

Independence of Recognition Memory and Priming Effects: A Neuropsychological Analysis

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In order to examine the relation between recognition memory and priming effects, we have tracked the recovery of recognition memory and word completion ability during the hours after individual treatment given as part of a prescribed course of electroconvulsive therapy (ECT). Recognition memory was tested by a three-alternative, forced-choice method. In the word completion test, the initial letters of previously presented words were given as cues, and subjects were asked to complete each cue to form the first word that came to mind. Patients receiving bilateral ECT markedly improved their recognition memory performance 45 min to 9 hr after treatment. Word completion performance was normal at 45 min after treatment and did not change thereafter. Despite exhibiting normal priming effects, patients prescribed bilateral ECT scored at chance levels on recognition tests given 45 min after treatment. These findings support the view that recognition memory and priming are independent memory processes, and they suggest that the processes that support priming make little if any contribution to recognition memory. The results are considered in terms of neuropsychological evidence from amnesic patients for the existence of multiple memory systems.

The study of human amnesia can provide useful information about the organization of normal memory functions (for reviews, see Baddeley, 1982; Cermak, 1982; Hirst, 1982; Squire, 1982a, Weiskrantz, 1982). Amnesia is associated with brain dysfunction involving the medial temporal region or the diencephalic midline, and amnesic patients are severely impaired on conventional memory tests that assess free recall, cued recall, or

recognition. The same patients, however, have a preserved capacity for learning perceptuo-motor, perceptual, and cognitive skills, such as mirror tracing (Milner, 1962), mirror reading (Cohen & Squire, 1980), and the solutions to certain puzzles (Cohen & Corkin, 1981). In addition, amnesic patients exhibit normal priming effects; that is, like normal subjects their performance on word completion tests or other word identification tests can be biased by prior exposure to test words (Graf, Squire, & Mandler, 1984; Jacoby & Witherspoon, 1982; Rozin, 1976; Warrington & Weiskrantz, 1970, 1974). In the word completion test, a subject is shown words (e.g., define) and then word stems (e.g., def-) that must be completed to form "the first words that come to mind." Both skill learning and priming effects can occur in amnesic patients without conscious awareness of prior study sessions; and without recognition, as mea-

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sured by formal tests, of the previously presented stimulus material.

These results have suggested a distinction between two memory systems. One system is impaired in amnesia and depends on the integrity of the damaged brain regions, and the other is intact in amnesia and is independent of these regions (Cohen, 1984; Squire & Cohen, 1984). We have developed these ideas in terms of a distinction between declarative and procedural knowledge. Declarative knowledge is available to conscious awareness and includes the facts, lists, and data of conventional memory experiments. Procedural knowledge is implicit and available only by engaging the specific operations in which the knowledge is embedded. Declarative knowledge is created by adding new data structures. Procedural knowledge is created by modifying, biasing, or combining preexisting representations. In the case of priming effects, preexisting (declarative) representations are activated in a way that temporarily biases behavior. However, the information acquired through activation is not declarative, in the sense that it is not available to conscious awareness. Priming effects may be a part of procedural knowledge, or they may deserve separate consideration, recognizing the differences between skill learning and priming.

Similar suggestions about memory systems have been made by others on the basis of work with amnesic patients, normal subjects, and experimental animals (skill vs. conscious recollection, Moscovitch, 1982; semantic memory vs. cognitive mediation, Warrington & Weiskrantz, 1982; horizontal vs. vertical associative memory, Wickelgren, 1979; taxon vs. locale, O'Keefe & Nadel, 1978; habit vs. memory, Mishkin, Malamut, & Bachevalier, 1984; integration vs. elaboration, Mandler, 1980).

A major question about any proposed classification or memory taxonomy concerns how the hypothetical components interact with and influence each other. We have considered here conflicting accounts of the relation between priming effects and declarative memory, specifically, recognition memory. On the one hand, some studies have emphasized the independence of these two kinds of memory by demonstrating how variables that markedly affect recognition memory do not affect priming (Graf & Mandler, 1984; Graf, Man-

dlar, & Haden, 1982; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982). A second argument for independence came from a study of recognition memory and word fragment completion (Tulving, Schacter, & Stark, 1982). In this study the ability to complete word fragments (e.g., a_a_in) was facilitated by prior exposure to the test words. Although recognition memory for test words declined over a 7-day period, there was no reduction in fragment completion. Moreover, when the recognition test preceded the word fragment test, fragment completion was stochastically independent of recognition memory. That is, the probability of completing a word fragment was the same whether or not that word had previously been recognized as familiar.

On the other hand, it has been possible to demonstrate parallel effects of certain manipulations on recognition memory tests and on tests that assess priming, such as word completion or word identification (Jacoby, 1983; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982). These results have suggested that the two kinds of memory are not independent and that one can influence the other. Mandler (1980) and Jacoby (1983) proposed specifically that the processes that support priming can also serve as a basis for recognition memory. Recognition memory thus depends in part on the ability to detect the familiarity of words, for example, the extent to which a word "appears to jump out from the page" (Jacoby, 1982, p. 113). By this view, subjects can note their own facility or fluency in perceiving familiar test words, and can then correctly attribute this increased fluency to prior exposure to the words.

Neuropsychological studies of amnesic patients provide a unique method for determining the relation between recognition memory and word completion ability. The nature of this relation could be illustrated by determining the kind of dissociation that occurs in amnesia between these two abilities. If recognition memory and word completion ability are independent and based on separate memory systems, then it should be possible for recognition memory to be at chance at the same time word completion ability is intact. However, if perceptual fluency of a word serves as one basis for recognition memory, then so long as word completion ability is

intact, recognition memory may be impaired, but it should not be at chance.

The present study determined the level of recognition memory and word completion ability in patients who exhibited amnesia during a prescribed course of bilateral ECT. ECT is known to cause anterograde and retrograde amnesia as a prominent side effect of treatment (Price, 1982; Squire, 1982b). Following a postictal confusional period of about 30 min, amnesia is present as a relatively circumscribed disorder. By 45 min after treatment, patients can score normally on tests of verbal intelligence (Squire, 1975; Squire, Slater, & Chace, 1975). Amnesia is more pronounced following bilateral ECT than it is following right unilateral ECT. The severity of amnesia cumulates across the individual treatments in a series and diminishes to some extent between treatments. By scheduling memory testing at different times after treatment, it is possible to demonstrate different severities of amnesia in the same group of patients (Squire & Miller, 1974; Zinkin & Birtchnell, 1968).

In the present study, we assessed recognition memory and word completion ability at different times after ECT. We reasoned that if priming could serve as a basis for recognition memory, then at that interval after ECT when word completion ability is intact, recognition memory should be present at above chance levels. Alternatively, if the two abilities are independent, then it might be possible to find recognition memory still at chance at a time after ECT when word completion ability is fully intact.

Method

Subjects

Patients receiving bilateral ECT. This group consisted of one man and five women (mean age = 52 years; mean education = 12.2 years) who were patients at one of three local hospitals and were receiving a prescribed course of bilateral ECT for relief of depressive illness. Three patients had received prior ECT treatment, from 4 months to 22 years previously. Treatment was given in the mornings three times a week (Monday, Wednesday, Friday), as described previously (Squire, Slater, & Miller, 1981). Patients were treated with a Medcraft B-24 device, and electrode placement was bitemporal.

Patients receiving right unilateral ECT. This group consisted of four men and two women (mean age = 51 years; mean education = 15.6 years) who were patients at one of two local hospitals and who were receiving a prescribed course of right unilateral ECT for relief of

depressive illness. All patients were right-handed. None of the patients had received ECT previously. Right unilateral ECT was given in the same manner as bilateral ECT, except that both electrodes were positioned over the right side of the head in a frontal-parietal or frontal-temporal configuration. Patients were treated with a Medcraft B-24 device.

Normal control subjects. This group consisted of seven men and one woman (mean age = 44 years; mean education = 13.3 years) who were hospital volunteers, employees, or inpatients at the San Diego Veterans Administration Medical Center.

Materials

We selected 100 target words from Webster's Pocket Dictionary (average frequency of occurrence per million = 40, Kucera & Francis, 1967) and printed them individually on index cards in 12-mm high capital letters. Each word was four to nine letters long. The first three letters of each word, the stem of the word, were common to at least 10 other dictionary entries, but each word selected for the experiment had a different stem. The 100 target words were randomly assigned to 10 different learning lists of 10 words each. In addition we selected 220 words, 4 to 10 letters long, matched in frequency with the 100 target words. Two hundred of these words were used as distractor words on tests of recognition memory, and the other 20 formed a pool of filler words. Filler words were used at the beginning and end of the learning lists to prevent primacy and recency effects. None of these words began with the same three letters as the 100 target words.

Testing Schedule

Testing occurred on three different days during the course of bilateral or unilateral treatment. The three test days were scheduled on three consecutive treatment days when patients were receiving their third, fourth, fifth, or sixth ECT treatments. Testing began on the day of the third or fourth treatment of the series and continued on the days of the next two prescribed treatments. On the first and third days of testing, we assessed word completion ability on three occasions during the hours after ECT. On the second day of testing, we assessed recognition memory on four occasions during the hours after ECT. Thus, there were 10 test conditions for each patient, 6 for assessing word completion and 4 for assessing recognition memory. The 10 learning lists were counterbalanced across these 10 test conditions.

For testing word completion on Days 1 and 3, the study/test trials began at 45 min, 65 min, and 85 min after bilateral or right unilateral ECT. For testing recognition memory on Day 2, the study/test trials began at 45 min, 65 min, 85 min, and 9 hr \pm 1 hr after ECT. For practical reasons, the actual time that testing began sometimes differed from the scheduled time by a few minutes, but 68% of all testing occurred within 2 min of the scheduled time, and the largest discrepancy for any subject was 12 min. One patient receiving right unilateral ECT discontinued treatment after the 2nd test day; this patient's word completion scores were based on the three tests given on Day 1.

For control subjects there were four test conditions, three for assessing word completion during one day, and one for assessing recognition memory on the following day. On the same day that recognition memory was

assessed, the six learning lists that had not yet been given to the control subjects were used to obtain a baseline for word completion. To obtain the baseline, the control subjects were given 60 word stems from the six unused learning lists and were asked to complete them to form the first words that came to mind. The probability of generating words from the learning lists provided a measure of baseline or chance performance. This measure was also used to assess baseline performance for the patient receiving ECT because the 10 test conditions given to these patients exhausted the available target words. On the basis of previous work (Graf et al., 1984), we expected the baseline performance of ECT patients and control subjects to be nearly identical.

Procedure

Subjects were first instructed in a study task that they would engage in during presentation of the word lists. Words were presented on index cards, and subjects read each word and rated it on a 5-point scale according to how much a word was liked or disliked. Subjects were given enough time with each word to provide a rating, usually about 5 s per word. To facilitate the rating judgment, an index card showing the numbers from 1 (*dislike extremely*) to 5 (*like extremely*) was displayed continuously in front of the subjects. The ratings were recorded by the examiner. The same method was used for presenting all 10 word lists.

To assess word completion, a learning list of 10 words (plus three filler words at the beginning of the list and two at the end) was presented once while subjects rated the words. Then after 15 min, during which the subject was free to engage in other activities, subjects were shown 10 three-letter word stems printed individually on index cards, and were told that each cue was "the beginning of an English word. Complete these letters to make a word. You can say any English word—but say the first word that comes to mind." Subjects were encouraged to say the first word to come to mind, except for proper nouns. Subjects were given as much time as they needed to complete each word, though no subject ever required more than 15 s. When a proper noun was generated, the experimenter asked for an alternative completion. After all 10 word stems were completed, a second learning list was presented at its scheduled time in the same manner as the first, and it was followed 15 min later by another word completion test. Finally, the third learning list of the day was presented at its scheduled time, and word completion was again tested 15 min later.

For patients receiving bilateral or unilateral ECT, the time of testing was determined by the time of the ECT treatment, as described earlier (testing began 45 min, 65 min, and 85 min after ECT). For control subjects, three word-completion tests were scheduled on a single day, so that the time between successive list presentations (20 min) and the presentation test interval (15 min) was the same as for patients receiving ECT.

To assess recognition memory, a learning list of 10 words (plus three filler words at the beginning of the list and two at the end) was presented once using the orienting task. Then 15 min later, subject were shown groups of three words on index cards, one word from the presentation list and two distractor words. Subjects were instructed to "pick out [from each group of three words] the word that I showed you on a card, even if

you have to guess." Subjects were given as much time as they needed to make their choices. After the first recognition memory test was completed, a second learning list was presented at its scheduled time in the same manner as the first, and it was followed 15 min later by another recognition memory test. In all, a total of four tests of recognition memory were given, beginning 45 min, 65 min, 85 min, and 9 hr \pm 1 hr after ECT. Two patients receiving right unilateral ECT did not receive the 9-hr test, so the data for this time point were based on the scores of four patients. For control subjects, recognition memory was tested only once on the day after the word completion tests. The procedure for the control subjects was identical to the procedure used for the patients.

Results

Figure 1 shows performance on three-alternative, forced-choice word recognition (left panel) and on word completion (right panel) by patients prescribed bilateral or unilateral ECT and by control subjects not receiving ECT. Overall word completion performance across all subjects (mean = 29.7%) was significantly above the baseline score obtained from control subjects (9.8%). The main findings were that the three groups performed similarly on the word completion test, but patients receiving bilateral ECT were severely impaired on the tests of recognition memory. All statistical comparisons reaching the .05 level were considered significant.

The completion test results for the two groups receiving ECT were the same on test days 1 and 3, $F(1, 9) = .58$, $MS_e = 4.52$, so these scores were combined in subsequent analyses. To score the completion test, we counted the number of target words that subjects produced while completing the test cues. The mean number of target words produced by patients prescribed bilateral ECT, patients prescribed unilateral ECT, and control subjects were 3.34, 2.64, and 2.88, respectively. An analysis of variance (ANOVA) showed no significant effect of subject group, $F(2, 17) = .50$, $MS_e = 4.61$, or time of study, $F(2, 34) = .23$, $MS_e = 1.49$, and no significant Group \times Time of Study interaction, $F(4, 34) = .68$, $MS_e = 1.49$. Chance or baseline performance obtained from the control subjects was 9.8% (.98 words). This value corresponded closely to previous values obtained with these same learning lists for amnesic patients, including patients receiving ECT, and control subjects (range = 8.2% to 11.7%, Graf et al., 1984). These values were based on the performance of 35 subjects, each of

whom completed 40 word stems. Accordingly, in this study 9.8% was taken as the guessing baseline for all subjects. All three subject groups exhibited a completion ability that was above the baseline ($t_s > 3.9$).

The recognition test results were examined in an ANOVA involving the two groups receiving ECT and four ECT test intervals. For this analysis, the two patients prescribed unilateral ECT who did not receive the fourth (9 hr) test were assigned the score that they had received on the third (85 min) test. There were significant effects of group, $F(1, 10) = 27$, $MS_e = 4.1$, time of study, $F(3, 30) = 6.9$, $MS_e = 1.53$, and a Group \times Time of Study interaction, $F(3, 30) = 3.8$, $MS_e = 1.53$. Newman-Keuls analyses showed that patients prescribed bilateral ECT were impaired at the first three testing times (45 min, 65 min, and 85 min after treatment). Furthermore, at 45 min after ECT, recognition performance of patients prescribed bilateral ECT was not significantly different from the chance value of 33% correct, $t(5) = .9$. By 65 min after

treatment, the anterograde amnesia had diminished to some degree $t(5) = 1.79$, and by 85 min after treatment the recognition score of these patients was significantly above chance, $t(5) = 5.1$, $p < .01$.

Control subjects were given a single recognition test using the same word sets and instructions that were given to the patients receiving ECT. This group provided a normal score by which to judge whether by 9 hr after treatment the patients receiving ECT had recovered their recognition memory ability. There was no significant group effect when the performance of control subjects was compared with the results for the 9-hr test condition for the two groups prescribed ECT, $F(2, 15) = 2.36$, $MS_e = 2.13$. However, a Newman-Keuls analysis showed that the patients receiving bilateral ECT performed worse than the control subjects, $P < .05$.

Discussion

Amnesic patients have been shown previously to exhibit normal priming, despite being

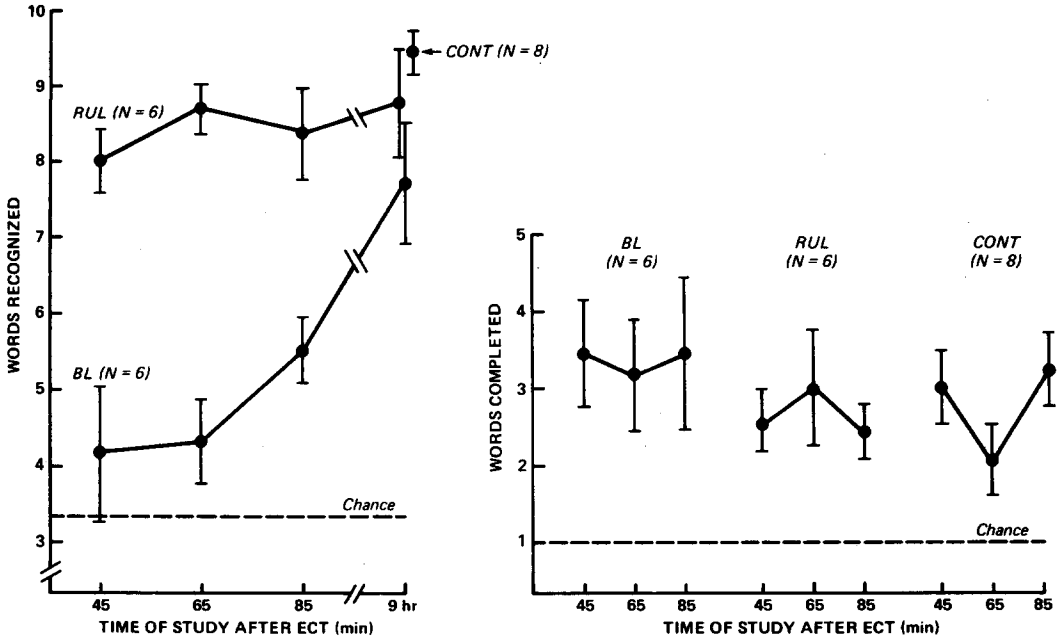


Figure 1. Recognition memory (left panel) and word-completion performance (right panel) as a function of time tested after electroconvulsive therapy (ECT). (For each test, 10 target words were presented in a semantic orienting condition, and a 3-choice recognition memory test or a word completion test was given 15 min later. The control subjects did not receive ECT, but the interval between their word completion tests was identical to that of the ECT patients. Control subjects were also tested once on recognition memory. BL = bilateral ECT; RUL = right unilateral ECT; CONT = control subjects. Error bars show standard errors of the mean.)

severely impaired on tests of recognition memory (Graf et al., 1984; Jacoby & Witherspoon, 1982). That finding is consistent with the idea that these two tests reflect the operation of separate memory systems, but it left open the possibility that recognition memory performance may ordinarily derive some benefit from the same process that supports priming.

The present study tracked the recovery of word completion ability and recognition memory during the hours after individual treatments given as part of a prescribed course of ECT. Word completion ability was fully intact as early as 45 min after bilateral ECT. Yet at this same time, recognition memory was not significantly above chance levels (chance = 3.3 words), and three of six patients obtained a score below 3.3. We were also able to examine some additional data obtained during preliminary studies of this problem while determining the appropriate temporal parameters for our formal tests. Including the six patients reported here, we obtained word completion and recognition memory data for 13 patients at 45 min after bilateral ECT. The combined word completion score was $2.62 \pm .40$, and the combined recognition memory score was $3.8 \pm .60$. This word completion score was significantly above baseline, $.98 \pm .14$; $t(19) = 3.1$; and it was not significantly different from the word completion score obtained by patients tested 45 min after right unilateral ECT, $2.5 \pm .37$; $t(17) = .18$, or from the score obtained by control subjects on their first test, $3.0 \pm .46$; $t(19) = .61$. In contrast, the combined recognition score ($3.8 \pm .6$) was still not significantly above chance, 3.3; $t(12) = .82$. The median recognition score of all 13 patients was 3, and 7 scored below chance (chance = 3.3). Of course, the group recognition scores we obtained were numerically greater than the chance value of 3.3, and it is possible that recognition performance would have exceeded chance levels significantly if a larger number of subjects had been tested. Nevertheless, it seems fair to conclude that amnesic patients can perform close to chance despite a normal capacity for priming. Accordingly, in amnesic patients the processes that support priming have little and perhaps no influence on recognition memory ability.

The priming and recognition memory findings presented in this study, seem related to the learning of skills and procedures, which are also intact in amnesia and independent of recognition memory (Cohen, 1984; Squire & Cohen, 1984). Recently, in a study of retrograde we found that patients who learned to read mirror-reversed text prior to receiving bilateral ECT subsequently showed an entirely preserved ability to mirror read, but performed at chance when trying to recognize the particular words they had read (Squire, Cohen, & Zouzonis, 1984). Kolers (1976) has reported some similar data for college students reading transformed text after a 1-year delay. Thus, we suppose that the processes underlying skill learning, like those underlying priming, are independent of recognition memory and normally make little if any contribution to recognition memory performance.

Several writers have proposed that the processes underlying priming (Mandler, 1980; Jacoby, 1983) or skill learning (Kolers, 1975, 1976) provide for a kind of fluency or familiarity that can support recognition performance. This view is contradicted by our present finding, and it also seems at odds with our observations of amnesic patients of various etiologies over the past decade. Amnesic patients do not express feelings of familiarity toward recently encountered people, places, or objects, and they are not commonly in a tip-of-the-tongue memory state where they recognize an event as familiar without being able to identify it exactly. It is far more common that they deny feelings of familiarity altogether.

Most amnesic patients cannot provide a clear test of the issue addressed here. Word completion ability, as measured by the tests used in this study, persists for only about 2 hr after list presentation (Graf & Mandler, 1984; Graf et al., 1984), and most amnesic patients are not impaired to the extent that their recognition memory would fall to chance during this interval. With such patients it would therefore be difficult to determine whether recognition memory is above chance because amnesia is not sufficiently severe or because recognition is being supported in part by priming. However, case H.M., the

celebrated patient who became amnesic following bilateral resection of the medial temporal region (Scoville & Milner, 1957), is severely amnesic; and in the extensive literature involving this case one can find examples of his recognition ability falling to chance in a minute or less (Prisko, 1963; Sidman, Stoddard, & Mohr, 1968). Moreover, in one study of priming involving perceptual identification of previously presented words, his recognition memory was at chance one day after learning when measurable priming effects could still be demonstrated (Nissen, Cohen, & Corkin, 1981).

In summary, patients receiving ECT markedly improved their ability for recognition memory during the period 45 min to 9 hr following bilateral treatment. Yet priming effects were present at full strength as early as 45 min after treatment and did not change thereafter. The crucial observation was that at 45 min after ECT, despite exhibiting normal priming, patients scored no better than chance on tests of recognition memory. These findings provide a further demonstration that recognition memory and priming can behave independently, and they show that the processes underlying priming make little if any contribution to recognition memory. This conclusion is limited to verbal material presented on a single occasion and does not rule out the possibility that a different relation between recognition memory and priming might be found by using other kinds of materials or by special training techniques. These possibilities are relevant to issues of rehabilitation with amnesic patients. The results also do not rule out the possibility that priming could contribute to recognition memory in normal subjects, though not in amnesic patients. One possibility is that priming is a necessary condition for recognition memory but is not by itself sufficient to support recognition performance.

The results support the formulation, developed in detail elsewhere (Cohen, 1984; Squire & Cohen, 1984), that the brain has organized its information processing capacity around distinct memory systems. One of them, termed declarative, supports the learning of new episodic and semantic knowledge and depends on the integrity of the brain regions damaged in amnesia. Skill learning

and priming are independent of these brain regions.

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