encountered before. As far as we know, this task demands more extensive learning and transfer than any reported in previous research with amnesic patients. Accordingly, it provides a useful yardstick for measuring just how far the preserved learning abilities of a severely amnesic patient can be extended. In addition, the task has considerable ecological validity: it represents an actual company job, and H.D.'s continued employment was contingent on her ability to learn it.

GENERAL METHOD

A total of 14 different programs comprised the laboratory training phase of the present study. To simplify our description of procedures and results, we have organized our report into segments that correspond to conceptually distinct components of the task. In this General Method section, we present a summary of the case history, an outline of the general job requirements and training phases and an overview of the procedure. We then present specific methods and results for each of four different phases of job training: (1) document discrimination, (2) acquisition of rules and procedures, (3) simulated job performance in the laboratory and (4) performance in the workplace.

Case history

The patient, H.D., is a 32-yr old woman who became amnesic after contracting herpes simplex encephalitis in 1980. Since that time, she has had serious difficulty functioning independently in everyday life. Testing has revealed a stable level of performance on a number of neuropsychological tasks over the past 5 yr and has confirmed her profound memory disorder. Her score of 65 on the Wechsler Memory Scale is extremely low; on immediate tests of logical memory, visual reproduction and hard associates, she scores 5, 4 and 0, respectively, and she is unable to recall any of the stories, drawings or hard associates after a 30-min delay. On a 2-hr delayed test of recognition memory for 16 complex scenes, she performs at chance (Hits = 9; FA = 9), and even on an immediate test of recognition memory for eight low frequency words, she shows little ability to discriminate between targets and lures (Hits = 7; FA = 6). H.D. has a slight dysnomia and her full-scale IQ of 84 on the WAIS-R is probably depressed (Verbal IQ = 79, Performance IQ = 95). She has no other cognitive deficits (for a more detailed description of H.D.'s neuropsychological profile, see [10]).

At the start of the present study, H.D. was working 3 days a month performing the meter card job described earlier [10]. Our goal was to extend the range of her abilities in the data-entry task so that she could be employed on a full-time basis. Shortly after we began the first phase of laboratory training, however, the company requested that we prepare H.D. for a temporary microfilming job that needed to be filled immediately (for a description, see [11]). Accordingly, there was a 5-month break in H.D.'s training for the data-entry task.

As was the case in our previous job-training study with H.D., no control subjects were used in the present research. Some of the reasons for this involve the extensive time demands of the training procedure, which requires hundreds of hours spread across several months, and the fact that H.D. had already learned some of the critical

information for the job in our earlier study of her [10]. Most importantly, however, control subjects could not be used because of practical constraints: control subjects would not have been able to take part in the final phase of the study, involving performance in the workplace, and the company information used for training was confidential and could not be made available to non-employees.

Job requirements and training phases

The general requirements of the job were similar to those of the single document (i.e. meter card) task that H.D. was already performing in the workplace. The major difference was the addition of 11 new document types. The task required that information by extracted from the documents and entered into a computer display consisting of nine coded column headings. The computer display was identical to that used in the meter card task and H.D. knew the meanings of all headings except one. She also knew that the entry for the first column, headed ACD, was "A", indicating that new information was being added to the file. Rules and procedures concerning entries for all other columns were entirely new and thus had to be acquired by the patient.

In order to succeed at the new job, H.D. had to: (a) learn to discriminate among the 11 different document types and learn the two-letter codes associated with each type, and (b) learn the locations on each document of the data that had to be entered into the computer. Because characteristics and locations of data varied as a function of document type, the second part of the job could not be accomplished until the first part was completely mastered. The first phase of laboratory training was therefore devoted to document discrimination.

The second segment of training had two parts. The first was concerned with learning how to find and recognize five different kinds of information on each document. Much of this learning was rule-based and rather complex; information varied not only across document types, but also within a document type. The second part of this phase was concerned with the acquisition of procedures. Practice in performing each step of the data-entry task was provided, and the various components of the procedure were gradually linked together into their appropriate sequence.

We also included a third phase of training that was designed to provide extensive practice in carrying out all aspects of the task with new documents that were not encountered previously. Because there was an unlimited number of different exemplars of many of the document types, it was impossible to train the patient on every possible variation that might occur. Although some variability was introduced in the first two training phases, only 40 different examples of the 11 document types were used. This third phase of training allowed us to assess whether the rules that had been acquired for processing those 40 documents could be applied to the handling of new documents. It also provided an opportunity to simulate in the laboratory some of the variability that existed in the workplace while still maintaining some degree of experimental control over the training procedure. Accordingly, this part of training served as a bridge between the controlled laboratory setting with its limited set of specific documents and the real-world situation in which uncontrollable variation could be expected to occur.

The final phase of the study concerned actual performance in the workplace.

Apparatus and procedure

The data-entry job was performed at the company on an IBM 3278 terminal that was connected to a mainframe computer. An Apple IIe microcomputer was modified to simulate the IBM keyboard and data-processing system for purposes of laboratory training.

The general strategy that we used to teach H.D. the job was to break the complex task down into a number of simpler components and teach each component directly and explicitly. As each individual component was acquired, it was linked to a previously learned one and training on the integrated unit was provided. In this way, the job components were re-assembled into the sequence that was appropriate for performance of the actual date-entry task.

In the first two training phases, which required the acquisition of a large number of facts and rules concerning the different document types, the training technique was the method of vanishing cues. Errors and omissions were cued with word fragments of required responses, and two dependent measures were recorded: the number of letter cues and the time taken to complete a training trial.

In phases 3 and 4, the patient no longer received trial-by-trial feedback via the vanishing cues procedure. Although the computer did not provide fragment cues, H.D. had the opportunity to detect errors on her own and correct them. If she did not do so, prompting and explanations were provided by the experimenter.

PHASE I: DOCUMENT DISCRIMINATION

Method

The task in the first process of training was to learn (a) the discriminating features of each document and (b) the two-letter codes that identified each type of document to the computer system.

Fifty incomplete sentences were presented one at a time on the computer screen, and the patient's task was to type the correct completion on the keyboard. If she did not know the correct response or if she typed an incorrect completion, cues were provided in the form of initial letters of the target word until the correct response was made. Across training trials, letters were gradually withdrawn until all target words could be generated without letter cues.

The first two sentences in the program provided general information about the job; the remaining sentences provided specific information about the 11 types of documents with three to six sentences describing each one. In the first half of phase I, the patient was permitted to study examples of the documents as the sentences describing them appeared on the computer screen. For six of the document types (*order, confirmation, shipping ticket, invoice, payment* and *correspondence*), there were two different exemplars in each folder; for the other five types (*general shipping ticket, request for adjustment, credit note, returned goods* and *instant return*), there was only one example of each because all exemplars were similar. In total, 17 different sample documents were studied.

Examples of sentences for one document type are shown below, with target responses indicated in parentheses.

(1) When products are shipped to a customer, a document is sent along with them. This document is called a ——— (SHIPPING TICKET). Folder number 3 contains examples of shipping tickets.
(2) A shipping ticket always has the words "shipping ticket" on it, either in the corner at the ——— (TOP RIGHT) or in the corner at the ——— (BOTTOM LEFT).
(3) Some shipping tickets have the word invoice in the top right corner. In this case, in the bottom left corner will be printed the number ——— (4) and also the words ——— (SHIPPING TICKET).
(4) The type code for a shipping ticket is ——— (ST).

The sentences describe the purpose of the document and direct the reader to search in both the top right corner and the bottom left corner of the documents for discriminating information. Both of these locations usually have to be checked to be certain of a document type. For example, a document that says "INVOICE" in the top right corner may be an invoice, a shipping ticket, a payment or an order. At least one other feature of the document has to be sampled in order to make a correct decision. Note also that the final sentence concerning each document required the patient to type the two-letter code that would later have to be entered into the computer display in the TYPE column.

When the 50 sentences had been correctly completed, the patient was asked to free recall as many of the document types as possible by typing their names on the keyboard. This task was included because we thought that it might be useful for H.D. to be able to generate possible document types when faced with difficult discriminations such as the "INVOICE" problem described above. Three trials were conducted during each training session except the first when the patient was able to complete only one trial. Sessions took place twice weekly until performance on the sentence completion task was perfect. At the end of the ninth session, when perfect performance had been attained, the patient was given the 17 sample documents in a random order and asked to sort them by type into labelled piles.

In the second half of phase I, the patient was presented with the same sentence completion task but no sample documents were provided for study. The documents themselves therefore could not be used as cues to complete the sentences correctly. There were three trials per session, free recall was required at the end of each trial, and the sorting task was given at the end of each session. Training continued for eight sessions, two per week, by which time performance was almost perfect. Training was then discontinued for 5 months while the patient was trained for the unrelated job mentioned earlier. When the program was resumed 5 months later, the patient was given one four-trial training session to test her retention of the previously acquired knowledge, before proceeding to phase II.

Results

The results of phase I are summarized in Table 1. As can be seen in the top half of the table, initial performance on the sentence completion task was slow and inaccurate. The patient required about 80 min to complete the 50 sentences and needed 87 letter cues to produce the correct responses. She was unable to produce any of the document types on the free recall test until the end of the third session. Across trials and sessions, however, performance improved substantially; by the end of the ninth session, perfect performance on sentence completion was achieved in approximately 20 min. Note, however, that the patient at this time was still unable to free recall all of the document types, although she had increased her recall from 0 to 6 by the end of the first half of training. She was able to sort correctly all of the 17 sample documents except one, and mean sorting time was 12.9 sec per document.

When the sentence completion task was attempted without the accompanying documents, performance initially declined, but once again it improved across trials. These results are summarized in the lower part of Table 1. In addition, by the end of eight sessions, the patient was able to recall all 11 document types. Sorting was also perfect in a time of 7.5 sec per document.

Over the 5-month interval, H.D. retained most of what she had learned. On the first trial

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Table 1. Phase I: document discrimination. Number of hints and times per trial

Session (3 trials/ session)	Range of hints	Mean hints per trial	Range of times (min)	Mean times per trial	Free recall (/11)
Part 1					
1*	87	87	79.9	79.9	0
2	77–54	65	60.3–33.5	42.6	0
3	43–31	36.7	36.8–29.3	33.4	0–4
4	25–15	19.7	30.6–26.2	28.5	0–5
5	7–5	5.7	20.2–18.7	19.7	4–5
6	3–2	2.3	25.4–20.6	22.5	4–7
7	3–2	2.3	24.1–21.2	22.6	5–6
8	3–0	1.3	22.0–19.6	20.8	6–7
9	1–0	0.5	20.0–19.7	19.9	6–7
Part 2					
1–4	13–5	8.3	22.8–14.1	16.6	5–10
5–8	11–1	3.2	20.1–14.3	17.1	9–11
5 mos. delay	5–1	3.3	18.2–16.0	16.9	11–11

* *One trial only.*

after the delay, she needed only five hints to complete the 50 sentences and she freely recalled all 11 document types. She also sorted all documents correctly in a time of 7.3 sec per document.

PHASE II: ACQUISITION OF RULES AND PROCEDURES

Method

The second phase of training was concerned with learning how to locate the various pieces of information on each document and enter them into the computer display. The training materials consisted of a total of 10 programs. Two companion programs (*Rules* and *Procedures*, respectively) were devoted to each of the five kinds of information that had to be learned: customer numbers, document numbers, frame and roll numbers, second reference numbers and dates. As suggested by their names, the *rules* programs were concerned with the acquisition of rules governing the classification of information on the documents and the *procedures* programs attempted to teach procedures for accomplishing the actual data-entry task. Rules programs consisted of a series of sentence completion tasks, explaining how to locate and identify the critical data on each kind of document. Between 4 and 18 sample documents were used to illustrate application of the rules. The successful completion of each rules program was followed by its corresponding procedures program, in which the patient was required to execute the data-entry procedures with respect to the information just learned, together with all information learned previously (i.e. learn X, enter X, learn Y, enter XY, learn Z, enter XYZ, etc.). The same 40 documents, which included those from the rules programs, were used with all procedures programs. As training progressed, the patient was thus required to enter more and more data from each document, until by the end of this phase of training, complete entries for all 40 documents could be handled. Throughout this phase of training, cues in the form of initial letters of target responses were provided when needed, and training in each program continued until one perfect trial was achieved. H.D. participated in the first three sets of rules and procedures programs on a twice-weekly basis, completing usually three or four trials per session. All training after that point was conducted on a daily basis.

The first rules program (1R) attempted to teach information concerning customer numbers. Thirty-four incomplete sentences conveyed general information about customer numbers, as well as specific rules for locating customer information on different types of documents. Example sentences appear in Table 2. Note the probabilistic nature of many of the rules that are presented and also the variability that occurs across types of documents. Thirteen sample documents, one of each type (except two orders and two invoices), accompanied this training program.

When the patient had acquired all of the rules and information associated with customer numbers that had been provided in program 1R, the first procedures program (1P) was presented. Here H.D. was required to enter three pieces of data, for each of 40 documents, into the first three columns of the computer display. First, she typed an "A" in column one under the heading ACD. This operation had been learned in conjunction with the meter card job. In the second column, headed CUST #, the customer number for each document was typed, and in the third column,

Table 2. Sample sentences from the training programs concerned with acquisition of rules. Correct completions are indicated in parentheses

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Program 1R: CUST #

(1) Customer numbers may begin with any number and have any number of digits from two to six. Most of the time, the number of digits in the customer number will be ——— (FIVE)

(2) There will also be some customer numbers that have six digits. A six-digit customer number that does not begin with a 0 will begin with a ——— (4)

(3) Customer numbers will often, but not always be ——— (CIRCLED).

(4) Occasional customers are all assigned the same numeric customer number. It is the number ——— (99903). All 99903 customers are then assigned an alphabetic customer number

(5) To type letters into what is usually a numeric field, you must hold down the ——— (RIGHT SHIFT KEY)

Program 2R: DOC #

(1) On orders and confirmations, the usual DOC # is the ——— (INVOICE NUMBER)

(2) However, on some orders and confirmations, there may not be an invoice number. If there is no invoice number, then the DOC # is the ——— (ORDER NUMBER)

(3) An order number will be written next to the words Order #, Purchase Order, or P.O. #. The number of digits in an order number is almost always ——— (SIX)

(4) Sometimes there are two order numbers. One is the number assigned by the company and the other is the customer's order number. The company's order number serves as the DOC # when there is no invoice number

Program 4R: 0 INV #

(1) The DOC # for a credit note is the CR #. The second reference number for a credit note is the ——— (INVOICE NUMBER)

(2) This number should be entered into the column headed ——— (0 INV #)

(3) If there is more than one invoice number on a credit note, then in the 0 INV # column you should enter ——— (NOTHING)

(4) The DOC # for an instant return is the IR #. The second reference or 0 INV # on an IR is the ——— (CREDIT NUMBER)

(5) Remember how to recognize a credit number. The number of digits in a credit number is ——— (SIX) and the first digit is ——— (4). The credit number will be handwritten in a felt tip pen, usually blue or black

(6) On "Returned Goods", the second reference number is the ——— (AR NUMBER)

(7) At the top of the document next to the words "Returned Goods" are the words ——— (AUTHORIZATION TO RETURN). The AR is usually under that heading.

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under the heading TYPE, the two-letter codes that had been learned in the document-discrimination task, had to be entered. H.D. worked through the 40 documents in the same pre-determined random order on each trial.

The second rules program (2R) presented information about document numbers in 45 incomplete sentences (see Table 2 for examples), which were accompanied by 13 sample documents. In the procedures segment (2P), the patient was required to make two entries for each of the 40 documents: the TYPE and the DOC #. Because the choice of document number is always dependent on the type of document and the two pieces of information are entered into the computer display in adjacent columns (3 and 4), it seemed reasonable to group these two items together. In addition, because of the potential confusion between document numbers and customer numbers (i e. in many cases they have similar properties), the two-item grouping seemed like a reasonable intermediate step to be achieved before attempting integration of all previously acquired information.

The third rules program (3R) served as a brief refresher course concerning the characteristics of frame and roll numbers. These numbers had appeared on meter cards in the job H.D. had mastered previously [10], but their location on some of the new documents was different. The program was short, consisting of just eight incomplete sentences with four sample documents, and only one four-trial session was conducted.

The third procedures program (3P) required the patient to execute all components of the task that had been learned to that point. Entries in five columns had to be made for each of the 40 documents—ACD, CUST #, TYPE, DOC #, FRAME, in that order—for a total of 200 entries per trial. The 40 documents were processed in the reverse order to that used in the prior lessons.

The next pair of rules and procedures programs were concerned with what are called *second reference* numbers. These numbers are entered into the computer display under the column heading 0 INV #. This column was always left blank in the meter card task that H.D. learned previously. There are a number of problems associated with choosing the correct items for this column. First, the heading stands for "other invoice number", but the number to be entered in this column frequently is not an invoice number. Second, all documents do not have second reference numbers, even those of the same document type. The difficulty of this task is illustrated by the example sentences

shown in Table 2. Fifty-eight such sentences constituted program 4R, along with 18 sample documents. In the program 4P, six entries were required for each of the 40 documents, for a total of 240 responses.

The last pair of programs in phase II dealt with the appropriate dates to be selected from each document. In program 5R, 30 sentences were presented for completion along with 13 sample documents. The problem encountered in this task related to the fact that there were often several dates on each document and they appeared in a variety of formats (e.g. June 9, 1987, 06/09/87, 09 06 87) and styles (i.e. stamped or handwritten). Almost none of the dates was, in fact, in the form required for data-entry (i.e. 87 06 09). The final task (program 5P) in this phase of training required the entry of all seven items for each of the 40 documents.

Results

The patient successfully completed all segments of phase II over a period of 3 months. Results are summarized in Table 3. Performance in both rule learning and procedural tasks improved steadily across trials. By the end of this training segment, H.D. was able to enter all information from the 40 sample documents without error in a time of approximately 40 sec per document. Note, however, that all information from these 40 documents had been entered into the computer display many times in the course of training. Although we had no estimate of the speed with which this task should be performed, we knew that H.D. entered information from meter cards at a rate of approximately 10 sec per card. Given the complexity of the present task, we decided to set a time criterion for our patient of approximately 20–25 sec per document. The next phase of training was directed towards achieving that goal.

Table 3. Phase II: acquisition of rules (R programs) and procedures (P programs). Trials to criterion, range of hints and times per trial

Program	Number of entries required	Number of trials to criterion	Number of hints per trial	Times per trial (min)
1R	34	14	48 0	74.0 18.4
2R	45	15	37 0	77.2 29.6
3R	8	4	4 0	7.7 3.5
4R	58	36	46 1	73.2 23.4
5R	30	22	30 0	29.2 10.7
1P	120	15	9 0	35.3 11.4
2P	80	14	16 0	26.6 10.6
3P	200	11	13 0	52.5 17.1
4P	240	16	23 0	33.2 16.8
5P	280	36	16 0	37.2 25.9

PHASE III: LABORATORY PERFORMANCE

Method

In this training segment, extensive practice in data-entry was provided under conditions that closely simulated the real-world job. Two hundred and forty documents were selected from a large company sample and divided into 12 groups of 20 documents each. Groups 1 9 consisted of documents of the same type (e.g. group 1 were all invoices, group 2 were all payments, and so on); groups 10–12 were composed of documents of different types. We chose these groupings to correspond to those that occurred naturally on the job so that later we would have some basis for comparison to performance in the workplace. In addition, this organization allowed us to assess which documents were the most problematic so that practice could be focused on the areas of greatest difficulty.

Sessions were conducted daily over 9 consecutive working days. On the first day, H.D. was required to enter information from all 240 documents, 20 documents per computer screen, just as in the actual job. She also entered the ROLL number at the bottom of each screen and "sent the information to the mainframe" using the ENTER key. These latter functions had been used previously with meter cards. The same 12 groups of documents were entered each day in a different random order. When performance on any group of 20 documents was perfect for 3 consecutive days, that group of documents was dropped from training. Because of the time constraints under which we were working, performance did not reach criterion on every document group. However, every document group was entered perfectly on at least one trial.

Results

Results from phase III are shown in Table 4. The following points can be noted.

(1) Although H.D. had never encountered any of these specific documents before, she performed the data-entry task on the first trial with very few errors. Her performance suggested that she had in fact learned a set of rules that she was applying in new circumstances.

(2) For almost all of the uniform document groups, the entry times per document on the first trial were as fast as those for the 40 overlearned documents in the previous phase of training (i.e. approximately 40 sec).

(3) The mixed groups of documents, not surprisingly, were more difficult to handle than the consistent groups. Criterial levels of performance were not reached for any of these groups, although errors were relatively few. Times were also noticeably longer for the mixed than for the uniform groups.

(4) By the end of laboratory training, the time required to enter groups of documents of the same type into the computer was within our target range of 20–25 sec per document. For the mixed groups, times were somewhat longer, between 30 and 40 sec.

Table 4. Phase III: laboratory performance on 240 documents grouped by TYPE. Trials to criterion (three consecutive perfect trials), errors and mean times per document

Document types	Trials to criterion	Errors per trial (141 entries)	Mean time per document (sec)
Payments A	4	3–0	39.6 24.6
Payments B	7	2–0	43.6–25.6
Shipping tickets (for parts invoices)	6	2–0	58.2–21.9
Shipping tickets (other)	5	1–0	38.6 22.3
Invoices—service	4	2 0	34.2 16.9
—repair	5	1–0	41.9–23.0
—parts	4	3–0	41.7 25.6
—change	6	2 0	57.4–24.6
General tickets	7	1–0	27.6 16.8
Orders and confirmations	11 + *	4 0	72.3–32.7
Specials	11 + *	4–0	85.3 36.5
Mixed	11 + *	3–0	90.0 42.1

* Three consecutive perfect trials not achieved.

PHASE IV: PERFORMANCE IN THE WORKPLACE

Method

H.D. began performing the job in the workplace immediately following completion of training. She worked $2\frac{1}{2}$ to $3\frac{1}{2}$ hr each day in the computer filing department of the corporation performing the data-entry task that she had learned in the laboratory. She was accompanied on-the-job for 5 weeks by an experimenter who monitored her performance continuously, assisted her with special problems and ensured that the job was performed correctly.

Documents were presented to H.D. for data-entry in different orders, sometimes in groups of the same type and sometimes in mixed bundles. Not all document types appeared every day or even every week. All documents were new in the sense that H.D. had not encountered exact replicas of them during training. Although there were similarities within document types, there were also endless variations, and many documents bore little resemblance to those encountered earlier. As H.D. entered information from each document the experimenter recorded the type of document, the time taken to enter each complete 20-record screen, and the number of errors committed. When H.D. made an error she was prompted by the experimenter to correct it, and these correction times were included in the times per screen. Many unexpected problems also arose that the experimenter could not solve. In these cases, a supervisor's help was enlisted and timing was suspended. Most of the problems related to variations in documents that had never been seen before and did not conform to the acquired rules in any straightforward way. When it became evident that such variations would continue to occur, H.D. was provided with a tray in which to place documents that she did not know how to handle. Although for several days she had to be prompted to use the tray, after 2–3 weeks she began using the "problem" tray spontaneously. By the end of the fifth week, H.D. was handling all procedures without assistance, and so the experimenter no longer accompanied her to the workplace. The experimenter returned to the company a month later to monitor H.D.'s performance in a non-intrusive fashion for 1 week.

Results

Despite all of the inconsistencies, variability and new experiences for H.D. on-the-job, she nevertheless managed to perform the task. There was an initial slowing in data-entry speed relative to laboratory performance, but by the end of 5 weeks, documents were being entered more quickly than they had been at the end of laboratory training. This comparison is illustrated in Table 5. Groups of documents that roughly corresponded to those used in the last phase of laboratory training were selected from all of the documents that H.D. had entered on-the-job. (These represented only a fraction of all the documents entered during this period.) Although the mean times per document were based on different numbers of entries, the trend towards faster performance over time reflects the improvement that was taking place.

Table 5. Comparison of data-entry speed on selected new documents in the workplace to final speed attained in the laboratory on similar document types

| Document type | Final laboratory | Mean time per document (sec) Weeks in the workplace | | | | | 1 mo. delay |
		1	2	3	4	5	
Payments	25.1	40.8	36.0	34.0	25.3	23.0	22.7
Shipping tickets	22.1	—	23.8		21.2	19.8	—
Invoices	21.8	—	37.3	—	21.3	19.6	18.0
General shipping tickets	16.8	—	—	—	22.4	16.5	13.8
Orders and confirmations	32.7	42.9	46.1	29.8	21.9	21.0	22.2
Specials	36.5		36.2	30.0	29.0	26.1	24.0
Mixed	42.1	62.0	64.4	45.4	31.8	32.8	30.0

Table 6 displays, in summary form, the data from all documents entered in the workplace. Notice that a growing number of documents was being processed across weeks on the job, indicating that H.D. was becoming increasingly efficient at the task. In the first week, H.D. handled only 979 documents. By the end of the fifth week, she was processing 1671 documents, and a month later that total had risen still further to 1790 documents. She also made very few errors; during the fifth week on-the-job, she made only 16 errors across 1671 documents. Her mean time to enter information from one document also declined from an initial level of 49 sec per document to 24 sec per document, and the number of documents being processed per hour on the job increased from 61 to 114. This latter measure includes other organizational aspects of the job in addition to actual data-entry. The results suggest that these tasks were also being handled more efficiently over time.

Table 6. Phase IV: performance in the workplace. Number of documents processed per week and per hour on the job, number of data-entry errors and mean time to enter each document

Week (5 days)	Total number of documents entered	Total number of errors	Mean number of documents entered per hr	Mean time to enter one document (sec)
1	979	60	60.7	48.6
2	957	43	64.4	39.3
3	1031	39	64.8	37.3
4	1370	20	89.0	25.9
5	1671	16	100.6	23.6
1 mo. delay	1790	—	114.0	24.5

DISCUSSION

Previous research has demonstrated that amnesic patients can learn various kinds of perceptual, motor and cognitive skills [1, 3, 6, 19–21], show intact repetition priming effects on a number of implicit memory tests [15, 25, 37] and acquire complex new knowledge necessary to program and interact with a microcomputer [12–14]. The present study extends these findings by demonstrating that a severely amnesic patient can learn to perform a data entry job that requires more extensive and more complex new learning than any task heretofore reported in the literature on organic memory disorders. Despite a serious memory impairment, patient H.D. acquired over 250 discrete items of new information, many of which were individually complex, and used this knowledge appropriately to perform the data entry task both in the laboratory and the workplace. These results suggest that amnesic patients' preserved learning abilities can be extended well beyond what has been reported previously.

As noted in the introduction, some investigations of preserved learning, primarily those concerned with skill acquisition and priming effects, have demonstrated that amnesic patients can show *normal* memory performance on various kinds of tasks. Because we were unable to use control subjects for the reasons discussed earlier, we could not ascertain whether H.D. exhibited normal learning in this study. However, in our earlier laboratory investigations of computer learning, H.D. exhibited much slower learning than did control

subjects. Because of numerous similarities between those computer tasks and the present data-entry job, we assume that such a result would also have been observed in this study. It is theoretically important, however, to be able to compare directly the performance of amnesic patients with that of control subjects on complex real-world tasks. Accordingly, we have constructed laboratory analogs of the computer data-entry jobs learned by H.D., and are currently testing additional patients and control subjects.

Demonstrations of normal priming and skill learning in amnesic patients have led to the suggestion that the memory systems that support these phenomena are distinct from the system involved in explicit recall and recognition (e.g. [5, 17, 24, 33, 34, 38]). An important question concerns whether H.D.'s learning of the data-entry task was mediated by a spared memory system, or whether performance on the data-entry task was supported by the damaged system that underlies recall and recognition of recent events. Although our results do not permit an unambiguous answer to this question, it seems likely that spared memory processes contributed to task performance. The teaching technique that we used, the method of vanishing cues, was designed specifically to tap patients' preserved priming abilities. Because H.D., like other amnesic patients, shows intact priming effects, we assume that the spared mechanisms underlying such effects were involved in learning. On the other hand, H.D. was eventually able to exhibit free recall of document types following extensive repetition without the vanishing-cues procedure. Free-recall performance is typically thought to depend on the system that is damaged in amnesia. These considerations suggest that H.D.'s damaged memory processes may also have made some contribution to learning in the data-entry task. Indeed, in a task as complex as the present one, we would expect the involvement of a variety of memory processes and systems.

In our previous studies of computer learning in H.D. and other amnesic patients [12–14], we found that amnesics exhibited little transfer of knowledge when they were tested with cues that differed from the exact cues used during training—a phenomenon referred to as *hyperspecific learning* [13, 24]. In the present study, we observed evidence of similar transfer problems: when H.D. began to enter novel documents at the workplace, her entry times slowed considerably compared to her times for entering familiar documents. However, in the absence of appropriate data from control subjects, we cannot determine whether H.D. had special difficulties in transfering acquired knowledge to novel test situations. Moreover, the fact that H.D. was able to apply the rules and procedures acquired during training to entirely novel documents, albeit at a slowed rate, indicates that *some* transfer of training occurred. An important task for future research will be to elucidate exactly what kinds of information can be transfered by amnesic patients from one test situation to another.

Our findings also have implications for research on remediation of memory disorders. As we and others have argued previously [9, 22, 29, 40], attempts to restore memory functions or to teach general purpose mnemonic strategies to amnesic patients have not been successful. As an alternative to such approaches, SCHACTER and GLISKY [29] argued that it would be more useful to try to teach amnesic patients *domain-specific knowledge*—knowledge and skills that can be applied in a particular sector of a patient's everyday life. Our previous demonstration that H.D. could be trained to perform a data-entry task indicated that vocational training represents a promising direction for domain-specific research. The present data confirm and extend this suggestion by showing that a severely impaired patient can master a job of much greater complexity than has been investigated previously. Note, however, that despite its evident complexity, the present job possesses three characteristics that we argued previously are crucial for successful training of amnesic patients [10]: (1) the

job can be broken down into simple *components*, (2) all relevant knowledge can be trained *directly* and *explicitly* and (3) once learned, the job can be executed *repetitively*, and does not place ongoing demands on memory. The fact that the present training program was successful underscores the importance of ensuring that these features are present in attempts to train memory-impaired patients for real-world jobs. As discussed in our earlier paper [10], however, it is not yet possible to determine whether positive outcomes will be observed with memory-disordered patients other than H.D. For example, H.D. possesses excellent attentional skills that may be instrumental in her success. Moreover, although H.D.'s memory disorder is severe, it is not quite as severe as that of a patient such as H.M. (e.g. H.D. shows a 20-point split between WAIS-R IQ and WMS MQ, whereas H.M.'s WAIS/WMS split is considerably larger). We do not know how a profoundly amnesic patient like HM would perform on the present task. A critical problem for subsequent studies will be to explore whether patients with different or more severe forms of amnesia can learn the sort of complex job tasks that we have used with H.D.'s.

Finally, it should be noted that the positive outcome of this study has had enormous impact on patient H.D.'s everyday life. When we began our first job training study with her [10], H.D. was at risk of losing her position in the company, an event that would have had devastating consequences for both the patient and her husband. The fact that we were able to train H.D. to perform the part-time data entry task convinced the company to allow us to begin training her for the task described here. With the success of the present intervention, H.D. is now employed at the company on a full-time basis.

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