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Learning and Retention of Computer-Related Vocabulary in Memory-Impaired Patients: Method of Vanishing Cues*

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ABSTRACT

Several investigators have suggested that microcomputers might serve as useful external aids for memory-impaired patients. However, knowledge of basic computer vocabulary may be necessary for patients to use and benefit from a microcomputer. The present paper describes a procedure, the *method of vanishing cues*, which facilitated the acquisition of computer-related vocabulary in four memory-impaired patients. The method involves the systematic reduction of letter fragments of to-be-learned words across trials. Although learning was slow and strongly dependent on first-letter cues, all patients acquired a substantial amount of the vocabulary and eventually were able to produce the target words in the absence of fragment cues. Further, they retained the vocabulary over a 6-week interval and showed some transfer of the knowledge they had acquired. These findings suggest that memory-impaired patients may eventually be able to use a microcomputer as a prosthetic device.

Memory disorders are among the most common sequelae of numerous types of neuropsychological dysfunction. In relatively pure cases of amnesia, such as those observed with restricted damage to limbic structures, severe memory deficits occur in the absence of corresponding intellectual deficits; in other cases, such as those observed with head injury or dementing illnesses, memory disorders of varying severity frequently occur in conjunction with cognitive and intellectual deficits. One feature that is characteristic of virtually all memory-impaired patients, however, is a reduction or loss of the ability to live an independent life. Patients with memory impairments require direction and supervision by others in many of their daily activities. At the Unit for Memory Disorders, we have begun research designed to explore the possibilities of helping such people in their day-to-day living. Our basic approach has been shaped by the assumption that a good deal of the responsibility for directing and

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supervising a patient might be taken over by a patient's personal computer. A number of investigators have suggested that a computer has the potential of serving as a helpful compensatory device for memory-impaired people, in a manner analogous to other prosthetic devices such as artificial limbs: a computer might be able to substitute for the person's impaired memory in the same way as other prostheses substitute for damaged or lost parts of the organism (e.g., Harris, 1984; Jones & Adam, 1979; Kirsch, Levine, Fallon-Krueger, & Jaros, 1984; Schacter & Glisky, 1986; Skilbeck, 1984).

In the present paper, we describe the initial part of a research program that explores whether memory-impaired patients can acquire the knowledge that is needed to operate and interact with a microcomputer. Specifically, the paper describes a study designed to teach four memory-impaired patients a small vocabulary of computer-related terms. We began our project with this phase, because we reasoned that knowledge of a number of basic terms would facilitate patients' ability to interact with the computer. The computer would not be of much help to patients if they did not know the meanings of the words that are involved in using the computer or "talking" with it.

The report consists of four main sections: (a) a short review of the literature concerning the learning capacities of memory-disordered patients, (b) a description of the procedures we used, (c) a summary of the quantitative and qualitative observations we made, and (d) a discussion of our main findings and their implications for our overall aims of computer-assisted living by memory-disordered people.

LEARNING CAPACITIES OF MEMORY-DISORDERED PATIENTS

It is by now well known that even patients with serious memory impairments can learn and retain *some* new skills and knowledge (e.g., Brooks & Baddeley, 1976; Cohen, 1984; Graf, Squire, & Mandler, 1984; Milner, Corkin, & Teuber, 1968; Moscovitch, 1982; Schacter, Harbluk, & McLachlan, 1984; Warrington & Weiskrantz, 1974, 1982), but so far little evidence exists regarding patients' ability to acquire meanings of new words. One relevant study has been described briefly by Gabrielli, Cohen, and Corkin (1983). Gabrielli et al. attempted to teach various memory-disordered patients, including the amnesic patient H.M., the meanings of a number of low-frequency words that were unfamiliar to them (e.g., anchorite, welkin). There were 15 learning trials on each of 10 successive days of training. Acquisition and retention of the new vocabulary was tested by requiring patients to match words with their definitions, appropriate sentence frames, or synonyms. Gabrielli et al. observed virtually no vocabulary learning in any of their patients.

The failure to demonstrate vocabulary learning in memory-disordered patients by Gabrielli et al. (1983) is perhaps not surprising, given the well-known fact that such patients have great difficulty learning paired-associate lists consisting of unrelated words. At least superficially, the task requirements in both situations are quite similar: The person must learn to produce a verbal response to an unrelated verbal stimulus. Difficulty with learning unrelated paired-associates is usually considered to be one of the most prominent symptoms in virtually all forms of memory impairment. For example, Wechsler (1917) reported that Korsakoff patients were unable to learn a short list of unrelated paired-associates, even with several repetitions, which led him to devise the "hard" associates of the Wechsler Memory Scale (1945). It has since been demonstrated repeatedly that various types of memory-disordered patients are unable to learn unrelated paired-associates in either a single trial or over 2-3 trials (e.g., Baddeley & Warrington, 1970; Cohen & Squire, 1980; Jones, 1974; Shimamura & Squire, 1984). There is also evidence that these difficulties persist even with extended training: Ryan and Butters (1980) found that Korsakoff patients' performance did not improve over eight trials, and a pilot study in our laboratory indicated that four memory-impaired patients showed little evidence of paired-associate learning even after 96 repetitions.

In summary, then, the evidence suggests that learning of unrelated paired-associates may be beyond the capabilities of many memory-disordered patients. This deficit is present despite the fact that in typical studies both the stimulus and response terms that the patient has to associate are already "represented" in the patient's verbal repertoire or semantic memory. To the extent that the processes underlying vocabulary learning are similar to those entailed in paired-associate learning, learning of new vocabulary may indeed constitute a task of which memory-disordered patients are incapable.

There is some reason for limited optimism, however, if we consider two other kinds of evidence concerning memory-impaired patients. First, even patients with severe amnesia can learn and retain *related* paired-associates, pairs in which the response term is associatively or phonemically similar to the stimulus term (e.g., Kinsbourne & Winocur, 1980; Shimamura & Squire, 1984; Winocur & Weiskrantz, 1976). Thus, to the extent that the connections between some computer terms and their definitions are not completely meaningless, it is possible that memory-impaired patients might be able to learn such connections. Second, recent work has indicated that some memory-impaired patients show retention of unrelated paired associates on tests that do not require conscious recollection of study-list pairs. For example, Graf and Schacter (1985) exposed memory-impaired patients and normals to a list of unrelated paired-associates (e.g., *window* – REASON), and then gave a word-fragment completion test in which subjects were provided with the stimulus and the first three letters of the response (e.g., *window* – REA ____). Subjects' task was simply to write down the first word that came to mind. Graf and Schacter found that memory-disordered patients and normal people showed comparable amounts of retention on this test. Although this associative influence on word-completion performance may occur only in patients with relatively mild memory impairments (Schacter & Graf, in press), numerous studies have shown that severely amnesic patients' retention of individual words is improved by letter-fragment cues (e.g., Diamond & Rozin, 1984; Graf et al., 1984; Warrington & Weiskrantz, 1970, 1974, 1978). These findings suggest that memory-disordered patients' ability to acquire new vocabulary might be facilitated by a teaching technique that provides initial letters of target words as cues.

In the research that we describe here, we used a method that attempts to exploit the previously demonstrated effectiveness of word-fragment cues for memory-impaired patients. The method is partly based on the definition of learning as an acquired ability "to respond to reduced cues" (Hollingworth, 1932). Such a conceptualization of learning naturally suggests a technique that Skinner (1958), for instance, found very useful in developing programs for his teaching machines. Skinner assumed that learning would be facilitated not only by more actively involving the learner in the process, but also by arranging the contingencies of learning in such a manner as to minimize the probability of erroneous responses or response omissions. Skinner achieved this latter objective by using prompts and hints that produced the desired response initially; stimulus control of behaviour was then gradually decreased by "fading out" the provided stimulus information, until the response was made in the absence of any controlling external stimuli. Although Skinner's work focussed on normal subjects, Jaffe and Katz (1975), in a preliminary study, provided anecdotal evidence of the effectiveness of the Skinnerian procedure with a Korsakoff patient, by successfully teaching him the names of two hospital staff members.

In our research, we have labelled this Skinnerian procedure the *method of vanishing cues*. This label is descriptive of the procedure's central feature: the systematic reduction of cue information across learning trials. In the present study, definitions are presented along with letter fragments of the vocabulary words. Letters are then systematically withdrawn from the fragment and the patient is thus guided gradually towards the goal of producing the appropriate word without letter cues.

A DEMONSTRATION EXPERIMENT

Method

We think of our study as a demonstration experiment in that its primary purpose was to demonstrate that the vanishing-cues procedure can help a variety of memory-impaired patients to learn and retain some definitions of computer-related terms. The design of the experiment also made it possible to examine the effects of certain manipulated variables (such as learning trials and sessions) and to make a variety of comparisons (such as between the method of vanishing-cues and a standard anticipation method, and between memory-impaired patients and control subjects).

Four memory-impaired patients participated in the study. Each patient was tested in eight learning sessions, spaced 2 or 3 days apart, and an additional learning and test session 6 weeks later. Each patient attempted to learn two lists of computer-related terms and their definitions, one list by the method of vanishing cues, the other by a standard anticipation method. At the beginning of a particular session, the subjects' knowledge of both lists was tested by production and matching tests. Next, eight learning trials on one of the lists were given, followed by another set of production and matching tests. This same procedure was then repeated for the second list. The bulk of the data that we will report come from the "beginning-of-session" and "end-of-session" production and matching tests of the two lists. We will also report results of a "transfer" production test given after training.

Subjects

Three of the four memory-impaired patients who participated in the study had suffered closed-head injuries, and the fourth one developed a memory defect following viral encephalitis. All patients were seen more than 2 years following their accidents or illness. The patients were selected to represent a range of impairments that are characteristic of the memory-impaired patients that are typically encountered in clinical and rehabilitation contexts. Table 1 presents patient characteristics and the results of neuropsychological testing which was carried out 1-4 months prior to the initiation of the study. (Patients G.R. and C.H. were also tested 3-6 months after participating in the study and no significant changes were observed on any of the neuropsychological tests.) In all cases, patients' FSIQ on the WAIS-R (Wechsler, 1981) exceeded their MQ on the WMS (Wechsler, 1945). Although the mean IQ-MQ difference (11.9) appears to be somewhat low, it must be remembered that IQ on the WAIS-R is typically 7-8 points lower than on the WAIS (Wechsler, 1981). If we adjust for this difference between the WAIS and WAIS-R, the mean IQ-MQ splits in our patients are fairly similar to those of other memory-disordered patients (i.e., a 15-20 point IQ-MQ split).

The four patients differed in the severity of their memory impairments. The most severe memory deficits were shown by patient C.H. He had held a clerical position prior to his head injury and is currently unemployed and living at home with his parents. He is unable to recall anything after a delay of several minutes, as reflected by his scores on the WMS delayed tests (Table 1), and does not remember any of his numerous previous visits to our laboratory. Nevertheless, C.H.'s IQ is in the normal range, and he shows no signs of comprehension or naming problems, as indicated by his normal performance on the Token Test (De Renzi & Faglioni, 1978) and the Benton Visual Naming Test (Benton & Hamsher, 1976) (Table 1). Patient B.T.'s memory problems are milder than those seen in patient C.H., but she also performs quite poorly on delayed recall tests. She shows no deficits on tests of intellectual function, comprehension, and naming. B.T. was employed as a writer prior to her head injury and now writes for the same employer on a part-time basis. Overall, the pattern of test results observed in patients C.H. and B.T. resembles the pattern that is observed in the classical amnesic syndrome, with C.H. representing a severely amnesic patient and B.T. representing a mildly amnesic patient.

Patients H.D. and G.R. both exhibited moderate to severe memory impairments, but also showed evidence of some cognitive deficits. H.D. developed memory impairments after a bout of viral encephalitis, yet has managed to retain a low-level clerical position, largely because of a supportive employer who has structured H.D.'s job so that it places minimal demands on memory. H.D., like patient C.H., has severe difficulties recollecting day-to-day events, and remembers nothing on delayed memory tests (Table 1). However. H.D.'s FSIQ is somewhat low, and she had problems on the Benton Visual Naming Test. although she is not characterized clinically as anomic. Patient G.R. was a university student at the time of her head injury and now lives at home with her family and is unemployed. Although G.R.'s performance on the Token Test and Benton Naming Test is in the norma range, she has attentional problems, extensive motor slowing, and a relatively low IQ. We included patients G.R. and H.D. in our study, even though they have cognitive deficits ir

Table 1. Characteristics of Memory-Impaired Subjects

	Patients				
	G.R.	H.D.	C.H.	B.T.	Mean
Diagnosis	CHI	Encephalitis	CHI	CHI	
Years Post-Trauma	3	3.5	2.5	2	
Age	24	30	32	25	27.8
Education (Yrs)	15	12	16	16	14.8
WAIS-R					
FSIQ	73	82	88	100	85.8
VIQ	82	79	96	109	91.5
WMS	61.5	61	79.5	93.5	73.9
Logical Memory					
Immediate	6	2.5	7	9	6.3
Delayed	2	0	0	0	0.5
Visual Reproduction					
Immediate	3	1	10	6	5.0
Delayed	1	0	0	3	1.0
Hard Associates					
Immediate (Trial 3)	2	0	0	1	0.8
Delayed	0	0	0	1	0.3
Token Test (Normal > 29)	34	34.5	34	34	
Benton Visual Naming (Normal > 50)	54	40	56	56	

Table 2. Characteristics of Control Subjects

Subject	Age	Education (Yrs)	WAIS-R	VIQ	WMS
M.M.	26	12	92	89	96.5
Y.T.	24	15	107	107	105.5
B.D.	31	17	91	95	122
R.B.	47	12	109	100	132
Mean	32.0	14.0	99.8	97.8	114.0

addition to memory impairments, because we wanted to determine whether the results obtained with our vanishing-cues procedure could be generalized across different types of memory-impaired patients.

A control group was also included that consisted of four subjects roughly matched to the patients on the basis of age and verbal IQ. Three of the four subjects in the control group had suffered closed-head injuries that had not resulted in any substantial memory deficits. The fourth one (R.B.) had no history of any neurological impairment. Relevant characteristics of the control subjects are presented in Table 2.

Materials

Thirty words related to the understanding and operation of an Apple II+ microcomputer were selected from computer manuals as the to-be-learned words. All words were between four and ten letters in length. Two separate 15-word lists were constructed such that the target words in each contained a total of 85 letters, and individual words in the two lists were approximately matched for length. In each list, nine of the words had unique initial letters and first letters of three words were repeated once. Definitions of all target words consisted of short phrases. For example, *the blinking symbol on the screen that marks typing location* defined the word CURSOR; *a list of choices presented by a program* was the definition for the word MENU. The entire set of definitions and targets are listed in the Appendix.

Procedure

All subjects were given the task of learning to recognize and to produce the target words to the definitions. The training procedure used on the learning trials differed for the two methods.

Under the standard anticipation method, a definition was displayed in the centre of the computer screen and the subject had 10 s to produce the corresponding target word by making a verbal response. The correct response made by the subject, or the failure to produce it in the allotted time, caused the correct word to appear on the screen below its definition for 2 s. Following a 1-s blank interval, the definition of the next word in the list appeared, and the procedure was repeated. Definitions were presented in this same way on every trial.

In the vanishing-cues condition, stimulus presentation varied from trial to trial. On trial 1 of the first session, each definition was exposed for 10 s; then the first letter of the corresponding word was displayed, together with hyphens indicating the number of missing letters. The subject's task was to try to produce or guess the target word. Whenever the subject failed to produce the correct word within 10 s, the next letter of the word was added, and the subject again had 10 s to produce or guess the word. This procedure continued until the subject either correctly produced the word, or until the word had been displayed in its entirety. For example, the definition that read *programs that the computer carries out* was followed first by S———, then by SO———, SOF——, SOFT——, SOFTW——, and so on, until the subject correctly responded "SOFTWARE". The correct response made by the subject was immediately confirmed by the appearance of the target word on the screen for 2 s. All 15 definitions were presented in this way on trial 1 of the first session.

On all subsequent trials, stimulus information was contingent upon the subject's performance on the previous trial. Each definition was presented for 10 s, accompanied by a letter fragment of the corresponding word. The number of letters in the fragment was always one less than the number that the subject had needed for the correct production of that target word on the previous trial. Correct response by the subject was confirmed by the appearance of the target word for 2 s, followed by the next definition. Whenever the subject failed to produce the correct word within 10 s, a letter was added to the word fragment and the subject again had 10 s to produce the correct response. This incremental procedure was continued until terminated by the correct response or the presentation of the whole word.

The subjects were told that they should try to associate each target word with its definition, because they would eventually be required to produce the target word in the absence of any letter cues, although they were not explicitly informed of the pattern of letter withdrawals.

The computer program kept track of the subject's performance with each word on each trial, and on each new trial always provided the subject with a word-fragment smaller by one letter than the one that the subject had been able to manage on the previous trial.

At the end of eight trials on a given list, subjects were given two tests – a production test and a matching test. In the production test, subjects were presented with the definitions, one at a time, and were asked to verbally produce the correct vocabulary word. No letter cues were provided. Each definition was shown on the screen for a maximum of 10 s and subjects tried to respond with the appropriate item. They were told whether an answer was right or wrong and were scored correct if the appropriate response occurred in the 10-s interval whether or not it was the first response that they gave. No record was kept of incorrect responses. Subjects then completed a paper and pencil matching test. They were given a list of definitions and a numbered list of target words, and their task was to write the number of each word next to its correct definition.

After eight learning trials and tests, as just described, for one list, subjects had a short rest period and then began the second list. Two of the subjects in each group learned List 1 by the method of vanishing cues and List 2 by the standard anticipation procedure; for the other two subjects, lists were studied in the opposite conditions. One of each pair of subjects began training with List 1, the other began with List 2. The order in which lists were studied was reversed each session.

Successive sessions were given at intervals of 2 or 3 days. At the beginning of each session after the first, the production tests and the matching tests were given for both lists. These were followed by eight learning trials and the two tests for each list as in the first session. Definitions were presented in a different random order on each study and test trial. There was a 1-min rest period between trials and a longer rest period between lists. The four patients participated in eight sessions over a period of 4 weeks. The four control subjects participated until they achieved perfect performance.

Six weeks after the final training session, subjects returned to the laboratory for a "delayed" test and learning session (session 9). At the beginning of this session they were again given the production and matching tests for both lists. Three of the four patients and all four control subjects were then given eight learning trials on each of the two lists, together with "final" production and matching tests. (Patient B.T., the least impaired of the four, had virtually perfect scores on the initial production and matching tests in this 6-week delayed session and declined to participate in further learning trials.)

Three or four days after the 6-week delayed session, each subject was given a "transfer" production test. For this test, 30 sentences were constructed in which the final word was one of the 30 vocabulary words that the subjects had learned in the study. Each sentence preserved the meaning of the original definition but the specific wording was altered. For example, the word LOOP was originally defined as *a repeated portion of a program*. The sentence to be completed with the word LOOP was: *If you want a program to perform the same operations repeatedly, you put the instructions in a* ——. The number of letters in the missing word was indicated by hyphens and the subjects' task was to complete the sentence by producing the appropriate missing word.

Sentences appeared on the computer screen and subjects were required to type their responses on the keyboard. They were instructed that, if they did not know the word that completed the sentence, they should guess. If they had no idea as to what they should type, they could press the RETURN key for a hint. (Practice at using the RETURN key was provided to all subjects before the sentence-completion task was begun.) The first hint consisted of the initial letter of the target word, and additional letters were added one at a time, as needed. After the presentation of each additional letter, the subject was given an opportunity to type in the correct word. Whenever the subject produced an incorrect response, the word INCORRECT appeared on the screen, and the next letter was added to the fragment. Subjects worked independently, at their own pace.

In this "transfer" test, the 30 words from both lists were combined, and then grouped into four categories according to which aspects of computer operation they concerned: (a) parts of the computer and information flow, (b) screen operations, (c) disk operations, and (d) writing a program. Subjects selected the order of these four categories for testing. Within a category, sentences occurred in the same fixed order for all subjects.

RESULTS

A few words were correctly produced or guessed at the beginning of the first training trial: two words in the standard anticipation condition for two patients (G.R. and B.T.) and one control subject (Y.T.), and one word in each condition for another control subject (B.D.). Although these words remained as members of to-be-learned lists for these subjects, they were ignored in the analysis of the data. The results that we now describe are reported in terms of the proportions of the words whose computer-related meanings were initially unknown to the subjects. In the description of the results, we concentrate on the performance of the patients, and report these findings in some detail. The performance of control subjects will only be briefly summarized.

Patients' production-test performance

The performance on "beginning-of-session" and "end-of-session" production tests for the patient group, for the eight training sessions as well as for the 6-week delayed session, is summarized in Figure 1. We wish to note the following points:

(1) The proportion of words correctly produced showed an overall increase across the eight learning sessions. This increase means that memory-impaired

Table 3. Proportions of Words Produced Correctly on End-of-Session Tests

Patient	Condition	Session								
		1	2	3	4	5	6	7	8	Delayed
G.R.	Anticipation	.15	.54	.54	.38	.38	.46	.46	.62	.31
	Vanishing Cues	.33	.47	.47	.73	.87	.73	.73	.73	.80
H.D.	Anticipation	.20	.33	.47	.67	.67	.80	.80	1.00	.87
	Vanishing Cues	.13	.47	.60	.80	.93	1.00	1.00	1.00	1.00
C.H.	Anticipation	.27	.33	.40	.40	.47	.40	.60	.67	.60
	Vanishing Cues	.13	.33	.60	.53	.60	.73	.73	.67	.73
B.T.	Anticipation	.46	.77	1.00	1.00	.92	1.00	1.00	1.00	1.00[a]
	Vanishing Cues	.60	.73	1.00	1.00	1.00	1.00	1.00	1.00	.93[a]

[a] B.T. did not participate in the final training session, and so beginning-of-session scores are reported.

patients are capable of learning computer-related vocabulary.

(2) Learning occurred both with the method of vanishing cues and with the standard anticipation method, with the former yielding a higher overall level of performance than the latter. For the first three learning sessions, the two methods yielded practically indistinguishable outcomes. But the method of vanishing cues was superior to the standard anticipation method in the subsequent sessions, particularly in the "end-of-session" tests. To provide information about individual patient's performance, we have displayed in Table 3 end-of-session results for each patient. The advantage for the method of vanishing cues was evident in three of the four patients; only the mildly impaired patient B.T., who attained perfect performance by the end of session 3, failed to show any difference between the two methods. The severely impaired patient H.D. showed a consistent advantage through sessions 2-7 for the method of

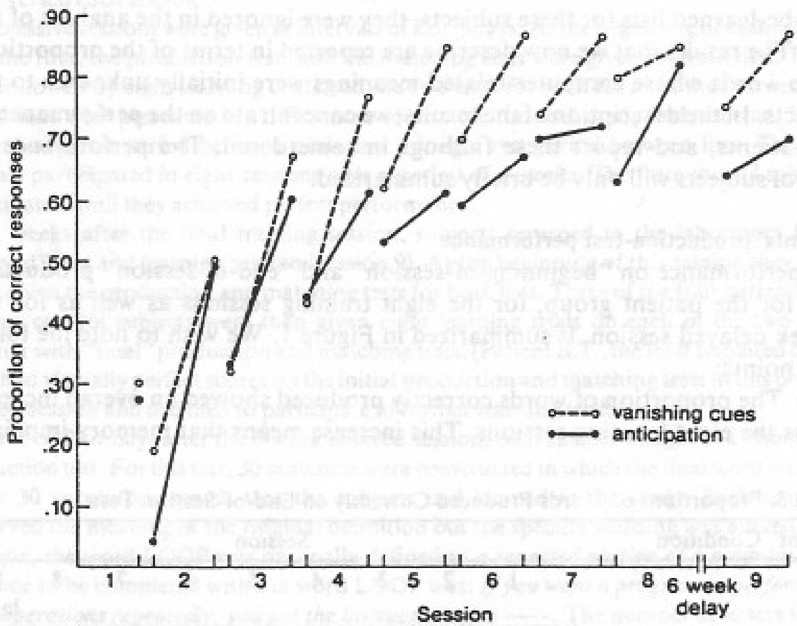

Figure 1. Proportion of computer-related words produced correctly in the presence of an appropriate definition on beginning- and end-of-session tests. The broken lines depict performance for words that had been exposed during training trials with the method of vanishing cues. The solid lines depict performance for words that had been exposed during training with a standard anticipation procedure. The initial point in each condition represents performance at the end of Session 1. The final two points in each condition depict performance at the beginning and end of Session 9, which was conducted 6 weeks after the termination of Session 8. The first eight sessions were conducted twice weekly.

vanishing cues, and achieved perfect performance in both conditions by the conclusion of the eighth session. However, as Table 3 shows, patients C.H. and G.R. at no time were able to produce all of the vocabulary words. Collapsed across the three final end-of-session tests, these two patients produced approximately 70% of target words in the vanishing cues condition, and 50% of targets in the anticipation condition.

(3) The overall pattern of performance (Figure 1) shows a great deal of systematic fluctuation: Rises in performance attributable to the learning trials within a session are accompanied by large losses of information between the sessions, making for a striking saw-toothed appearance of the overall curves, especially under the method of vanishing cues. Thus, a good deal of what patients learned in a given session was lost by the beginning of the next one. (This pattern of results, however, was also observed in control subjects.)

(4) Retention of the acquired information over the 6-week retention interval following the eighth training session was remarkably stable, especially for the words acquired with the method of vanishing cues. The loss of information over the 6-week interval was about the same as the loss of information over intervals of 2 or 3 days between sessions 5 and 6, 6 and 7, and 7 and 8, sessions in which the level of performance had reached a virtual asymptote (Figure 1). The loss of information over 6 weeks was slightly larger for the material learned with the standard anticipation method, but here, too the beginning-of-session delayed-test performance was about the same as the beginning-of-session test performance from the later training sessions, sessions 6, 7, and 8.

We performed statistical tests on various aspects of these complex data, using a non-parametric test for comparison of two proportions (Bennett & Franklin, 1954). The following findings may be worth mentioning. Collapsed across the first eight sessions, production test performance was higher in the vanishing cues condition than in the anticipation condition, both on beginning- ($p < .05$) and end-of-session ($p < .01$) tests. The decrease in performance over the 6-week delay between sessions 8 and 9 was significant in the anticipation condition ($p < .05$), but not in the vanishing cues condition. In addition, the final level of performance at the end of the "delayed" session was higher in the vanishing cues condition than in the anticipation condition ($p < .05$).

Patients' matching-test performance

Matching-test performance of patients for the eight training sessions and the 6-week delayed session is graphically summarized in Figure 2. These data seem to be somewhat "noisier" than the data from production tests, but some general patterns are, nevertheless, discernible.

(1) The overall trend of the matching data parallels the overall trend of the production data: increasing performance across the eight training sessions. Individual patient's end-of-session matching performance is displayed in Table 4. As on the production test, patients B.T. and H.D. achieved perfect performance by the eighth learning session, whereas patients C.H. and G.R. did not.

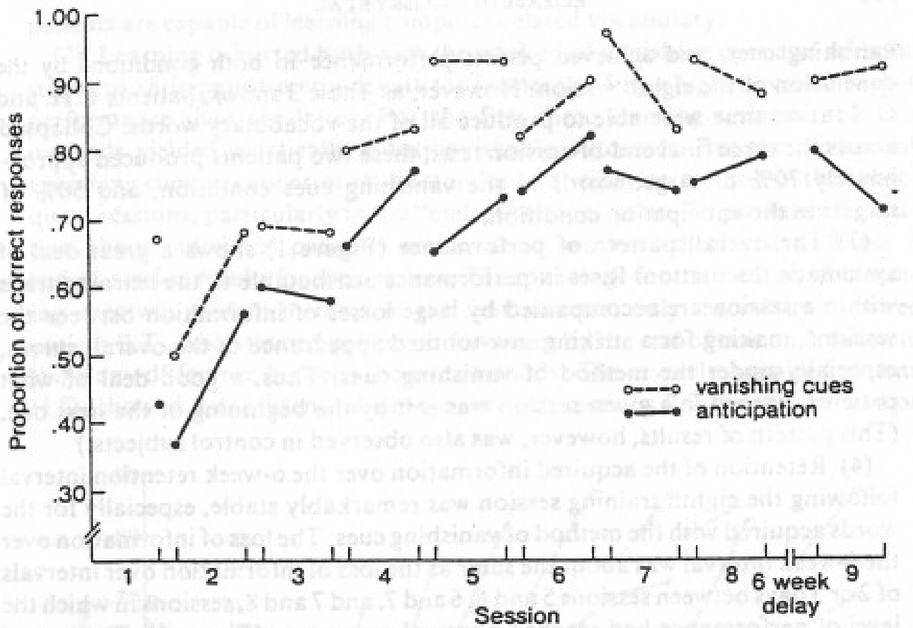

Figure 2. Proportion of computer-related words correctly matched to their definitions on beginning- and end-of-session tests. The broken lines depict performance for words that had been exposed during training trials with the method of vanishing cues. The solid lines depict performance for words that had been exposed during training with a standard anticipation procedure. The initial point in each condition represents performance at the end Session 1. The final two points in each condition depict performance at the beginning and end of Session 9, which was conducted 6 weeks after the termination of Session 8. The first eight sessions were conducted twice weekly.

Table 4. Proportions of Words Matched Correctly on End-of-Session Tests

Patient	Condition	Session								
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G.R.	Anticipation	.08	.54	.38	.54	.46	.62	.54	.62	.46
	Vanishing Cues	.60	.40	.47	.53	1.00	.60	.80	.80	.80
H.D.	Anticipation	.40	.67	.60	.87	1.00	1.00	1.00	1.00	1.00
	Vanishing Cues	.27	.73	.73	1.00	1.00	1.00	1.00	1.00	1.00
C.H.	Anticipation	.53	.33	.47	.67	.47	.67	.40	.53	.40
	Vanishing Cues	.87	.73	.53	.80	.73	1.00	.53	.73	.87
B.T.	Anticipation	.69	.69	.85	1.00	1.00	1.00	1.00	1.00	1.00[a]
	Vanishing Cues	.93	.87	1.00	1.00	1.00	1.00	1.00	1.00	1.00[a]

[a]B.T. did not participate in the final training session, and so beginning-of-session scores are reported.

(2) The data obtained from the vanishing-cues condition held a small, but consistent, advantage over those from the standard anticipation condition throughout the experiment.

(3) Within-session and between-session changes in performance were much more variable on the matching tests than they were on the production tests: performance was as likely to increase from the end of one session to the beginning of the next as it was to decrease, and in several sessions there was no improvement of matching performance from the beginning of the session to the end.

(4) Matching performance showed no reduction at all across the 6-week retention interval: subjects did approximately as well at the beginning of the delayed-test session as they had done in the later learning sessions, sessions 6, 7, and 8. And there was no improvement in matching performance as a result of the eight learning trials in the delayed session. A similar absence of improvement in performance in the later learning sessions suggests that the patients' performance had reached a virtual asymptote.

Statistical analyses revealed that during the first eight sessions, matching test performance was higher in the vanishing cues condition than in the anticipation condition on both beginning- and end-of-session tests ($p < .01$). There was no decline in matching performance for either condition after the 6-week delay, but performance in the vanishing cues condition remained significantly higher than in the anticipation condition on the final test of session 9 ($p < .01$).

Analysis of Letter Reductions

One advantage of the method of vanishing cues is that it permits a fine-grained analysis of learning in terms of the number of letters required for correct identification of the target words. The 15 words in each of the two lists contained a total of 85 letters. On the first trial of the first session, patients required a mean of 53 of the 85 letters to guess correctly the vocabulary words, or an average of 3.5 letters per word. By the final trial of session 1, the mean number of letters needed for successful generation of the targets had decreased to 18 or 1.2 letters per word. This reduction suggests that considerable learning took place during the first training session.

Figure 3 shows the number of letter cues needed to complete target fragments for each of the four patients. The number of letters needed on the first and last trials of each of the eight sessions is plotted. All patients showed a substantial decline in the number of letters required for identification of the words both across and within sessions, with a particularly sharp reduction observed during session 1. Even though few words were produced at the end of the first session in the absence of letter cues (patients H.D. and C.H. produced only two), the letter data suggest that patients had acquired some knowledge of the vocabulary. The rate of letter reduction, particularly for patients G.R. and C.H., tends to slow considerably during the middle training sessions. This levelling off of performance occurred at approximately the point at which just the first letter of each

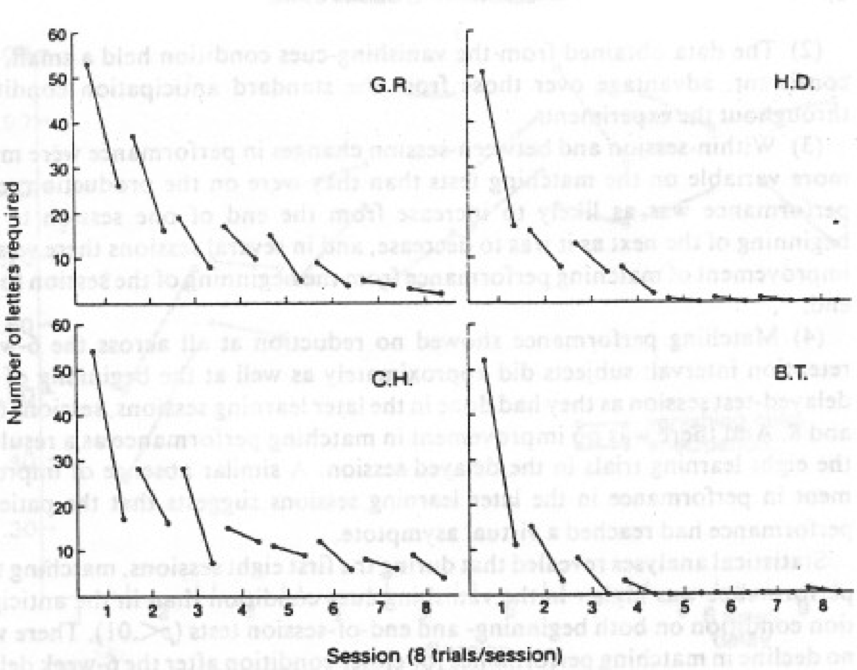

Figure 3. The number of letters required by four amnesic patients to complete fragments of computer-related words in the presence of their definitions. On a given trial, letters were added until the word was completed correctly. On the next trial, one less letter of the word was provided than was required for a correct response on the preceding trial. Sessions were conducted twice weekly.

word was required for correct responding.

Patients seemed to experience particular difficulty producing the vocabulary items when the final letter was withdrawn. This observation was confirmed by further analysis of the patterns of letter reductions. The data of interest concern the number of trials required to make each of the reductions from *n* to *n-1* letters (i.e., from needing 6 letters to 5, from needing 5 to 4, etc.). Patients needed a mean of 1.9 trials to make each of the successive transitions down to the point at which one letter remained. They then took a mean of 8.4 trials to reduce from one to zero letters.

Transfer Production Test

The results of the transfer test, which was conducted several days after session 9, indicated that all patients correctly produced without letter cues some of the vocabulary words when the definitional cues were changed. Further, they produced more of the words originally learned by the method of vanishing cues than by the standard anticipation procedure. Patients correctly generated 51%

of the words from the vanishing cues condition that they had produced at the end of initial training, compared to 37% of words from the anticipation condition. The difference between these proportions, however, was not statistically reliable.

For words that patients failed to produce without letter cues, the proportions of letters that were needed for correct completion of the words were analyzed. In the anticipation condition, 47% of the letters were needed for correct completion; in the vanishing cues condition the proportion of letters used was 30%. This difference was reliable ($p<.01$).

Control group

As expected, the matched control group learned the vocabulary much more rapidly than did the memory-impaired patients. Whereas only two of the four memory-impaired patients were able to produce all of the vocabulary words by the end of eight sessions, two controls achieved perfect scores on production tests after two sessions, one needed three sessions, and one completed the training in five sessions.

Comparisons between the two training procedures – the method of vanishing cues and the anticipation procedure – revealed no differences on any of the test measures for the control subjects. There was no hint of an advantage for the method of vanishing cues, as had been observed in the memory-impaired group. Analysis of the patterns of letter reductions in the vanishing cues condition revealed that controls, like patients, showed a sharp decline in the number of letters required for identification of target words across trials of the first session. However, unlike patients, they did not experience extraordinary difficulties producing the vocabulary words when the final letter of the words was withdrawn. Controls required a mean of 2.3 trials to make the reduction from one to zero letters, compared with a mean of 1.2 trials to make the earlier reductions.

Results of delayed tests indicated that controls showed greater forgetting of the vocabulary across the 6-week retention interval than did patients, probably because they had received an average of only three learning sessions whereas patients completed eight. After a single re-learning session, however, performance of controls was again perfect. There were no differences between training conditions on delayed tests.

On the transfer production test, control subjects produced significantly more ($p<.01$) of the learned vocabulary words without letter cues on the first trial (.63) than did the memory-impaired patients (.44). The controls' superior performance on the transfer test was observed even though they had received fewer initial learning trials than had the memory-impaired patients.

DISCUSSION

The experiment described here has demonstrated that memory-impaired patients can learn new computer-related words and retain them over a 6-week interval. Acquisition of the new vocabulary was observed with both the method of vanishing cues and a standard anticipation procedure, but the vanishing cues procedure yielded higher levels of learning and retention than did the anticipation procedure. Consistent evidence of learning was observed in each patient, including two who had such severe memory disorders that they demonstrated little or no explicit recollection of their visits to the laboratory. Indeed, one patient (C.H.) claimed throughout the training sessions that he had never before worked on an microcomputer. Nevertheless, he was able to learn the definitions of 20 new computer terms and showed substantial retention over a 6-week interval.

In addition to increasing the rate of new learning for memory-impaired patients, the method of vanishing cues provided two other advantages over the anticipation procedure. First, all patients reported that they enjoyed the learning procedure when the method of vanishing cues was used. They generated a correct response on every trial, were encouraged by their success, and were eager to participate in the training. This feature of the vanishing cues procedure contrasted sharply with the anticipation procedure, during which patients frequently expressed discouragement and even anger at their many failures, and were often reluctant to continue. Second, words that were learned by the method of vanishing cues were more likely to be produced to the altered cues on the transfer task than were words learned by the anticipation procedure.

These observations provide some grounds for optimism regarding the acquisition of vocabulary in memory-impaired individuals, and document the usefulness of the vanishing cues procedure. However, other aspects of the results are more sobering. Although patients were able to acquire the new vocabulary, learning was slow relative to controls, and even after eight learning sessions, performance of two patients, C.H. and G.R., was not yet perfect. Patients' performance appeared to be limited by their strong dependence on first-letter cues for succesful production of words, a dependence that was not observed in control subjects. Memory-impaired patients were in addition decidedly less capable of responding with the learned vocabulary items when the nature of the cue was changed on the transfer test.

Our finding that memory-impaired patients could, albeit with some difficulty, acquire new vocabulary contrasts with the failure to observe such evidence in the study by Gabrielli et al. (1983). The use of the vanishing cues procedure may be partly responsible for the different results in the two studies, but the fact that we also observed reasonably consistent learning in the anticipation condition indicates that additional factors are involved. One such factor may have to do with patient differences. A second factor may be related to the fact that most of the to-be-learned responses in the present studies were part of patients' linguistic repertoire prior to the experiment (e.g., SAVE, RUN), whereas the words used by Gabrielli et al. (e.g., ANCHORITE) were not. Patients in the Gabrielli et al. study thus had to integrate the response terms, as well as associate them to their definitions. In contrast, our patients for the most part only had to establish an associative connection. A third possible factor, alluded to in the introduction, is that most of the words in our study had some sort of meaningful relation to their definitions (e.g., *to store a program*--SAVE), whereas no such relation was present in the materials used by Gabrielli et al. A fourth possible reason for the discrepant results is that in Gabrielli et al.'s study, the to-be-learned words were unrelated to one another. In our experiment, however, all words came from the same set of "computer-related" terms. Perhaps there are subtle cross-connections among items that are developed during learning, leading to the development of an integrated mental structure that facilitates acquisition and retention of individual components.

One of the puzzles posed by the present research concerns the reasons why the method of vanishing cues facilitated performance of memory-impaired patients. It is unlikely that the reinforcing aspects of the procedure can account for this result. Control subjects, too, found the method enjoyable and reinforcing, but they performed no better in the vanishing cues condition than they did in the anticipation condition. Similarly, it seems unlikely that the advantage of vanishing cues can be attributed to mnemonic benefits associated with generating the target response or engaging in increasingly difficult retrievals of the response. If such were the case, we would expect the performance of control subjects to be facilitated as well.

The benefits of the vanishing cues procedure may derive from its effects on a type of learning that is relied upon by memory-disordered patients but not by normal subjects. A striking characteristic of patients' performance is its rigidity and somewhat mechanical quality. As noted earlier, patients depended heavily on the presence of first letter cues for successful performance, and showed significantly less transfer than did controls. In addition, even when patients produced correct responses, they sometimes expressed surprise that they had provided the appropriate word, and appeared not to remember that they had seen the word before. These features of learning are in some respects similar to the kind of learning that has been observed in experiments concerning priming effects, which were mentioned in the introduction. After studying a list of common words or other familiar items, memory-disordered patients show an enhanced tendency to complete letter fragments with recently presented words (e.g., CHA ___ for CHAIR), even though they do not explicitly remember having studied the words (e.g., Diamond & Rozin, 1984; Graf & Schacter, 1985; Graf et al., 1984; Schacter, 1985-b; Shimamura & Squire, 1984; Warrington & Weiskrantz, 1970, 1974, 1978). Several investigators have suggested that priming effects and explicit remembering are mediated by independent underlying processes or systems (e.g., Cohen, 1984; Graf et al., 1984; Moscovitch, 1982; Schacter, 1985-a; Squire, 1982; Tulving, 1983; Tulving, Schacter, & Stark, 1982; Warrington & Weiskrantz, 1982). It is therefore possible that the learning exhibited by memory-impaired patients in the present study was mediated by processes that are distinct from those involved in explicit remembering, and that the vanishing-cues procedure tapped these processes more efficiently than did the anticipation procedure.

Although we cannot be entirely certain regarding the theoretical implications of our results, the finding that patients with different degrees of memory impairment can acquire and retain a small vocabulary of computer-related terms does have some practical implications. First, the vanishing-cues procedure might be useful in a variety of contexts to teach memory-impaired patients information that is necessary for performing particular tasks or functions in everyday life. Most investigators concerned with memory remediation have examined whether patients' mnemonic function can be improved in some general sense; less effort has been made to teach patients information that is needed for overcoming specific everyday problems (e.g., Schacter & Glisky, 1986; Wilson, 1982). The present results indicate that the vanishing-cues procedure is an enjoyable and effective technique that supports learning in patients with relatively "pure" memory disorders (i.e., C.H. and B.T.) and also in patients with cognitive and intellectual deficits (i.e., G.R. and H.D.). It thus seems reasonable to suggest that the technique has the potential for wide application.

A second practical implication of the vocabulary learning we observed is that an important condition for patients to benefit from a microcomputer has been satisfied. We do not yet know, of course, whether patients can use microcomputers as external memory aids. However, in extensions of this line of research (Glisky, Schacter, & Tulving, in press), we have employed the method of vanishing cues to teach patients how to use basic commands in the actual operation of a microcomputer, and have observed consistent evidence of learning on tasks that can be quite complex. Even our most severely impaired patient (C.H.) has now learned to perform a variety of disk storage and retrieval operations, can manipulate information on the screen, and can write and edit a simple computer program. These results provide further evidence that the vanishing cues procedure may be helpful for memory-impaired patients, and also provide some reason for expressing cautious optimism about the possible use of the microcomputer as a prosthetic device. A major task for future research will be to determine how patients can use their acquired knowledge of the computer to facilitate independence in day-to-day activities.

APPENDIX

LIST 1

HARDWARE	the computer and its physical devices
STRING	a sequence of characters
INPUT	information transferred to the computer from an external source
LOOP	a repeated portion of a program
MENU	a list of choices presented by a program
VARIABLE	a name assigned to a piece of information in a program
MEMORY	the computer's storage area
BASIC	a programming language
SAVE	to store a program
TEXT	information presented as readable characters

CATALOG	a disk's table of contents
PROCESSOR	it carries out instructions
REMARK	it describes what is going on in a program
DRIVE	it reads and writes information on a disk
LOAD	to transfer a program from storage to computer

LIST 2	
MONITOR	it displays information
INITIALIZE	to prepare a blank disk
OUTPUT	information transferred from the computer to an external device
FILE	a unitary collection of information on a disk
EDIT	to change or modify
SOFTWARE	programs that the computer carries out
CURSOR	the blinking symbol on the screen that marks typing location
ARRAY	a table of items
LOCK	to protect a file from being changed or erased
HOME	to clear the screen
GRAPHICS	information presented as pictures
SYNTAX	the structure of a computer command
MODEM	it transmits and receives information over a telephone line
BOOT	to start up the system
LIST	to display a program on the screen

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