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The Neuropsychology of Memory Illusions: False Recall and Recognition in Amnesic Patients

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Memory illusions have been explored extensively in cognitive studies of normal memory, but hardly at all in neuropsychological research with amnesic patients. The present experiment examined false recall and recognition of nonstudied words that are preceded by a list of strong associates. We used the Deese (1959) paradigm, recently revived by Roediger and McDermott (1995), in which people frequently claim that nonstudied words appeared on a presented list. Results showed that amnesic patients were less susceptible to false recognition than were matched controls and showed different patterns of false recall. To account for the observed differences between amnesics and controls, we suggest that false recognition of nonstudied words preceded by numerous associates depends on the same kinds of semantic and associative information about study list words that also supports accurate recognition. Amnesic patients do not retain such information, resulting in poor recollection of study list words and decreased susceptibility to false recognition.

Despite a century's worth of psychological research concerning memory distortions and illusions (Ceci & Bruck, 1993; Schacter, 1995a) and scattered observations of confabulations and related false memories in brain-damaged patients (Johnson, 1991; Moscovitch, 1995; Schacter & Curran, 1995), theoretical understanding of memory illusions has been almost entirely uninformed by neuropsychological observations. This contrasts sharply with other sectors of human memory research, where neuropsychological studies of amnesic patients have had a profound impact on theorizing about normal memory. Findings of spared implicit memory in patients with impaired explicit memory have led to numerous proposals about dissociable memory processes and systems (cf., Bowers & Schacter, 1993; Cermak & Verfaellie, 1992; Cohen & Eichenbaum, 1993; Johnson & Chalfonte, 1994; Moscovitch, 1994; Schacter, Chiu, & Ochsner, 1993; Shimamura, 1986; Squire, 1992; Tulving & Schacter, 1990), and demonstrations of temporal gradients in retrograde amnesia have illuminated the nature of consolidation processes (e.g., Cohen & Eichenbaum, 1993; McClelland, McNaughton, & O'Reilly, 1995; Squire, 1992).

These and other areas in which studies of amnesia have influenced the analysis of normal memory are all characterized by a com-

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mon feature: empirical and theoretical attention focuses on the *quantity* of information that amnesic patients and control subjects do or do not remember. On explicit tests of memory for recent experiences, amnesic patients remember less than do control subjects, whereas on implicit tests they produce similar numbers of study-list items. In studies of retrograde amnesia, inferences are based on the amount of information that patients and controls recall from different time periods.

Koriat and Goldsmith (1994, in press) have recently characterized this emphasis on the quantity of retained information as an expression of a ‘‘storehouse’’ metaphor of memory. Koriat and Goldsmith point to the existence of an alternative *correspondence* metaphor that focuses less on the amount retained and more on the qualitative characteristics of what people remember—how well memory corresponds to reality. This metaphor originated in the work of Bartlett (1932), and continued in the research of psychologists who focused on such issues as eyewitness testimony, where the qualitative correspondence between what a person remembers and what actually happened is more important than the sheer amount of remembered material (e.g., Loftus, 1979; Wells & Loftus, 1984).

Studies of memory illusions and distortions are closely tied to a correspondence metaphor of memory. During the 1970s, many cognitive psychologists focused intensively on investigating various kinds of memory distortions, including errors attributable to schema-based inferences (e.g., Sulin & Dooling, 1974), abstraction and generalization processes (e.g., Bransford & Franks, 1971), and misleading suggestions (e.g., Loftus, Miller, & Burns, 1978). More recently, memory illusions and distortions have become the subject of renewed interest, in part because of real-world controversies about the accuracy of traumatic memories recovered in psychotherapy (cf., Herman & Harvey, 1993; Lindsay & Read, 1994; Loftus, 1993; Ofshe & Watters, 1994; Schacter, 1995b, 1996) However, this correspondence-oriented research has had little effect on, and has been almost entirely uninfluenced by, studies of amnesic patients—in sharp contrast to the extensive interactions that have characterized quantity-oriented research.

One of the few attempts at examining memory distortion in amnesic patients is found in a study of false recognition reported by Cermak, Butters, and Gerrein (1973). Cermak et al. used the false recognition paradigm developed by Underwood (1965), in which lure items on a continuous recognition test are preceded either by unrelated words or by words that bear an associative, semantic, or physical relation to the lure. Underwood reported a modest but significant increase in false alarms to related lures in comparison to unrelated lures. In the Cermak et al. study, Korsakoff amnesics and controls encountered four different types of lures: unrelated, associates (e.g., table–chair), synonyms (e.g., robber–thief), and homophones (e.g., bear–bare). Amnesic patients produced significantly more false alarms to associates and homophones than did control subjects, and they also showed a slight, nonsignificant trend for more false alarms to synonyms and unrelated words.

We will say more about these results later (see General Discussion), but for now we note that the Cermak et al. data suggest that amnesic patients are sometimes more prone to false alarms than are nonamnesic controls—that is, not only do amnesic patients remember less than controls do, but what they claim to remember may also be less accurate than what nonamnesic individuals claim to remember. Other studies of recognition memory have shown that amnesics sometimes exhibit a higher false alarm rate than control subjects even to nonstudied words that have no particular relation to studied words (e.g., Knowlton & Squire, 1995; Verfaellie & Treadwell, 1993; for discussion, see Roediger & McDermott, 1994). Together with their reduced hit rates, the elevated false alarm rates of amnesic patients in the latter studies may reflect an inability to discriminate between studied and nonstudied items, resulting in haphazard guessing. This pattern is similar to the mirror effect in recognition exhibited by normal subjects, where manipulations that lower hit rates tend also to increase false alarm rates (e.g., Glanzer & Adams, 1990).

Evidence that amnesic patients sometimes make more false positive responses than control subjects raises the possibility that they might be unusually susceptible to memory illusions that are expressed by false alarms to nonstudied items. Consistent with this idea, Reinitz, Verfaellie, and Milberg (1996) report that amnesic patients are more prone than controls to false alarms based on illusory memory conjunctions, where subjects claim to have seen a new stimulus when in fact they have seen only its component features (Reinitz, Lammers, & Cochran, 1992), and Kroll, Knight, Metcalfe, Wolf, and Tulving (1996) report similar findings in patients with left, right, or bilateral hippocampal damage.

Roediger and McDermott (1995; see also Read, 1996) have recently found another striking memory illusion. Using a paradigm developed initially by Deese (1959), Roediger and McDermott presented subjects with lists of words that are all strong associates of a critical, nonpresented word. For example, when the nonpresented word was *sleep*, the presented list of associates consisted of *bed, rest, awake, tired, dream, wake, night, blanket, doze, slumber, snore, pillow, peace, yawn,* and *drowsy*. Following presentation of a series of such lists, subjects were given a free recall test and a yes/no recognition test. Roediger and McDermott, like Deese, found that subjects often intruded the nonpresented word on a free recall test. In addition, they found that subjects made an extraordinarily high number of false alarms to critical lures such as *sleep* on the recognition test. In one experiment, for example, the hit rate for studied items was .79 when the recognition test was preceded by a recall test and .65 when the recognition test was preceded by unrelated distractor activity. The corresponding false alarm rates to critical lures were actually higher than the hit rates—.81 and .72, respectively. Subjects expressed high confidence in their false alarms; indeed, they were just as confident about their false alarms to critical lures as they were about their hits to studied words. In addition, subjects were asked to make remember/know judgments about studied and nonstudied words, where a ‘‘remember’’ response indicates that subjects possess a specific, vivid recollection of having encountered a word during the study list, and a ‘‘know’’ response indicates that word just seems familiar (cf., Gardiner & Java, 1993; Tulving, 1985). Roediger and McDermott found that subjects often claimed to remember having encountered the critical lures on the study list. In fact, subjects provided remember responses to critical lure words just as often as they provided remember responses to studied words.

In the present experiment, we examined whether amnesic patients are also subject to the memory illusions embodied in false recall and recognition of nonpresented associates such as *sleep*. On the one hand, the observed tendency of amnesic patients to false alarm more often than control subjects in some conditions leads to the prediction that they would be especially susceptible to this memory illusion. On the other hand, however, false recall and recognition of critical lures in the Roediger and McDermott paradigm might depend on very different processes than those that underlie false alarms in other situations. Specifically, false recall and recognition of words such as *sleep* may depend on retaining and remembering associative or semantic information about the list of presented words. If it does, then amnesic patients may be less prone to false memories of *sleep* because they may fail to remember the semantic or associative information that ordinarily misleads non-memory-impaired subjects into claiming that they remember something that never happened.

To examine these possibilities, we exposed amnesic patients and control subjects to a series of lists containing strong associates of a nonpresented critical word. Immediately after presentation of half the lists, patients and controls attempted free recall; after the other half of the lists, they carried out unrelated arithmetic problems. Finally, all subjects were given yes/no recognition tests for studied words, critical lures, and unrelated lures. In addition to indicating whether a word had appeared previously on a study list, subjects also indicated whether they actually remembered the prior presentation of the words or whether they just knew that the word had been presented previously.

METHOD

Participants. Twelve amnesic patients (10 male, 2 female) and 12 individuals with intact memory functioning (10 male, 2 female) participated in the experiment. The amnesic patients had all been screened at the Memory Disorders Research Center of the Boston VAMC. Six patients had a diagnosis of alcoholic Korsakoff syndrome and 6 patients had a variety of nonalcoholic etiologies (anoxia, encephalitis, thalamic infarct). Because the alcoholic and nonalcoholic amnesics performed similarly on the experimental task, they are further treated as a single amnesic group. They had a mean age of 57.2 years and an average of 13.5 years of education. Their overall level of intellectual functioning was in the average range, as indicated by a mean Verbal IQ of 98.9 on the Wechsler Adult Intelligence Scale—Revised. Likewise, their attentional capabilities were intact, as indicated by a mean score of 103.8 on the Attentional Index of the Wechsler Memory Scale—Revised (WMS-R). In contrast, they consistently exhibited severe deficits on a variety of explicit memory tasks. On the WMS-R, they obtained a mean General Memory Index of 82.1 and a mean Delayed Memory Index of 58.5. Details on individual patients are presented in Table 1. The control group consisted of 12 individuals who were matched to the amnesics in terms of age, education and overall level of intelligence. Six of these individuals had a history of alcoholism and the other 6 had no history of alcoholism. Their mean age was 52 years; they had an average of 13.4 years of education and a Verbal IQ of 107.7.

Materials. The target materials consisted of 24 lists of 16 words, identical to those used by Roediger and McDermott (1995). Each list contained 15 words to be presented for study and a target word (critical lure) that was not presented for study. The study words were all highly associated to the critical lure and were ordered such that the strongest associates occurred first in the list. The 24 lists were subdivided into three sets for counterbalancing purposes.

Design and procedure. All participants were tested in two conditions, a Study + Recall condition and a Study + Arithmetic condition, which were administered in two sessions separated by at least 1 week. Half of the subjects received the Study + Recall condition during the first session and the Study + Arithmetic condition during the second session. For the other half of the participants, this order was reversed.

A set of eight lists was used in each condition. The remaining eight lists were not studied. Four of these appeared on the recognition test that accompanied the Study + Recall condition, whereas the other four appeared on the recognition test that accompanied the Study + Arithmetic condition. Lists were counterbalanced so that they were used equally often in the Study + Recall condition, in the Study + Arithmetic condition, and as nonstudied lists. Nonstudied lists were counterbalanced across the two recognition tests. All participants were tested individually. Before presentation of each study list, they were told that a series of words would be presented via a tape player and that they should try and remember the words. The words were recorded in a female voice and were presented at a rate of approximately 1.5 s per word. Immediately following presentation of a study list, participants were asked to say out loud as many of the words as they could remember (Study + Recall condition) or to perform simple addition and multiplication problems (Study + Arithmetic condition). Approximately 1 min was given for either of these tasks, after which the next study list was presented. Eight study lists in the same condition (Study + Recall or Study + Arithmetic) were presented during a single session. Presentation of all eight study lists took approximately 20 min.

The recognition test was administered ap-

TABLE 1

CHARACTERISTICS OF AMNESIC PATIENTS

			WMS-R		
Etiology	Age	VIQ	GM	ATT	DLY
Korsakoff	67	93	76	109	62
Korsakoff	60	90	99	99	61
Korsakoff	73	123	104	116	56
Korsakoff	66	88	76	96	53
Korsakoff	68	87	82	93	60
Korsakoff	64	83	66	99	<50
Anoxia	57	109	65	89	61
Encephalitis	44	111	81	107	69
Anoxia	31	95	65	120	<50
Anoxia	36	95	90	115	<50
Encephalitis	67	126	102	114	<50
Thalamic	53	87	70	89	80
Mean	57.2	98.9	82.1	103.8	58.5

Note. VIQ, Verbal IQ from the Wechsler Adult Intelligence Scale (Revised); WMS-R, Wechsler Memory Scale-Revised; scores are presented separately for the indices of General Memory (GM), Attention (ATT), and Delay (DLY).

proximately 2 min after completion of the recall or arithmetic task that followed the final study list. Participants were presented with a list of words and were asked to indicate for each word whether or not it had been presented on one of the audiotapes. In case they thought a word had previously been presented, they were then asked to indicate whether they remembered or knew the word. Instructions for the remember/know judgment were similar to those used by Roediger and McDermott (1995). Participants were told that a remember judgement should be made if they could specifically recollect hearing a word on the tape recorder. It was explained that such recollection might include remembering something about the speaker's voice or about the thoughts they had when they heard the word. They were told that a know judgement should be made if they felt or knew that a word was presented earlier on the tape recorder, but if they could not recollect anything specific about the word or its occurrence.

The recognition test contained 48 words, 24 studied words and 24 nonstudied words. The studied words were obtained by selecting for each of the eight study lists the items in serial positions 1, 8, and 10. The nonstudied words consisted of the critical lures corresponding to each of the eight studied lists, the critical lures corresponding to four nonstudied lists, and the items in serial positions 1, 8, and 10 of these nonstudied lists.

RESULTS

Free recall. We first analyzed the mean proportion of study list words and critical lures produced by amnesic patients and control subjects on the free recall test, averaged across the eight target lists. As expected, amnesic patients recalled on average a much smaller proportion of study list words (.27) than did controls (.52), $t(22) = 5.10$, $p < .0001$. In addition, amnesics intruded a nonsignificantly smaller proportion of critical lures (.29) than did controls (.33), $t(22) < 1$. Thus, amnesics produced about the same proportion of study list targets and critical lures (.27 vs .29), whereas control subjects recalled significantly more study list targets than critical lures (.52 vs .33), $t(1) = 3.26$, $p < .01$). A combined ANOVA that included Type of Item (studied vs critical lure) as an independent variable revealed a significant Subject Group × Type of

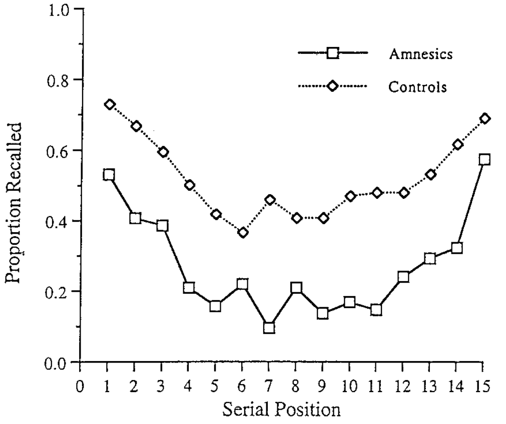

FIG. 1. Probability of correct recall in amnesics and control subjects as a function of serial position.

Item interaction, $F(1,22) = 7.39$, $MSE = .017$, $p < .05$, confirming the above findings. They provide evidence for a difference in the relation between critical lure intrusions and recall of target items in amnesic patients and controls, respectively.

Figure 1 presents the proportion of recalled target items as a function of serial position in the study list. Following Roediger and McDermott (1995), we compared intrusions of critical lures to the mean proportion of words recalled from the nonrecency and nonprimary portions of the serial position curve (positions 4–11). For control subjects, the proportion of words recalled from these positions (.44), like the overall recall rate, was higher than the proportion of lures intruded (.33), although this difference did not reach significance, $t(11) = 1.64$, $p = .13$. By contrast, for amnesic patients the proportion of words recalled from the middle positions of the serial position curve (.17) was smaller than the proportion of critical lures intruded (.29); $t(11) = 2.27$, $p < .05$. Consistent with these findings, an ANOVA including Type of Item (Studied vs Critical Lure) as a factor revealed a significant Group × Type of Item interaction, ($F(1,22) = 7.40$, $MSE = .021$, $p < .05$). Once again, it looks as though the relation between recall of studied words and intrusion of critical lures differs in amnesic patients and control subjects.

One issue that complicates the interpretation of the above analyses is the fact that amnesics made on the average many more noncritical lure intrusions (1.32/list) than did control subjects (.55/list), $t(22) = 2.40$, $p < .05$. Furthermore, the nature of these intrusions was somewhat different for the two groups. For amnesics, 22% of their intrusions were unrelated to the studied lists, 48% were related to the just studied list and 30% were related to previously studied lists. For the controls, the corresponding percentages were 19, 79, and 2%. Thus, while the two groups were equally likely to produce unrelated intrusions, $t(22) = <1$, amnesic patients were less likely than controls to produce intrusions related to the just studied list, $t(22) = 2.72$, $p < .05$, and, correspondingly, more likely to produce perseverations to previously studied lists, $t(22) = 2.65$, $p < .05$. Because of differences between the two groups in the number as well as the pattern of intrusions, we computed for each subject the proportion of critical lures intruded as a function of the total number of intrusions (critical lures + unrelated intrusions). According to this adjusted measure, amnesic patients intruded a significantly smaller proportion of critical lures (.14) than did control subjects (.27), $t(22) = 2.15$, $p < .05$.

One question addressed by Roediger and McDermott concerns whether critical lure intrusions arise from associative processes operating during the recall test itself. If so, then one might expect more critical lure intrusions when subjects recall many targets from a list than when they recall few targets. To address the issue, we examined recall of target items as a function of whether or not subjects produced the critical lure (only 10 amnesic patients were included in this analysis because 2 never produced a critical lure). Amnesic patients recalled more target items from lists for which they produced the critical lure (mean = 4.8) than from lists for which they did not produce the critical lure (mean = 3.9; $t(9) = 2.44$, $p < .01$). Control subjects, in contrast, showed comparable levels of target recall whether they produced the critical lure (mean

TABLE 2

RECOGNITION DATA FOR STUDIED AND NONSTUDIED TARGET WORDS AND STUDIED AND NONSTUDIED CRITICAL LURES IN AMNESIC PATIENTS AND CONTROL SUBJECTS

	Proportion of old responses					
	Overall		R		K	
Item type/Condition	A	C	A	C	A	C
Studied						
Studied + recall	.54	.85	.30	.71	.24	.14
Studied + arithmetic	.46	.83	.25	.71	.21	.12
Nonstudied	.34	.18	.14	.06	.20	.12
Critical lure						
Studied + recall	.60	.83	.38	.70	.22	.13
Studied + arithmetic	.57	.89	.30	.83	.27	.06
Nonstudied	.43	.29	.17	.11	.26	.18

Note. R and K refer to remember and know responses, respectively. A and C refer to amnesic patients and control subjects, respectively. In the text, values reported are collapsed across the recall and arithmetic conditions.

= 7.6) or not (mean = 8.0; $t(11) = 1.04$; ns). We also examined the output position of the critical lure, reasoning that a relatively late output position for the critical lure would tend to indicate a role for associatively related items produced previously during the recall test (cf., Roediger & McDermott, 1995). For amnesic patients, the average output position for critical lures was 4.8 (of 5.8 words produced for lists in which there was a critical lure intrusion). For control subjects, the average output position for critical lures was also 4.8, even though the total number of items produced for these lists was considerably higher (8.6). Thus, in relative terms the amnesic patients produced the critical lure later than did the control subjects. Although not conclusive, these last two analyses are consistent with the possibility that associative processes during the recall test play a more prominent role in the critical lure intrusions of amnesic patients than control subjects.

Recognition. The first column of Table 2 presents the proportion of old responses to studied words, critical lures, and their corresponding distractors for amnesic patients and control subjects. The results are presented separately as a function of subjects' activities prior to the recognition test: free recall or arithmetic. However, ANOVAs revealed that type of task (free recall vs arithmetic) did not yield any significant main effects or interactions, so all subsequent analyses are collapsed across the free recall and arithmetic conditions. Although the table entries provide separate proportions for the recall and arithmetic conditions, in the text we refer to mean proportions averaged across these two conditions.

Analyses of studied words and corresponding distractors revealed a significantly higher hit rate in control subjects (.84) than in amnesic patients (.50), $t(22) = 5.94$, $p < .0001$, together with a significantly higher false alarm rate in the amnesics (.34) than in the controls (.18), $t(22) = 2.26$, $p < .05$. Adopting the standard high-threshold correction procedure, we subtracted the false alarm rate from the hit rate. This analysis revealed, as expected, that recognition accuracy in amnesic patients (.16) was significantly lower than in control subjects (.66), $t(22) = 9.60$, $p < .0001$. We obtained a nearly identical pattern of results when we analyzed critical lures (nonpresented words preceded by a list of high associates) and their corresponding distractors (words drawn from the same pool of critical lures that were not preceded by a list of high associates). Overall, amnesic patients made many fewer false alarms to critical lures (.59) than did control subjects (.86), $t(22) = 3.85$, $p < .001$. By contrast, the amnesic patients made more false alarms to the distractors for critical lures (.43) than did the control subjects (.29), just as they did in the preceding analysis of distractors for studied words. However, this difference was not statistically significant, $t(22) = 1.35$, $p = .19$, largely because the present analysis was based on fewer items than the preceding analysis, which led to increases in between-group variance. Most importantly, however, a combined ANOVA that included Type of Item (Critical Lure vs Distractor) as an independent variable revealed a highly significant Subject Group × Type of Item interaction, $F(1,22) = 28.79$, $MSE = .017$, $p < .0001$. This crossover interaction confirms that amnesic patients and control subjects responded in a qualitatively different manner to the critical lures and their corresponding distractors.

Despite their tendencies to make more false alarms to distractors, amnesic patients made fewer false alarms to critical lures than did control subjects. Indeed, when we subtracted the proportion of old responses to distractors from the proportion of old responses to critical lures, the corrected proportion was much smaller in amnesic patients (.16) than in control subjects (.57), $t(22) = 5.36$, $p < .0001$. Amnesic patients did, however, make significantly more old responses to critical lures than to distractors, $t(11) = 3.05$, $p < .05$, indicating that the presentation of associatively related items reliably influenced their recognition performance.

A comparison of studied items and critical lures revealed that both amnesic patients and control subjects provided more old responses to critical lures than to studied items (.59 vs .50 for amnesics and .86 vs .84 for controls), replicating a finding by Roediger and McDermott (1995). An ANOVA that included Item Type (Studied vs Critical Lure) as a factor revealed that the main effect of this variable approached but did not attain significance, $F(1,22) = 3.59$, $MSE = .021$, $P = .07$. The Subject Group × Item Type interaction was nonsignificant $F(1,22) = 1.43$, $MSE = .021$, $p = .25$.

However, this analysis is complicated by the fact that false alarm rates of both amnesics and controls were higher to distractors that were drawn from the pool of critical lures than to ‘‘ordinary’’ distractors for studied items. An ANOVA that included Type of Distractor as a factor revealed a significant main effect of this variable, $F(1,22) = 8.91$, $MSE = .027$, $p < .01$, along with a nonsignificant interaction with Subject Group ($F < 1$). Roediger and McDermott (1995) reported a similar effect. To take into account these differing false alarm rates, corrected recognition scores for studied items and critical lures were compared. Whereas amnesic patients’ corrected recognition scores were the same for studied items and critical lures (.16), controls’ corrected recognition scores were higher for studied items (.66) than for critical lures (.57), although the effect fell just short of the conventional significance level $t(11) = 2.17$, $p = .052$. These results imply that control subjects remembered specific information about studied items above and beyond the information that drove their critical lure responses, whereas amnesic patients did not. However, when an ANOVA was performed on these corrected scores, it failed to reveal a significant Subject Group × Item Type interaction, $F(1,22) = 1.99$, $MSE = .013$, $p = .17$.

For the recognition tests that were preceded by free recall, it is possible to examine responses to studied words and critical lures as a function of whether or not they were produced on the recall test. Table 3 presents the relevant data. There was a main effect of Recall $F(1,22) = 16.66$, $MSE = .047$, $p < .001$, indicating that subjects were more likely to call old those studied words and critical lures that were produced in the recall test than those studied words and critical lures that were not produced. Consistent with previous analyses, there was also a main effect of Subject Group, $F(1,22)$, 18.21, $MSE = .097$, $p < .001$. In addition, however, there was a significant Recall × Type of Item interaction, $F(1,22) = 4.50$, $MSE = .041$, $p < .05$, indicating that

TABLE 3

PROPORTION OF ITEMS CALLED OLD ON THE RECOGNITION TEST BY AMNESIC PATIENTS AND CONTROL SUBJECTS IN THE STUDY + RECALL CONDITIONS AS A FUNCTION OF WHETHER THE WORDS WERE PRODUCED ON THE FREE RECALL TEST

	Production rate in free recall		Recognition	
Condition	A	C	A	C
Studied				
Produced	.27	.52	.74	.98
Not produced	.73	.48	.44	.74
Critical lure				
Produced	.29	.34	.58	.96
Not produced	.71	.66	.59	.76

Note. A refers to amnesic patients and C refers to control subjects.

the tendency to call critical lures old was influenced less by recall/nonrecall than was the tendency to call studied items old.

Although the three-way interaction of Recall × Type of Item × Subject Group did not achieve statistical significance, $F(1,22) = 2.34$, $MSE = .041$, $p = .14$, inspection of Table 2 reveals that the Recall × Type of Item interaction is entirely attributable to the fact that for amnesic patients, critical lures that were produced on the free recall test and those that were not produced received a nearly identical proportion of old responses on the recognition test (.58 vs 59, respectively). In contrast, critical lures that had been produced on the recall test by control subjects received more old recognition responses than those that had not been produced (.96 vs .76), $t(11) = 2.87$, $p < .05$. Likewise, studied words that had been recalled by amnesic patients received more old recognition responses than did studied words that had not been recalled (.74 vs .44), $t(11) = 6.70$, $p < .0001$, and the same was true for studied words in control subjects (.98 vs .74), $t(11) = 6.68$, $p < .0001$. These analyses imply that production of critical lures did not influence recognition in the same way for amnesics and control subjects.

Remember vs know responses. We subdivided the proportion of old responses made by amnesic patients and controls into remember and know responses, respectively (Table 2). Roediger and McDermott found that subjects claimed to remember critical lures as often as they claimed to remember studied words, and our data show a similar pattern for both control subjects and amnesic patients. Overall, control subjects provided remember responses to .71 of the studied words and .77 of the critical lures; the corresponding proportions for amnesic patients are .28 and .34. Our data also reveal that differences in recognition performance between amnesics and controls are attributable to these marked between group differences, which were highly significant for both studied words,$t(22) = 7.76$, $p < .0001$, and critical lures, $t(22) = 5.71$, $p < .0001$. However, these effects are mitigated by the fact that neither the control subjects nor the amnesic patients used know responses more often for studied words than for their corresponding distractors ($t < 1$ for both amnesic patients and controls). Similarly, neither group used know responses more often for critical lures than for their corresponding distractors ($t < 1$ for both amnesics and controls). These analyses imply that both subjects groups tended to use the know response when they were just guessing that a word had appeared on the list, and used the remember response whenever they felt a degree of certainty that a word had been studied previously. In the Roediger and McDermott (1995) experiment, subjects did provide more know responses to studied than nonstudied words. Since our instructions were nearly identical to theirs, it is unclear why our subjects showed a general bias to use the remember response for previously studied items. Whatever the reasons, the analysis of remember responses tells us little more than the analysis of old responses, so we cannot make much of our remember/know data.

GENERAL DISCUSSION

We found that non-memory-impaired subjects, like college students in previous studies, often falsely claimed to remember encountering critical lures such as *sleep* on a study list, making many more false alarms to critical lures than to associatively unrelated lures. Amnesic patients also made more false alarms to critical lures than to unrelated lures. However, they were far less susceptible to false recognition of critical lures than were controls, whereas they made more false alarms to unrelated lures than control subjects did. On the free recall test, controls and amnesics intruded similar numbers of critical lures, but when we took into account amnesic patients' tendencies to intrude more noncritical lures than control subjects, we found that the amnesics intruded a smaller proportion of critical lures than did controls.

Despite the fact that amnesic patients made fewer false alarms to critical lures and a smaller proportion of critical lure intrusions than did controls, our data also suggest that amnesics' recognition and recall were both influenced less by memory for particular study list items than was controls' performance. Corrected recognition scores were higher for studied words than for critical lures in control subjects, but were identical in amnesic patients. Similarly, control subjects produced more studied words than critical lures on the free recall test, whereas amnesics produced identical numbers of studied words and critical lures; when we restricted analysis to the middle serial positions, amnesics actually produced more critical lures than target words. We first discuss the implications of our recognition data and then turn to the free recall results.

Although amnesic patients made fewer false alarms to critical lures than did control subjects, we observed the opposite pattern for false alarms to unrelated lures. False alarms to critical lures appear to be based on memory processes that also support accurate recollection of words that were actually presented. Just as amnesic patients retain less information than controls about words that appeared on the list, they also fail to retain the semantic or associative information that supports false alarms to critical lures. At the time of study, control subjects may generate associates to each target item and link or bind target items to each other (Johnson & Chalfonte, 1994), thereby generating a well-organized or focused representation of the theme of the list (Norman & Schacter, 1996). Studied words that fit this thematic representation are likely to be judged as old, but so are critical lures. Just as old words, critical lures may enable control subjects to recollect other studied words that fit the general theme of the list, thus enhancing their experience that they are actually remembering a previously studied item.

By contrast, amnesic patients retain only a degraded and poorly organized semantic representation of the theme of the study list and the individual words in it. Their impaired recollection of such information produces both fewer hits to old items and fewer false alarms to critical lures than is observed with control subjects. Because our amnesic patients all had damage to medial temporal and/or diencephalic brain structures, and because there are both theoretical and empirical reasons to believe that the hippocampus and related structures contribute to remembering a recently studied word (cf., Johnson & Chalfonte, 1994; Moscovitch, 1994; Schacter, Alpert, Savage, Rauch, & Albert, 1996; Schacter, Reiman, Uecker, Polster, Yun, & Cooper, 1995; Squire, 1992), it seems clear that memory processes that are impaired in amnesia play an important role in false alarms to critical lures.

On the other hand, amnesics are more likely than control subjects to make false alarms to unrelated lures. This may occur because controls can use their well-organized thematic representation to reject unrelated distractors. Amnesic patients are less able to do so, and hence make false alarms to unrelated distractors based on haphazard guessing and perhaps some misattributions based on fluent processing (Jacoby, Kelley, & Dywan, 1989) of nonstudied words that overlap in some way with studied words (although our unrelated distractors bear no systematic relation to studied items, some orthographic or phonological, and semantic features of these words occasionally overlap with studied words). As Jacoby and colleagues have pointed out, if a word is processed fluently or easily, then a person may mistakenly attribute this fluent processing to a prior encounter with that word during the study episode, even though the word was never presented (Jacoby et al., 1989; Jacoby, 1991; Kelley & Jacoby, 1990).

This latter point can help to illuminate the pattern of results observed in the earlier study of false recognition in amnesic patients by Cermak et al. (1973). Using a continuous recognition procedure, they found that amnesics made more false recognition responses to associates and homophones of studied words than did controls. The rates of false recognition responses to these items were not nearly as high as those observed in the present study, probably because critical lures were preceded by only a single related word. Thus, in contrast to the Roediger and McDermott paradigm, subjects did not develop the kind of well-organized semantic representations of the list that drive false alarms to critical lures. We suggest that in the Cermak et al. experiment, false recognition to associates and homophones was instead driven by fluency-based processes. Normal subjects, we suggest, were able to counteract these effects because they could recollect the identity of the presented associates and distinguish them from the lure items—that is, they could use recollection to oppose fluency (Jacoby, 1991). Amnesic patients, however, could not remember the identity of the studied items and thus could not oppose the effects of fluency (Cermak, Verfaellie, Sweeney, & Jacoby, 1992). Hence, amnesic patients made more false recognition responses than did controls. Interestingly, amnesic patients did not make excessive numbers of false recognition responses to synonyms in the Cermak et al. (1973) experiment. Cermak et al. explained this finding with reference to impaired encoding processes in amnesia, but since neither amnesics nor controls made more false recognitions to synonyms than to unrelated lures it is unclear whether deficient encoding is relevant.

In view of the foregoing considerations, it should be possible to produce within a single experimental situation either reduced or enhanced false recognition in amnesic patients, depending on the number of prior associates to a lure. When large numbers of associates mislead control subjects into producing illusory recollections, amnesic patients should show reduced false recognition; when a single or small number of related items yield fluent processing that can be opposed by conscious recollection in control subjects, amnesics should show enhanced false recognition. Extending this logic a step further, it is known that increasing the numbers of study list words related to a lure word results in a systematic increase in false alarms (Hintzman, 1988; Shiffrin, Huber, & Marinelli, 1995). By systematically varying the number of associates to critical lure items, it should be possible to specify a crossover point where amnesics shift from enhanced to reduced false recognitions. From our perspective, this crossover point would indicate when false recognitions in control subjects are enhanced rather than inhibited by memory for the general theme and individual items in a list.

Having suggested that false recognition of critical lures depends on memory for the general theme of the study list and the individual words in it, we can ask at a more fine-grained level of analysis how such illusory recollections come about. Roediger and McDermott (1995) consider several possible sources of false alarms to critical lures that are preceded by numerous associates. One draws from Underwood's (1965) classic ''implicit associative response'' account, which holds that at the time of study, target words activate associates that are later confused with the target itself. One version of this idea holds that associates are truly activated implicitly, in the sense that the subject does not become consciously aware of the associate during study; it is generated by spreading activation through an associative network. One problem with this idea, as Roediger and McDermott (1995) note, is that people claim to remember the critical lures, whereas responses based on implicit spreading activation would not be expected to generate such recollective experiences. Our data lead to a similar concern about this view, because if responses to critical lures were based solely on nonconscious activation processes, we might expect amnesic patients to be influenced to the same degree as control subjects.

By another version of Underwood's account, subjects consciously think of the word at the time of study and are later subject to source memory confusion (Johnson, Hashtroudi, & Lindsay, 1993), such that they can no longer remember whether they actually heard it or only thought of it themselves. Indeed, this sort of source misattribution is central to understanding false recognition of critical lures, because when they commit such false recognitions subjects are mistaking prior thoughts for prior perceptions. Because amnesic patients tend to have more difficulty remembering source information than do controls (Schacter, Harbluk, & McLachlan, 1984; Shimamura & Squire, 1987), problems in source monitoring alone cannot be responsible for false recognitions of critical lures in our experiment. That is, if amnesic patients were as likely as control subjects to generate the critical lure at the time of study, we would expect them to make more—not fewer—false alarms to critical lures. From the perspective of the source monitoring framework (Johnson et al., 1993), amnesic patients would have to be either (a) less likely than controls to think of the critical lure at all during the study phase of the experiment, (b) less likely to bind together the generated critical lure with other list items, perhaps because they do not reactivate previously studied words and generated critical lures in an attempt to actively rehearse the list, or (c) more likely to forget a critical lure word that they, like controls, generated in response to associates at the time of study. We know of no empirical basis for invoking the first possibility, whereas there are many theoretical and empirical reasons for invoking the latter two ideas (cf., Johnson & Chalfonte, 1994; Kroll et al., 1996; Reinitz et al., 1996; Schacter, 1994; Squire, 1992). Further research will be needed to delineate the exact source monitoring processes that are most relevant to critical lure false alarms.

The ideas that we considered earlier concerning memory for themes and individual items are closely related to Brainerd and Reyna's ''fuzzy trace'' account of false recognition (e.g., Brainerd, Reyna, & Kneer, 1995; Brainerd, Reyna, & Brandes, 1995; Reyna & Brainerd, 1995). By their view, recognition memory can be based either on a ''gist trace'' that preserves the general meanings and interpretations engendered by studied items or on a ''verbatim trace'' that preserves specific information about the exact identity of each item (we use the term ''specific trace'' rather than ''verbatim trace'' to avoid the implication of a literal recording of an item or event). In general, hits on a recognition test tend to be based on recollection supported by the specific trace, whereas false alarms are based on ''feelings of similarity'' supported by the gist trace. By this view, false alarms to critical lures would be attributable to strong feelings of similarity that are supported by a gist representation. If the gist representation is degraded in amnesic patients, they would be less likely to false alarm to critical lures, as we observed. In addition, a deficient specific representation would produce impaired hit rates. However, fuzzy-trace theory tends to characterize false recognition responses based on the gist representation as involving ''vague'' feelings of familiarity or similarity (e.g., Brainerd et al., 1995). Fuzzy trace theory may not be entirely applicable to the kinds of false alarms observed in the Roediger and McDermott paradigm, where people claim to vividly remember the critical lures, perhaps because this view says little about the kinds of source misattributions that likely play a role in critical lure false alarms. If the gist representation is the basis of false alarms to critical lures, then either it is capable of giving rise to strong feelings of recollection, or it supports a type of fluent processing that is enhanced in control subjects by recollection of specific information about other study list items. Fuzzy trace theory as it currently stands does not distinguish between these possibilities.

The fuzzy trace account does lead to an interesting perspective on another feature of our data: for control subjects, corrected recognition scores were higher to old items than to critical lures, whereas for amnesic patients, corrected recognition scores were identical to old words and critical lures. This implies that amnesic patients retained no specific representation of the studied items and based their recognition responses entirely on degraded gist representations. This account can simultaneously accommodate two key features of our recognition data: (1) in absolute terms, amnesics were less likely to false alarm to critical lures (because of a degraded gist representation), and (2) in relative terms, amnesics showed greater reliance on a general semantic match between study and test items than did controls (because of an absent specific representation). While we offer this hypothesis tentatively, it offers a promising avenue for future investigation.

Some of the same considerations apply to our free recall data. When their overall intrusion rate was taken into account, amnesic patients showed a lower proportion of critical lure intrusions than did control subjects. However, at the same time, control subjects recalled more targets than critical lures, whereas amnesic patients exhibited the opposite pattern. These qualitative differences are explicable if amnesic patients' production of studied words on the free recall test depends entirely on a degraded gist representation, because they have no specific representation of particular items. While an appealing idea, it does not readily accommodate one curious feature of our results: studied words that were produced on the free recall test were more likely to be recognized by both controls and amnesics than were nonproduced words, whereas critical lures that were produced on the free recall test were more likely to be recognized than nonproduced critical lures by control subjects but not by amnesic patients. This finding implies that studied words that amnesic patients produced on the free recall test differed in some way from the critical lures they produced. This could come about if amnesics' production of critical lures depends in part on associative processes operating during recall.

A further question that arises from this analysis concerns the relation between the gist representation that Brainerd and Reyna invoke, and which we suggest is degraded in amnesic patients, and the processes that drive false recognition when only a single associate precedes a lure item. Does the same gist representation drive false recognition in both cases? If so, it might be surprising that amnesic patients show greater false recognition in the experimental situation that Cermak et al. investigated, and impaired false recognition in the present paradigm. Such an outcome could come about, however, if control subjects in the Cermak-type paradigm can oppose the effects of the gist trace by calling on a specific trace, whereas amnesics have no specific trace available to oppose the effects of the gist trace. Thus, even a degraded gist representation could result in enhanced false recognition on the part of amnesic patients.

Finally, we wish to highlight that our study points toward the potential usefulness of neuropsychological data in analyzing and decomposing memory illusions. Just as studies of priming and procedural learning in amnesia have helped to dissociate underlying systems and processes, our results, considered together with previous data, support the conclusion that distinct underlying processes subserve different kinds of false recognition effects. Studies of other neuropsychological populations implicate additional sources of memory illusions. For example, Schacter, Curran, Galluccio, Milberg, and Bates (in press) have recently documented excessive false recognition in a patient with a right frontal lobe lesion, which they characterize in terms of deficient retrieval processes involved in generating a focused description of a study episode (see Norman & Schacter, in press; for a similar false recognition phenomenon, see Parkin, Bindschaelder, Harsent, & Metzler, in press). In a related vein, previous research and theorizing with confabulating patients has highlighted how disturbances of strategic retrieval and monitoring processes subserved by the frontal lobes, basal forebrain, and related structures can lead to memory distortions (cf., Johnson, 1991; Moscovitch, 1995; Norman & Schacter, 1996). Phelps and Gazzaniga (1992) and Metcalfe, Funnell, and Gazzaniga (1995) have shown that memory illusions can arise in split-brain patients when recognition responses are based exclusively on the left hemisphere, which generates a categorical or gist-like representation, as opposed to a more specific representation that is associated with the right hemisphere. And as noted earlier, Kroll et al. (1996) and Reinitz et al. (1996) report that amnesics and patients with damage to the left or to the right hippocampal system are more prone to illusory memory conjunctions than are normal controls. This may reflect impaired consolidation processes that ordinarily serve to bind together distinct attributes of an event into a unified engram. Considered together with our results, all of these studies point toward the conclusion that a variety of distinct neural and psychological processes underlie different kinds of memory illusions. We believe that future brain-oriented studies can help to reveal and disentangle them, and thereby establish a cognitive neuroscience of memory distortion that can illuminate these important but perplexing vulnerabilities of human memory.

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