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Transfer of New Learning in Memory-Impaired Patients*

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ABSTRACT

Previous research has produced conflicting evidence concerning transfer of new learning by amnesic patients. The present experiment investigated the hypothesis that different numbers of learning trials account for differences in transfer, such that the greater the number of repetitions of material in identical stimulus contexts the poorer the transfer. Six memory-impaired patients and six control subjects attempted to learn the names of business-related documents in response to descriptive definitions. Learning continued until one of the following criteria was reached: 50% correct, 100% correct, 100% correct plus 10 trials. In a transfer task, subjects were then asked to produce the target responses to altered definitional cues. The results of the experiment demonstrated that, contrary to prediction, transfer improved with numbers of learning trials. Results are consistent with the view that continued study of information allows better integration of new learning with prior knowledge and correspondingly higher levels of transfer. The theoretical implications of the findings are discussed in terms of the declarative/procedural and the episodic/semantic memory distinction. It is suggested that memory-impaired patients are capable of acquiring new semantic information although not at a normal rate. Implications for memory rehabilitation are also outlined.

Patients who suffer memory loss as a result of brain damage typically exhibit an inability to acquire new information. Recent experiments, however, have demonstrated that under appropriate learning conditions, amnesic patients are capable of acquiring considerable amounts of complex knowledge relevant to their functioning in everyday life – what Schacter and Glisky (1986; Glisky & Schacter, 1986) have termed domain-specific knowledge. A question of theoretical interest concerns whether the knowledge acquired by amnesic patients is qualitatively different from that acquired by normal subjects.

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In a series of experiments designed to teach amnesic patients computer knowledge, Glisky, Schacter, and Tulving (1986a, 1986b; Glisky & Schacter, 1988) demonstrated that, although patients were capable of acquiring new computer vocabulary and operating procedures, their learning was tightly bound to stimulus context and was not readily accessible to changed cues. Because transfer to new contexts was significantly poorer for amnesic patients than for normal subjects, Glisky et al. labelled patients' knowledge as "hyperspecific". Shimamura and Squire (1988), on the other hand, found that amnesic subjects were as likely as normal subjects to produce correct responses to paraphrases of sentences presented during initial learning. They concluded that, in their study, information acquired by amnesic patients was not hyperspecific but instead was qualitatively similar to information acquired by normal subjects and transferred normally across changes in sentence context.

There were a number of differences between the Shimamura and Squire experiments and the studies of Glisky et al. (1986a, 1986b) that might have accounted for differences in transfer. First, the materials to be learned in the Glisky et al. studies – computer vocabulary and computer procedures – were new. Subjects had no prior knowledge of the subject matter. Although some of the target words were familiar (e.g., load), their computer-related definitions (e.g., to transfer information from disk to computer) were unknown. Other words, such as modem, were completely novel. In the Shimamura and Squire (1988) study, the sentences to be learned described common everyday events, and although the final word was not predictable, it was a likely possibility (e.g., "At the fair, Sarah lost her *keys*"). Sentences were meaningful, describing life experiences that were familiar to subjects and were consistent with their knowledge of the world. Meaningful materials may be easily integrated with other knowledge and thus support better transfer than novel information.

A second difference between the two studies involved the learning or study procedures used. In the Glisky et al. experiments, learning was achieved by the method of vanishing cues, in which initial letters of target responses were provided as cues and then gradually withdrawn across trials. Shimamura and Squire used a standard study/test procedure.

Finally, the two studies employed different numbers of original learning trials. In the Glisky et al. experiments, patients were given many trials (e.g., 64 trials in the vocabulary study) to try to reach perfect levels of performance. Control subjects, on the other hand, reached criterion in many fewer trials; in the vocabulary study, for example, they received an average of 32 learning trials. Differences in performance on the transfer test between normal subjects and amnesic patients may thus have been a function of different numbers of learning trials (although both groups attained the same learning criterion). In the Shimamura and Squire study (i.e., Experiment 2), all subjects were given just 4 trials to learn the final word in 20 sentences. Control subjects acquired all of the words in two trials whereas patients had learned only 80% of the items after four trials. Performance levels of the two groups were equated prior to the transfer test by testing recall after different retention intervals. Good transfer performance in this study may have been attributable to the small number of learning trials. An explanation such as this was suggested by Shimamura and Squire (1988).

Shimamura and Squire proposed that the difference between the outcomes in their study and in the Glisky et al. studies may be accounted for in terms of differences between declarative and procedural knowledge. Amnesic patients are known to have great difficulty acquiring knowledge of facts – declarative knowledge – but are able to acquire, in a normal or near-normal manner, skills – that is, procedural knowledge. They speculated that extensive repetition of stimulus materials under identical encoding conditions (as occurred in the Glisky et al. experiments), may have encouraged the formation of an inflexible procedural memory representation that could not support good transfer. They further suggested that when only a few learning trials were provided as in their experiments, memory-impaired patients may have relied on residual declarative memory, which is thought to be flexible and capable of supporting good transfer (Squire, 1987).

Such an explanation could account for the finding in the Glisky et al. studies that degree of hyperspecificity was a function of severity of memory deficit. Patients with severe deficits may have little or no residual declarative memory and be forced to rely on procedural memory to acquire new knowledge. Less severely impaired patients may be able to make use of a damaged declarative memory thereby exhibiting less hyperspecificity. Differences in findings between the two experiments may therefore be partly a result of patient differences.

The Shimamura and Squire account is also consistent with Anderson's (1987) view of skill acquisition in normal subjects. Anderson, in his ACT* theory (1987; also Singley & Anderson, 1989), proposed that during the acquisition of skills, there is a gradual shift from reliance on declarative memory early in the process to proceduralization later in learning. Thus, good transfer is expected after a few learning trials when knowledge of the skill is still represented in declarative form, but poor transfer is expected after many repetitions when knowledge has become proceduralized. To the extent that knowledge acquisition by amnesic patients is accomplished through the procedural memory system, then the poor transfer in the Glisky et al. experiments could be attributable to a procedural representation of learning.

An alternative interpretation of the transfer results, which does not depend on the concept of procedural memory, is that repeated presentations of identical cue-target pairs may result in highly specific stimulus-response bonds that remain isolated from other information in the knowledge system. Because patients require many more learning trials than normal subjects to learn the definitions of new vocabulary, the stimulus response associations that they form may be less flexible than those of normal subjects, disconnected from other knowledge and thus incapable of supporting good transfer. If it is the case that specificity of acquired knowledge increases with number of learning trials, then one might predict that normal subjects would show similarly poor transfer with greater repetition of the stimulus materials. This notion is consistent with findings from classical paired associate learning experiments in which it was demonstrated that in an A-B, C-B paradigm, positive transfer decreased as degree of original learning increased (e.g., Bruce, 1933; Martin, 1965).

An alternative explanation of the hyperspecificity found in the Glisky et al. studies relates to the use of the method of vanishing cues. This procedure provides subjects with the initial letters of target responses and then gradually withdraws the letters across trials until subjects can produce target responses in the absence of letter cues. Many studies have demonstrated that amnesic patients are as likely as normal subjects to respond to partial cues with information that they have encountered previously, even though they may be unable to recall the prior experience (e.g., Cermak, Talbot, Chandler, & Wolbarst, 1985; Diamond & Rozin, 1984; Graf, Squire, & Mandler, 1984; Schacter & Graf, 1986; Shimamura & Squire, 1984; Warrington & Weiskrantz, 1968, 1974). This phenomenon is known as repetition priming. The method of vanishing cues, by providing partial letter information as cues for target responses, was designed to allow patients to take advantage of the same intact memory system or processes that mediate priming. Priming, however, has often been found to be highly specific, requiring representation of the perceptually identical stimulus in order to obtain effects (e.g., Graf & Ryan, 1990; Hayman & Tulving, 1989; Roediger & Blaxton, 1987), although exceptions to this finding have also been observed (e.g., Carr, Brown, & Charalambous, 1989). Thus, the findings of hyperspecificity in the Glisky et al. studies may have been obtained because learning was achieved through repeated priming. Patients may have been relying on highly specific perceptual representations of the material (Schacter, 1990; Tulving & Schacter, 1990) rather than on more abstract, meaningful representations. As noted previously, the lack of hyperspecificity in the Shimamura and Squire studies may have occurred because their patients relied on a damaged declarative memory system rather than on the more perceptually-based intact system that underlies priming.

The present experiment was designed to evaluate these various explanations of transfer effects. The stimulus materials – sentences concerning business-related documents – were chosen to represent domain-specific materials that might be encountered in a real vocational context. Although subjects may have had some general background knowledge about business procedures and forms, learning the names and functions associated with specific documents clearly required new learning. The task thus involved the acquisition of novel declarative or factual information. No learning or performing of procedures was required. In accordance with the suggestions of Shimamura and Squire (1988), it was hypothesized that transfer would be a function of the number of learning trials: the greater the number of trials, the stronger the stimulus-response bond, and the poorer the transfer. Because of its previous success as a teaching technique for amnesic patients, the method of vanishing cues was employed during study. If patients' learning under such conditions is accomplished solely through the perceptual memory system that mediates priming, transfer to semantically equivalent but perceptually dissimilar stimulus materials might be expected to be relatively poor independent of the number of prior learning trials.

METHOD

Design

This experiment was designed to examine the effects of different numbers of learning trials on subsequent transfer performance. A 2 X 3 mixed factorial design was employed. The between-subject factor was group: memory-impaired patients and normal control subjects. Three learning criteria were manipulated within subjects: 50% correct, which was referred to as underlearning, learning to one perfect trial, and overlearning, which consisted of 10 trials beyond the first perfect trial.

Subjects

Six memory-impaired patients and six normal control subjects participated in the experiment. The patients had suffered brain damage from a variety of etiologies including closed head injury, herpes encephalitis and aneurysm. Characteristics of the subjects along with relevant demographic information and test scores are summarized in Table 1. The mean IQ of the patient group on the Wechsler Adult Intelligence Scale-Revised (WAIS-R, Wechsler, 1981) was 100, which was in the Average range. The General Memory Index of 80, obtained from the WMS-R (Wechsler, 1987), indicated substantial impairment. Although all patients performed better on tests of intellectual ability than on measures of memory functioning, there was a wide range in the severity of their memory disorders. Two of the patients (J.F. and D.L.) had relatively mild impairments, two (C.C. and B.R.) had moderate deficits, and two (M.C. and J.L.) were severely impaired. The control group approximately matched the patient group in terms of age, education and current IQ and did not differ significantly on any of the measures except for general memory functioning.

All subjects attended 2-hr sessions, held twice weekly at the Amnesia and Cognition Unit, which is located in the Psychology Department of the University of Arizona.

Materials

Forty-eight business-related terms were selected to represent various procedures or departmental functions of a fictitious corporation. Definitional sentences of these terms were then constructed, each ending with one of the terms. By varying both the voice (active vs. passive) as well as key content words (by using synonyms), two alternative

Table 1. Descriptive Information and Selected Neuropsychological Data.

	Patients							Controls						
Subjects	JF	DL	CC	BR	MC	JL	$\bar{X}$	JB	DC	JS	BB	PC	PF	$\bar{X}$
Age	68	38	34	53	20	28	**40**	60	19	27	48	53	48	**42**
Education	14	19	14	12	12	14	**14**	12	13	16	15	12	15	**14**
WAIS-R FSIQ	119	130	94	103	78	77	**100**	104	106	103	104	101	110	**105**
WMS-R General MQ	97	106	72	93	57	58	**80**	130	113	132	120	122	104	**120**
WMS-R Delay MQ	103	96	67	62	<50	<50	**71**	121	133	134	123	108	98	**119**

sentences were created for each term. An example of an active sentence follows: "Before divisions initiate work on a new endeavor, they file a form called a(n) *PROJECT PROPOSAL*". The alternative version was formed in the passive voice, with synonyms replacing key content words: "Before effort is initiated on a new enterprise, divisions file a form called a(n) *PROJECT PROPOSAL*". The 48 terms were randomly divided into three groups of 16. Within each 16-item list, half of the sentences were in the active voice and half were in the passive voice. For each of these three lists a corresponding transfer list was derived from the alternate versions. All subjects were exposed to the lists in the same order, but across subjects, conditions were rotated through lists so that each pair of lists appeared in each condition an equal number of times, and each condition occurred equally often in the first, second, or third position in the learning sequence.

Procedure

Subjects' task was to learn the business terms, which were always the last words in a definitional sentence. They were required to learn three lists, one in each of the learning conditions. The procedure was the same in all conditions with the exception of the learning criterion. Subjects first learned a list to criterion (study/test phase), then received a transfer test with the alternate list (transfer phase), and finally "relearned" the transfer list to the same criterion (relearning phase). They completed all phases with one list before proceeding to the next condition/list.

The learning procedure involved a variation of the method of vanishing cues. Subjects were seated in front of an Apple IIGS microcomputer, next to an experimenter. Each trial proceeded as follows: the subject was presented with 16 sentences, one at a time, in random order. Sentences were presented with the to-be-learned term missing. After subjects read a sentence aloud, they were given 10 s to produce the correct response. Timing was controlled by the computer and was initiated by the experimenter with a key press. After 10 s the first letter of the target item appeared on the screen and the subject was instructed to try to generate the target item. Successive letters appeared every 10 s until either the subject provided the correct response or the term was fully spelled-out. Subjects were always provided with as many letter-hints as were needed to produce the correct response. Whenever the subject responded correctly, the experimenter pressed the return key and the full correct target item appeared on the screen for 10 s. The next sentence was then presented. After all 16 sentences had been exposed, subjects were given a cued-recall test in which the 16 sentence frames appeared on the screen one at a time with the final target item missing. Subjects were required to produce the missing word; no letter cues were provided. The purpose of this test was to assess when the appropriate criterion had been reached: 50% correct, 100% correct, 100% correct + 10 trials. It was not always possible for subjects to reach the 50% criterion exactly. The experimenter was required to make a judgement whether to present an additional learning trial. When criterion was reached, subjects were given an immediate transfer trial in which they were required to produce the target responses to the alternate forms of the sentences. They then continued "relearning" the transfer list, using the vanishing cues technique to the same criterion as the original list. In the 50% condition, subjects continued relearning until they responded correctly to the same items that constituted the original 50% learning criterion.

RESULTS

All patients were able to acquire the factual information to the specified criteria. Table 2 shows the number of trials to criterion for patients and control subjects in each of the learning conditions. For comparison purposes, the results for the overlearning condition do not include the 10 overlearning trials. The underlearning

Table 2. Number of Trials to Reach Learning Criteria.

Patients	Underlearning*	1 Perfect Trial	Overlearning**
JF	2 (8)	5	10
DL	2 (6)	11	9
CC	6 (7)	21	25
BR	6 (7)	16	13
MC	25 (8)	31	73
JL	10 (8)	53	41
$\bar{x}$	8.5 (7.3)	24.5	28.5
Controls			
JB	2 (7)	8	9
DC	2 (12)	4	4
JS	1 (10)	3	3
BB	1 (8)	9	4
PC	1 (7)	7	6
PF	2 (7)	6	10
$\bar{x}$	1.5 (8.5)	6.2	6.0

* Numbers in parentheses are actual numbers of items correct.
** Does not include 10 overlearning trials.

condition represents trials to reach 50% correct; the numbers in parentheses represent the actual number of items (out of 16) that were attained. Although we were not entirely successful in achieving exact 50% performance levels, the subject groups did not differ in the number of items acquired, t (10) = 1.28, $p >$ .22. A 2 X 3 ANOVA indicated that patients required significantly more trials than control subjects to reach criterion in all conditions, F (1, 10) = 6.86, $p < .03$. There was also a main effect of condition, F (2, 20) = 7.30, $p < .01$, but no Group X Condition interaction. Neuman-Keuls tests indicated that, not surprisingly, subjects required significantly fewer trials to learn 50% of the items than to learn all of the items. There was no difference between the other two conditions. Note also that all subjects required approximately three times as many trials to learn a complete list as they needed to learn the first half.

The results also suggest that severity of memory disorder was an important determining factor in trials to criterion. The mildly-impaired patients, J.F. and D.L., learned more quickly than the moderately-impaired patients, C.C. and B.R., who out-performed the severely-impaired patients, J.L. and M.C.

Results of the transfer task are summarized in Table 3. The dependent measure represents the proportions of responses produced to the original cues that were also produced to the transfer sentences. Patients achieved reasonably good transfer performance in this task, producing, on the average, 80% of the originally learned items to the changed sentence frames. Nevertheless, they performed

Tabel 3. Proportion of Responses Produced to Original Cues that were also Produced to Transfer Sentences.

	Underlearning	1 Perfect Trial	Overlearning
Patients	.56	.89	.95
Controls	.87	.95	1.00

more poorly than control subjects who produced 94% of the items to the changed cues. Most importantly, the results provided no evidence of poorer transfer with increased numbers of learning trials. On the contrary, both groups of subjects showed highest levels of transfer in the overlearning condition and lowest levels of performance following underlearning.

A 2 X 3 ANOVA confirmed a main effect of group, F (1, 10) = 10.6, $p < .01$, and a main effect of condition, F (2, 20) = 19.5, $p < .001$. There was also a significant interaction between these two factors, F (2, 20) = 5.83, $p < .01$. Patients were particularly disadvantaged in transfer following underlearning, where they were able to produce only 56% of originally learned responses compared to 87% for normal subjects. Tests of the simple main effects indicated that patients differed significantly from control subjects in the underlearning condition, t (10) = 2.98, $p < .02$, but not in the one perfect trial condition, t (10) = 1.48, $p > .17$. There was also a significant difference between groups, however, in the overlearning condition t (10) = 2.72, $p < .03$, attributable to the fact that all control subjects attained perfect performance, whereas only two of the patients performed perfectly.

The number of trials to relearn the transfer lists to original criterion showed a similar pattern of results: Control subjects required fewer relearning trials than patients; patients' performance was best in the overlearning condition. (Because of missing data for one patient, no analyses were performed on the relearning data.)

DISCUSSION

The present findings indicate that, contrary to our initial hypothesis, extensive repetition did not reduce transfer. Rather, transfer improved with number of learning trials. These results are thus inconsistent with theoretical accounts of learning by amnesic patients that suggest that the extensive repetition required for learning leads to the formation of inflexible procedural representations or rigid stimulus-response bonds that cannot support good transfer.

Instead, the findings suggest that, with repeated presentations, learning becomes more flexible and more accessible to changed cues. These results are consistent with the view that memory representations may become more elaborated with increasing study opportunities (cf., Bransford, Franks, Morris, & Stein, 1979). Elaborated representations are both more memorable (Craik & Tulving, 1975; Klein & Saltz, 1976), and also support better transfer (Bransford et al., 1979). When new material is first presented, it may be encoded rather directly with only weak connections to prior knowledge. Transfer is thus poor. With repetition, however, normal subjects may readily relate the new information to existing knowledge structures, thereby elaborating the new knowledge and increasing the probability of transfer. Amnesic patients, on the other hand, may have difficulty elaborating new information and associating it with prior learning, particularly early in the acquisition process (e.g., Cermak, 1979). They may be able to establish only simple stimulus-response bonds that remain isolated from prior knowledge and fail to support transfer. As learning progresses, however, with many repetitions of the material, patients may be able to begin to elaborate their representations with corresponding improvements in transfer.

The results of the present study do not provide sufficient evidence to conclude that transfer by amnesic patients is normal given sufficient learning experience. The transfer task in the present study was a relatively simple one and both groups of subjects showed nearly perfect transfer when all targets were recalled to original cues. This ceiling effect precludes any strong conclusions about the normality of patients' performance. A more difficult task might well have yielded differences in transfer between patients and control subjects. Nevertheless, the fact remains that the probability of transfer increased significantly with overlearning.

The same explanation, however, cannot account for the contradictory findings reported by Shimamura and Squire (1988) and Glisky et al. (1986a, 1986b): Shimamura and Squire found equivalent transfer for patients and control subjects after few learning trials, whereas Glisky et al. reported hyperspecificity of learning by patients after many trials. We speculate that the different outcomes in these studies may be attributable to the differences in meaningfulness of materials. Shimamura and Squire used sentences describing familiar everyday events, about which subjects would be expected to have considerable prior knowledge. Patients may have been able to elaborate these materials as well as normal subjects and thereby show equivalent transfer. In contrast, when learning computer vocabulary about which they had little or no prior knowledge, patients may have been unable to elaborate effectively in order to achieve good transfer. The materials used in the present study may be intermediate in familiarity between these two. Subjects might be expected to have some general knowledge about business documents and procedures based on their prior experience. This knowledge may have enabled elaboration late in the learning process after many repetitions. (Prior knowledge of materials was equivalent for patients and control subjects; both groups used the same numbers of letter cues to "guess" responses on the initial trial with each list.)

Memory-impaired patients in the present study appear to have acquired factual or declarative knowledge. How should this learning be characterized? Squire (1987) has suggested that amnesic patients are incapable of acquiring declarative knowledge, whether it be episodic (i.e., knowledge of a personal experience) or semantic (i.e., general information) as in the present case. Although procedural knowledge can be acquired normally by patients, the knowledge acquired in the present study does not appear to be procedural nor was it acquired normally. Furthermore, unlike procedural learning, it transferred reasonably well.

Glisky et al. (1986b) suggested that learning by the method of vanishing cues may be mediated by the same system that supports priming. Priming, however, has usually been found to be highly specific and incapable of supporting the kinds of transfer demonstrated here (e.g., Hayman & Tulving, 1989).

Other theorists have suggested that the amnesic deficit represents an impairment of episodic memory with a sparing of semantic memory (e.g., Kinsbourne & Wood, 1975; Shallice, 1988). Consistent with this view, Wood, Brown, and Felton (1989) reported the acquisition of new semantic information over a period of 11 years by a severely amnesic child. In a recent case study, Tulving, Hayman, and Macdonald (1991) demonstrated semantic learning by a severely amnesic patient. They concluded that meaningfulness of the materials to be learned was an important determinant of their patient's ability to achieve new semantic knowledge. The Glisky et al. computer learning studies (1986a, 1986b) and other demonstrations of the acquisition of job-related information by an amnesic patient (Glisky & Schacter, 1987, 1989) may also represent instances of new semantic learning. The hyperspecific nature of the knowledge acquired in these studies, however, seems inconsistent with characteristics normally attributed to semantic memory.

The findings in the present experiment, however, may represent acquisition of new semantic information, at least in the one perfect trial and overlearning conditions. Although acquisition is considerably slower in amnesic patients than in normal subjects, when presented for sufficient numbers of learning or overlearning trials, the new information may become increasingly well-integrated with prior knowledge so that better transfer to new situations and contexts is possible. In addition to the theoretical implications of these findings discussed above, there are also important applied or clinical implications (see also, Glisky, Schacter, & Butters, in press). Poor transfer or generalization of learning has plagued rehabilitation professionals in their attempts to train amnesic patients for real-world functional behaviors. The present results suggest that perhaps failure of transfer has been a consequence of too few learning trials. The findings also suggest that patients should be instructed or encouraged to relate new information that they are trying to acquire to prior knowledge in order to make the material more meaningful.

Finally, although an increasing number of studies seem to be indicating that acquisition of new semantic information by amnesic patients is possible, it is not yet established that the qualitative nature of the acquired knowledge is identical in amnesic patients and normal subjects. Further studies exploring the quality of new semantic learning in amnesic patients could provide important insights into the processes or systems involved in its acquisition.

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