

## AN INVESTIGATION OF PAIRED-ASSOCIATE LEARNING IN AMNESIC PATIENTS\*

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**Abstract**—Amnesic subjects are unable to learn unrelated verbal paired-associates but when words were combined according to their semantic or phonetic properties, original learning was the same in amnesic and control subjects. Amnesic subjects showed good retention of this learning after 30 min but were unable to learn a second, similar paired-associate task partly because of a large number of intrusion errors from List 1. Their performance on List 2 improved significantly when the differentiating characteristics were increased. The amnesic subjects' susceptibility to interfering influences was reaffirmed and conditions under which interference can be constrained were demonstrated. The relevance of the findings to current theoretical issues is also briefly discussed.

### INTRODUCTION

AMNESIC patients are severely impaired in the acquisition and recall of verbal material, but when interfering influences are reduced their performance improves significantly and can even reach the level of control subjects [1, 2]. Although the precise nature of the memory deficit remains to be determined, it seems clear that amnesic subjects are especially susceptible to the effects of proactive interference.

There is an interesting parallel between this aspect of the amnesic syndrome and the behaviour of lower animals with brain damage comparable to that typically associated with medial-temporal-lobe amnesia. For example, animals with hippocampal or fornical lesions are deficient in acquiring new responses following training on similar problems and this failure is often characterized by persistent intrusions from past learning [3, 4]. In rats with hippocampal damage, this effect seems to be related to the stimulus characteristics of the test conditions; manipulations which enhance the discriminability of environmental cues also reduce the amount of proactive interference [5, 6].

One task on which amnesic subjects typically have great difficulty is in learning and remembering verbal paired associates. If this difficulty derives from interference phenomena, e.g. from pre-existing or conflicting associations, paired-associate learning should prove possible if the tests were deliberately designed so as to constrain interference. Moreover, if learning and retention could be demonstrated, it would then be possible to control the constraints that apply to successive lists of paired-associates, and thereby to determine those conditions in which interference from one list to another would operate.

In the present series of experiments, the strategy adopted was to introduce a constraint

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\* This research was carried out while the first author was a visitor to the Department of Experimental Psychology, Oxford University.

on the response class by making pairs of words in each list conform to a semantic or phonetic rule. When it became clear that this allowed good learning and retention by amnesic subjects, interference was deliberately introduced between successive lists of paired associates by making the first members of the pairs of words common to both lists, and varying the nature of the constraint that applied to each of the lists.

## METHOD

### *Subjects*

Five clinically diagnosed amnesic subjects served as experimental subjects for this and most subsequent experiments (see Table 1). The amnesic patients were selected for inclusion on the basis of a specific memory impairment which was disproportionate in relation to the level of intellectual functioning. All had a severe memory defect as assessed by clinical methods. They were unable to recall day-to-day events, were disorientated in time and place, and had retrograde amnesia antedating the onset of illness. Three patients were Korsakoff alcoholics, one was a post-encephalitic, and one was a patient who recovered from an undiagnosed acute illness, probably encephalitic, that left him severely amnesic and deaf, with brief epileptic seizures thought to be of temporal lobe origin. The group's average age was 53 yr old and the average I.Q. was 106 (WAIS, full-scale prorated).

Table 1. Composition of subject groups

Amnesic Group					Control Group			
Sex	Age	IQ	Diagnosis		Sex	Age	IQ	Diagnosis
1. M	59	103	Korsakoff		1. M	32	113	Normal
2. F	61	87	Korsakoff		2. M	30	131	Normal
3. M	63	101	Korsakoff		3. M	55	122	Normal
4. F	54	116	Encephalitis		4. M	29	100	Non-Cerebral Damage
5. M	28	122	Unknown Etiology		5. F	56	109	Non-Cerebral Damage
					6. F	67	107	Multiple Sclerosis
					7. M	35	90	Left Temporal Lobectomy

The control groups for all the experiments were drawn from a population of seven subjects who were available for testing on at least five separate occasions. They were chosen to cover the same range of age and I.Q. as the amnesic group. Two subjects had central nervous system damage (one had sustained a left temporal lobectomy and the other had multiple sclerosis), 2 subjects were being treated for peripheral nerve lesions, without brain damage, and 3 subjects were normal controls with no known neurological condition. The average age of the controls was 42 and their average I.Q. was 107 (see Table 1). Not all control subjects were available for each test condition but a minimum of 4 subjects were included in each experiment with at least one representative from each control category. The multiple sclerosis patient was tested in all experiments, and the left temporal lobectomy subject only in Experiments 1 and 3. Because control subjects did not differ from each other in any of the tasks, they were treated as a single control group.

### *Materials*

All experiments involved paired-associate lists consisting of high frequency words drawn from the A or AA categories of the Thorndike-Lorge word counts [7]. Each word was printed in large black letters on a blank 3 × 5 in. index card. The specific properties of the word pairs will be described for each separate experiment below.

## EXPERIMENT 1

Experiment 1 had two principal objectives: (1) to determine if paired associate learning could be improved in amnesic subjects by limiting the number of competing response alternatives associated with each word and (2) to compare amnesic and control subjects on a test of transfer of learning, and to examine their error patterns. Following exposure

to an initial list of semantically-related paired-associates (e.g., calm-tranquil), subjects were presented with a second list of paired-associates consisting of the same stimulus words but a new response word which was similar in meaning to the original pair (e.g. calm-peaceful). The effects of List 1 experience on List 2 learning were of particular interest in this part of the experiment. If over a 20-30 min inter-task interval, the previous learning were simply forgotten, then relatively efficient learning of List 2 might be anticipated. Alternatively, a sensitivity to interference effects would result in exaggerated difficulty with the second list due to a tendency to make intrusion errors from List 1.

#### *Material*

Thirty-six triads of words were selected to comprise 3 separate sets of lists. Each set consisted of 2 lists of 12 paired-associates which had in common the same stimulus word but different response words. Each word within a pair was similar in meaning to the other word in the pair (see Table 2A for an example of a list). The first list is designated AA', the second list AA''. No special effort was made to select only synonyms and words were frequently linked on the basis of their common characteristics, e.g. List 1: army-soldier; List 2: army-battle. Three identical versions of each set were prepared with the pairs arranged in different sequences to discourage rote order memorization.

#### *Procedure*

In Experiment 1, subjects were given 1, 2, or 4 fixed presentations (FP) of List 1. These are designated as FP:1, FP:2, and FP:4 respectively. Five amnesic subjects were tested in conditions FP:1 and FP:4 but only 4 were available for FP:2. Six controls were tested in FP:1 and FP:4 and 5 were tested in FP:2. The order of FP condition varied between subjects but not according to any systematic pattern. At least 5 days, and usually 7 days, intervened between conditions.

Subjects were instructed to read aloud each pair as presented and to try to associate the words. They were told that they would later be given the first word of each pair and be asked to provide the second word. The pairs were presented at a rate of one pair every 2 sec. In conditions FP:2 and FP:4 approximately 60 sec elapsed between versions of List 1. This period was filled with irrelevant conversation. Sixty seconds following the last presentation, subjects were told that they would now be presented with the first word of each pair only and they were to provide the word that went with it. For this recall session, the stimulus word was presented for 10 sec or until the subject responded, after which the correct response word was always provided. Following the List 1 recall test the subject was offered coffee and was engaged in distracting conversation, or in an informal visual recognition task. The subject's first session was partially filled by individually presenting 40 picture post-cards of mainly rural scenes. Each card was presented for 20 sec during which the subject described the scene. In the List 1-List 2 interval of subsequent sessions, the subjects were asked to identify these familiar pictures paired with new post-cards. This test was conducted in about half the experimental conditions throughout the research, but the data will not be considered here. The entire interval lasted about 30 min but occasionally, depending on circumstances, was reduced to 20 min.

The 12 pairs of List 2 words were presented once only followed by a series of trials in which the subjects were to match the new response words with the same stimuli as in List 1. No advance information was provided about the types of words or of their relationship to List 1. During the presentation trial, the pairs were shown at a 2 sec rate but in the test trials, subjects had 10 sec to respond, after which the correct response word was always provided. Testing was terminated when an errorless trial was achieved or when nine trials had been administered. Thus, any subject receiving the full 9 trials would have been exposed to each list sequence a total of 3 times.

The following types of errors were analyzed during List 2 learning: Semantic Error (SE), any word similar in meaning to the stimulus word; Direct Intrusion (DI), substitution of the corresponding, and previously correct, word from List 1 (errors of this type were also categorized as SEs); Omission Error (OE), failure to respond within the 10 sec stimulus exposure period. Other types of errors recorded but not analyzed in Experiment 1 because of their infrequent occurrences were intrusion errors from Lists A, A' (excluding DIs), and A''. Semantically-related words from external sources also occurred too infrequently to warrant analysis.

## RESULTS

Amnesic subjects made an average of 3.8, 3.5, and 2.2 errors on the List 1 Recall test following 1, 2 and 4 exposures respectively. The corresponding figures for the control subjects were 3.5, 2.2, and 1.5 errors. There were no significant differences within either the amnesic or control groups across conditions nor did between-group scores differ in

any of the conditions. It is evident from these scores that amnesic and control subjects learned List 1 to a comparably high degree under all conditions.

On the second task the amnesic subjects were clearly impaired both relative to control subjects and to their own performance on List 1. Table 3 provides the overall error pattern for List 2 learning for the different numbers of initial exposures of the first list. The amnesic group made significantly more total errors, including Semantic Errors and Direct Intrusions, than control subjects under the three conditions. A different trend is evident with respect to Omission Errors, for which the between-group averages did not differ statistically in FP:1 and FP:4. In FP:2, the control subjects made significantly more Omission Errors than the amnesic subjects ( $F = 7.67$ ,  $df = 1/6$ ,  $P < 0.05$ ). It can also be seen from Table 3 that Semantic Errors accounted for nearly all the errors of the amnesic group with only a small percentage being Omission Errors. In contrast, Semantic Errors and Omission Errors were made in more equal proportions by the control subjects. Between-group comparisons of Semantic and Omission Errors percentages yielded significant differences in all three conditions ( $P < 0.05$ ).

A third differentiating characteristic between the error patterns of the amnesic and control groups was in the distribution of Direct Intrusion errors. When the first list had been presented 2 and 4 times, amnesic subjects not only made more Direct Intrusion errors than control subjects but such errors accounted for a significantly higher percentage of total errors. With only one initial presentation, the groups did not differ in terms of Direct Intrusions, but the relatively large number of such errors made by the control group does not appear to be typical of their general pattern and indeed is largely due to a high proportion of Direct Intrusions on the first test trial. On this particular trial, control subjects averaged 2 Direct Intrusions or 67% of the total errors which subsequently fell off on the next two trials, after which criterion was reached. This contrasts with conditions FP:2 and 4 where Direct Intrusions by control subjects consistently averaged 20-30% of the totals throughout List 2 testing.

It is worth pointing out that the persistence of Direct Intrusions was a chief limiting factor in the amnesic subjects' efforts to learn List 2. Figure 1 shows that in the FP:4

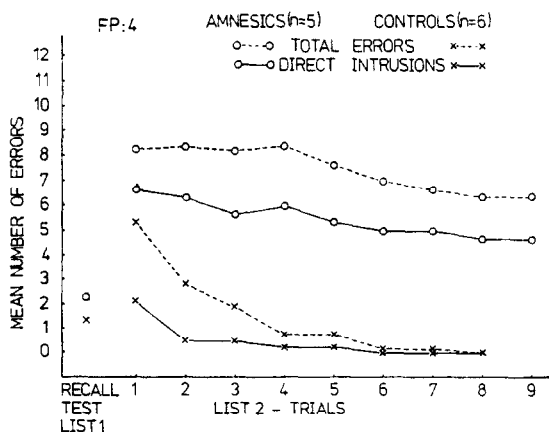


FIG. 1. Error patterns for FP:4 condition of Experiment 1 (AA'-AA''—semantically-related paired-associates sharing same first members of pairs. FP:4—initial list presented 4 times).

condition such errors consistently accounted for about 70% of the total errors across the 9 test trials. This basic relationship was the same in all three conditions, with perhaps the only notable variation being in FP:1 where Direct Intrusions accounted for approximately 50% of the total errors. Nevertheless, in this condition also the total error and Direct Intrusion curves were parallel across trials. It is also noteworthy that at no time did the amnesic group show appreciable learning of List 2. Comparisons of the average number of amnesic subjects' total errors and Direct Intrusions made in the first and last three trials did not show a significant decline in any of the FP conditions.

## EXPERIMENT 2

The next experiment tested the generality of the Experiment 1 findings by using rhyming paired-associates instead of semantically-related pairs of words. Since the three conditions yielded highly similar results in Experiment 1, only the condition in which the initial list was presented 4 times (FP:4) was used in the present study.

### *Material and procedure*

The procedure was identical to the FP:4 condition of Experiment 1 except that the stimulus and response pairings were selected on the basis of their rhyming characteristics (see Table 2B for an example of a list).

Five amnesic and four control subjects were available for testing in Experiment 2.

## RESULTS

Figure 2 shows that the same pattern of results was obtained using rhyming words as for the semantic conditions of Experiment 1. The amnesic group generally showed good initial learning of List 1. The relatively high amnesic group recall score is due mainly to one subject who made 5 errors; the other 4 subjects averaged 2 errors. Statistical comparisons of the amnesic and control groups' recall scores yielded non-significant differences ( $t = 1.94$ ;  $df = 7$ ,  $P > 0.05$ ).

Table 2. Examples of lists used in Experiments 1 and 2

A. Semantic		B. Phonetic	
Stimulus	Response	Stimulus	Response
chair	bench	hair	fair
bowl	plate	class	mass
break	destroy	treat	heat
cook	bake	blame	shame
wool	cotton	gain	rain
earth	soil	dear	fear
ask	inquire	corn	horn
wealth	fortune	steam	dream
army	soldier	pray	clay
doctor	nurse	gold	told
laugh	happy	wall	call
metal	steel	sail	mail

The interference pattern was once again evident: the amnesic group failed to show significant learning during List 2, and about 70% of all amnesic subjects' errors were Direct

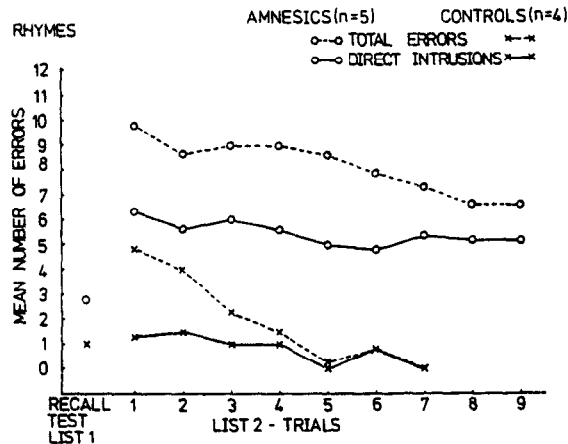


FIG. 2. Error patterns for Experiment 2 (AA'-AA''—rhyming paired-associates sharing same first members of pairs).

Intrusions; almost all of the remaining errors were external rhyming errors. As can be seen from Fig. 2, in contrast to the amnesic group, the control group had very few Direct Intrusions, the bulk of their errors being Omission Errors.

### EXPERIMENT 3

One of the most notable features of the results of Experiments 1 and 2 was the persistence of Direct Intrusion Errors by the amnesic group. In animals with damage to the limbic system, similar response perseveration has frequently been attributed to impaired inhibitory mechanisms [3, 4] or, alternatively, to a failure to detect or be constrained by cue changes within a familiar context [5].

In Experiment 3, an AA'-AB paired-associate paradigm was used to see if response perseveration of the sort observed in the previous experiments is an invariant characteristic of amnesic behaviour. Subjects were initially exposed to a list of semantically-related paired-associates (AA') and then tested on pairs of unrelated words (AB). If the interference phenomena observed in the two previous experiments were due simply to response perseveration, Direct Intrusion should again dominate the amnesic group's List 2 performance.

#### Material and procedure

The general procedures of the previous experiments were once again adopted. Subjects received 4 exposures of List 1, which consisted of pairs of semantically-related words (e.g. silent-quiet), followed 60 sec later by a recall test. About 30 min later, List 2 learning was attempted with unrelated pairs, using the same stimulus words of List 1 (e.g. silent-yellow).

Four amnesic and four control subjects were tested in this experiment.

### RESULTS

Figure 3 shows that List 1 recall by both groups was very similar and consistent with the results of Experiment 1.

Not surprisingly, amnesic subjects were totally unable to learn any of the unrelated paired-associates of List 2. The interesting development was that only about 14% of the total errors were Direct Intrusions from List 1. In fact, the amnesic group tended to derive

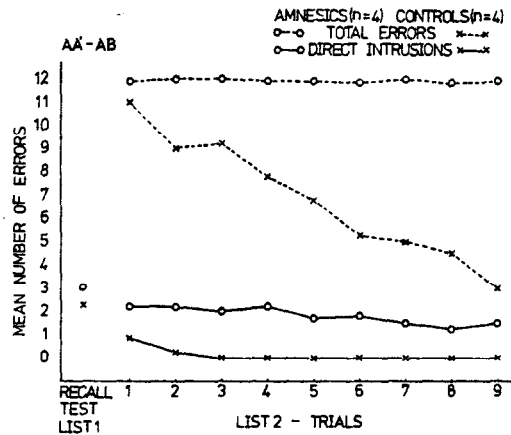


FIG. 3. Error patterns for Experiment 3 (AA'—semantically-related paired-associates, AB—unrelated paired-associates).

its responses from a variety of sources (see Table 4) such that it is difficult to discern any clear strategy. But it is interesting that the amnesic group showed an appreciable percentage of List A' intrusions other than Direct Intrusions (23.3%).

Table 3. Overall list 2 error scores under three list 1 conditions

	FP:1		FP:2		FP:4	
	Amnesic Group	Control Group	Amnesic Group	Control Group	Amnesic Group	Control Group
Total errors (T.E.)	47.2	4.8	69.8	4.6	66.6	12.0
Semantic errors (S.E.)	44.6	2.8	69.0	1.2	62.6	5.7
Direct intrusions (D.I.)	21.8	2.3	44.5	1.0	48.8	3.3
Omission errors (O.E.)	1.8	1.7	0.5	3.4	4.0	5.5
	%	%	%	%	%	%
S.E./T.E.	94.5	58.3	98.9	26.1	94.0	47.5
D.I./T.E.	46.2	47.9	63.8	21.7	73.3	31.7
O.E./T.E.	3.8	35.4	0.7	75.3	6.0	45.8

The control subjects also had difficulty in learning List 2 and in fact only one subject in this group was able to reach criterion in the allotted 9 trials. However, they made far fewer errors than the amnesic group and showed a clear learning trend over the testing period. The great majority of their errors were Omission Errors (66.6%) and intrusions from within List B (30.2%).

#### EXPERIMENT 4

The results of Experiment 3 showed that procedures which enhance the discriminability of successive paired-associate tasks also reduce the number of intrusion errors made by amnesic subjects. This suggests that new learning need not seriously be restricted if the salient features of the current situation can be dissociated from past events and serve to

Table 4. Classification of results of Experiment 3 list 2 (AB) scores

	Amnesic Subjects		Control Subjects	
	Mean	%	Mean	%
No. of trials to criterion	9.0	-	8.8	-
Total errors	105.6	-	60.5	-
Semantic errors (SEs)*	31.3	28.7	1.0	1.6
Direct intrusions (DIs)	15.3	14.4	1.0	1.6
List A intrusions	12.0	11.4	0.5	0.8
List A' intrusions (excluding DIs)	24.8	23.3	1.3	2.1
List B intrusions	17.5	16.6	18.3	30.2
External intrusions	19.0	18.0	0.25	0.4
Omission errors (OEs)	32.8	30.1	40.3	66.6

\*SEs include DIs and some external errors which were semantically related to the AA' combination of List 1.

constrain proactive interference effects. This idea was examined further in the following experiment where the relationship between training and test conditions was varied and the amnesic subjects' ability to learn semantically-related paired-associates was measured.

Specifically, subjects' ability to learn a list of semantically-related words was tested following conditions of (1) no prior training, (2) exposure to unrelated pairs of words, or (3) exposure to phonetically-related word pairs. Condition 1 served as a control for the general effect of prior paired-associate training while Condition 2 permitted assessment of the effect of prior experience with paired-associate lists in the absence of measurable learning. Condition 3 provided a situation where two similar lists could be learned and differentiated on the basis of an explicit rule. Failure to detect this rule would result in considerable proactive interference during efforts to learn the second list.

#### *Materials and procedure*

In all three conditions subjects were tested on similar lists of semantically-related paired-associate words. The testing procedure was the same as that for List 2 learning in the previous experiments. For condition 1 (AA' only;  $n = 5$  amnesic, 4 control subjects), subjects were given the test list with no prior training. In this condition, testing was simply delayed by about 35 min from the beginning of the session. The time was filled in the usual manner with at least 10 min taken up by the post-card recognition described previously.

Condition 2 (AB-AA';  $n = 5$  amnesic, 5 control subjects) and condition 3 (rhymes-semantics;  $n = 5$  amnesic, 5 control subjects) were similar in that both involved initial presentation of a paired-associate list according to the procedures for the FP:4 condition described in Experiment 1. In both conditions, a recall test was administered 60 sec after the fourth presentation of the first list followed by a 20-30 min filled interval and List 2 learning. The important difference was that for condition 2, List 1 consisted of unrelated pairs of words (AB) while for condition 3 List 1 comprised rhyming pairs of words. In both conditions 2 and 3, List 2 consisted of semantically-related pairs (AA'). Order of testing was not systematically controlled but varied considerably within each group of subjects. Five to 7 days intervened between conditions.

## RESULTS

The results are summarized in Fig. 4 which, for comparison purposes, also includes the corresponding scores for the comparable condition of Experiment 1, in which the first list was presented 4 times (FP:4). As expected, the amnesic group learned very little of the AB list in condition 2 but the rhyming words of condition 3 were learned to a high level.

The difference between amnesic and control subjects in recalling the List 1 AB words was statistically significant ( $t = 3.59$ ;  $df = 8$ ;  $P < 0.01$ ).

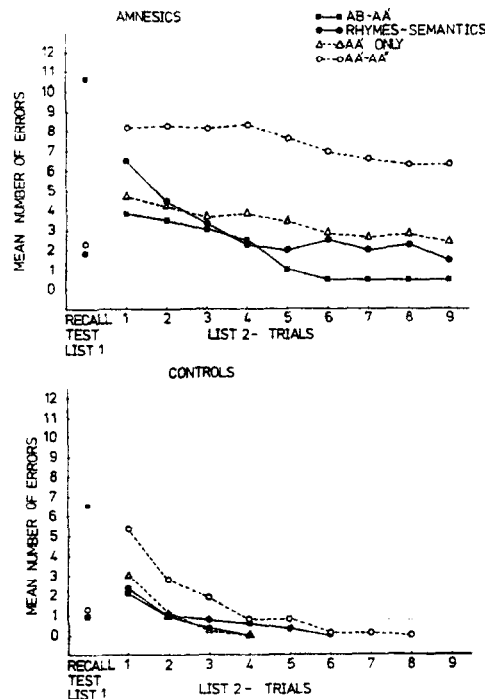


FIG. 4. Error patterns for Experiment 4. The AA'-AA'' scores are from Experiment 1 and are provided for comparison purposes.

The amnesic group displayed superior List 2 learning under all conditions relative to their performance in Experiment 1 (in which pairs of words in both lists were semantically related (AA'-AA'')). However, in all conditions of the present experiment they learned more slowly than control subjects. In all three conditions, error scores of the amnesic group declined significantly over trials ( $P < 0.02$ ). Analysis of variance applied to the amnesic group's List 2 learning scores revealed no significant interactions but significantly fewer errors were made in the AB-AA' condition than in the AA' only ( $F = 6.73$ ;  $df = 1/4$ ;  $P < 0.05$ ) and Rhymes-Semantic ( $F = 10.03$ ;  $df = 1/4$ ;  $P < 0.01$ ) conditions. There were no significant differences between the AA' only and Rhymes-Semantic conditions ( $F < 1$ ). The superiority of the AB-AA' group was something of a surprise and may have reflected a priming effect of presenting the stimulus words without any response learning. The AB presentation appears to have weakened normal pre-existing associations which probably accompanied the AA'-only condition and was obviously free of the kind of interference which could have been generated by prior training in the Rhymes-Semantic condition.

The performance of the control group did not differ with respect to any of the conditions of the present experiment; despite the trend suggesting more errors in the AA'-AA'' scores, the differences were not statistically significant.

#### EXPERIMENT 5

Most investigations of interference phenomena in amnesic subjects, including the previous four experiments, have tended to concentrate on proactive interference (PI)

effects. In the next study, the performance of amnesic subjects is compared with that of control subjects in a retroactive interference (RI) paradigm.

#### Material and procedure

Five amnesic and six control subjects were available for this experiment.

*RI condition.* Subjects were given four presentations of a list of semantically-related paired-associates (AA'), followed by a recall test. Fifteen minutes later, the same procedure was repeated with a similar list of paired words (AA'') which contained the same stimulus words as List 1. Fifteen minutes after the List 2 recall test, subjects were reminded that they had recently learned 2 sets of paired words. They were instructed that they would be shown the first word of each pair and were expected to provide the other member of the pair from the first list. A single recall test was administered in the usual manner.

*Retention control.* Subjects were given a new set of semantically-related paired-associates (AA') in the manner described for the RI condition. Thirty minutes later, subjects were reminded of this session and given a recall test for AA' words in the usual manner. The RI and control conditions were administered about one week apart with the order of testing varied between subjects.

## RESULTS

Table 5 shows that the amnesic group once again compared favourably with the control group in retaining semantically-related words for 60 sec. The average difference of 1.2 errors between the groups was not significant ( $t = 2.18$ ;  $df = 9$ ;  $P > 0.05$ ). However, amnesic subjects showed little learning of List 2 largely because of an exaggerated tendency to make Direct Intrusion Errors from List 1. As the amnesic group scored only an average of four correct responses in the List 2 recall test, it was reasonable to expect little RI in the second

Table 5. Mean number of errors in retroactive interference and control conditions

	AA'		AA''		AA'	
	Amnesic Group	Control Group	Amnesic Group	Control Group	Amnesic Group	Control Group
<u>Retroactive interference</u>						
Total errors	2.20	1.00	8.00	1.18	7.60	1.33
Semantic errors	1.40	0.33	7.40	1.00	7.20	0.33
Direct intrusions	-	-	6.40	0.67	5.20	0.33
Omission errors	0.40	0.50	0.60	0.19	0.40	0.50
<u>Retention control</u>						
Total errors	3.60	2.17			3.60	1.50
Semantic errors	3.00	1.17			3.40	0.13
Omission errors	0.60	1.00			0.20	1.33

Table 6. List 1 error recall scores of amnesic group according to diagnostic condition in Experiment 1

	Number of Presentations of First List					
	FP:1		FP:2		FP:4	
	Recall errors	DI <sup>3</sup>	Recall errors	DI <sup>3</sup>	Recall errors	DI <sup>3</sup>
Korsakoffs ( $\bar{X}$ )	4.0	48.7	4.0	77.0	2.3	63.3
Temporal lobe epileptic	3	24	4	51	3	90
Post-encephalitic	2	58	2	62	2	74

recall test of the AA' list. In fact, they made an average of 7.6 errors or 4.4 more errors than on the original AA' recall list. The amnesic group clearly exhibited RI since in the retention control condition, where there was no interpolated AA'' training, recall scores did not change appreciably over the 30 min inter-test interval. It is interesting that 5.6 errors (74% of the total) made by the amnesic group in the second AA' recall test in the RI condition were Direct Intrusions from List 2.

The control group did not show a significant increase in errors in the second AA' recall test of the RI condition ( $t < 1$ ) nor were the percent savings scores of the control group in the interference and Retention Control conditions significantly different ( $t < 1$ ). On this basis it does not appear that the controls exhibited RI, but it must be noted that in the Retention Control condition, ceiling factors may have prevented a substantial reduction in errors. Despite the possible ceiling effects, the percent savings of the control group (30.9%) in the Retention Control condition was significantly greater than that for the amnesic group (-5.6%) ( $t = 3.80$ ;  $df = 9$ ;  $P < 0.01$ ). Whereas the two groups did not differ on the first recall test in the control condition ( $t = 1.79$ ;  $df = 9$ ;  $P > 0.05$ ), amnesic subjects made significantly more errors on the second test ( $t = 2.67$ ;  $df = 9$ ;  $P < 0.05$ ).

The error patterns of the two groups in this experiment were generally the same as that previously observed. Amnesic subjects consistently made large proportions of Semantic Errors and Direct Intrusions in the RI tests and with one exception (AA'' recall), control subjects made more Omission Errors. Over all tests, control subjects distributed their errors more equally between Semantic and Omission Errors while the ratio of Semantic to Omission Errors for the amnesic group was approximately 10:1.

## DISCUSSION

Although amnesic subjects are unable to associate unrelated word-pairs (Experiments 3 and 4), when competing associations are reduced by limiting the range of the response set, they demonstrate a clear capacity for paired-associate verbal learning. In the present series of experiments, amnesic subjects were found repeatedly to be as competent as controls in learning pairs of words combined on the basis of their phonetic or semantic similarities and, in addition, showed good retention of this learning for as long as 30 min (Retention Condition, Experiment 5). The large number of Direct Intrusion errors frequently observed during List 2 learning (Experiments 1, 2, and 5) is further evidence that amnesic subjects had successfully transferred the material into long-term storage and were capable of recalling it, although in these instances, erroneously. The present set of results is closely similar to that of another study [2] in which intrusion errors were persistently exhibited by the amnesic subjects when they had to switch to an alternative response to the same cue.

Nevertheless, the amnesic subjects' ability to recall learned material is more severely affected by the passage of time than is the case for controls. For example, amnesic subjects did make slightly but significantly more errors than controls on the 30 min recall test in the Retention Control condition of Experiment 5. Similarly, when one of the amnesic subjects was administered one of the test conditions (FP:4) of Experiment 1 with a two-hour inter-list interval, both total errors and Direct Intrusion Errors in List 2 learning dropped by more than 50% when compared to the 30 min data for that subject. By contrast, the performance of a matched control subject for the two intervals was indistinguishable. These findings are, of course, to be expected and do not contradict the demonstrated

ability of amnesic subjects to accomplish relatively complex paired-associate learning. Rather, the evidence taken together strongly suggests a basic impairment not in terms of consolidation processes, but in the retrieval of learned items from storage [1]. Moreover, indications are that the progressive build-up of interfering influences over time severely restricts retrieval processes. This is clearly demonstrated in Experiment 5 where intervening learning accelerated the loss of original learning when compared with the condition where no competing activity occurred between original learning and testing.

In view of the close relationship between words used in the various combinations, it might be argued that sheer guessing could account for a high proportion of correct responses. This possibility was considered in preliminary investigations when two amnesic patients were asked to free-associate semantically-related response words to stimulus words comprising a paired-associate list typical of those used in the actual experiments. Each subject provided only three response words that were, in fact, included in the list. A guessing argument is further weakened by the result of a long-term retention test conducted with four of the amnesic subjects from the present group. The subjects were trained on a list of 12 semantically-related pairs of words until a criterion of no more than 3 errors per trial was reached. This required extensive training which if anything should have aided guessing if that indeed was the strategy. But seven days later the amnesic subjects could correctly recall an average of only 3-5 words. However, throughout the experiments reported above, amnesic subjects typically showed retention of 9 or 10 words of List 1 following a 30 min interval so that a considerable amount of learning was taking place over and above that to be accounted for by guessing.

Given the present and related evidence [2], therefore, it appears to be well established that the amnesic subject can learn efficiently when the response set is constrained and, moreover, when cues are deliberately made ambiguous with respect to two successive sets of material, he is likely to produce intrusions from the earlier set and hence to show grossly impaired learning. The present paradigm allows one to manipulate the stimulus and "correct" response cues independently of the rule that constrains the stimulus-response set. The fact that amnesic subjects showed very little response perseveration in Experiment 3 and in the Rhyme-Semantic condition of Experiment 4 indicates that they are not absolutely bound to respond mechanically to an item that has been strengthened by prior experience. If internal disinhibition is indeed one of the consequences of brain pathology suffered by amnesic subjects [4], then clearly, under certain conditions, the tendency to transfer inappropriate responses to new situations can be constrained. On the other hand, the findings that efficient learning was shown with either a semantic or a phonetic rule, that the amnesic subjects were sensitive to a shift from a phonetic to a semantic rule, and that well over 90% of the total errors committed by the amnesic subjects in all of the related paired-associate conditions were semantic errors, do not offer support to the view that Korsakoff patients may be unable "to employ spontaneously semantic encoding" [8].

It might be speculated that successive learning experiences might be poorly discriminated from each other by the amnesic subject, and hence interfere with each other. Poor discrimination might derive from a difficulty in "time-tagging", or an impairment in the discrimination of familiarity [9] or in the discrimination of "contextual cues" associated with the different experiences. The latter two hypotheses can be made consonant with the results of recent experiments with animals subjected to lesions of the hippocampus or fornix [9, 10, 5, 11], and these in turn add to the evidence for a continuity between the human and animal literature [12]. On the other hand, an undue susceptibility to inter-

ference, perhaps because of a difficulty in "unlearning" prior responses or strategies unless aided by various constraints or cues, might itself affect the ability of the subject to discriminate degrees of familiarity or contextual difference. This is not the place to pursue the various theoretical arguments in detail, but it is clear that any theory of amnesia will have to account for the pervasiveness of interference phenomena as an empirical fact.

Finally, it has been proposed that different memory disorders may be associated with specific neurological conditions and that the amnesic pattern for Korsakoff alcoholics is particularly severe [13]. Performance by our amnesic subjects could not be differentiated on the basis of diagnostic condition and although there was normal inter-subject variation, reliable qualitative or quantitative differences associated with etiology were not apparent. Table 6 shows, for example, that the average number of errors made in the List 1 recall tests of Experiment 1 and the percent Direct Intrusions were generally very similar. The only possible exception may have been where the post-encephalitic subject appeared to make fewer recall errors in FP conditions 1 and 2. If in fact a real difference does exist here, it probably reflects superior learning ability of this particular subject whose I.Q. was also above the average of the group. Throughout the various experiments and particularly in the second list test conditions it was customary to observe a uniform pattern among the amnesic subjects.

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Résumé :

Des sujets amnésiques sont incapables d'apprendre des paires associées de matériel verbal sans relation mais lorsque les mots sont combinés en accord avec leurs propriétés sémantiques ou phonétiques, l'apprentissage d'origine est le même chez les sujets amnésiques et chez les contrôles. Les amnésiques ont une bonne rétention de cet apprentissage 30 minutes plus tard mais sont incapables d'apprendre une seconde épreuve similaire de paires associées en raison du grand nombre d'erreurs dues à une intrusion de la liste numéro 1. Leurs performances avec la liste 2 s'amélioraient de façon significative quand on augmentait les caractéristiques permettant la différenciation. On a ainsi réaffirmé la susceptibilité des amnésiques aux influences d'interférence et démontré les conditions sous lesquelles l'interférence peut être réduite. On discute aussi brièvement le rapport de ces constatations avec les problèmes théoriques actuels.

Deutschsprachige Zusammenfassung:

Amnestische Personen sind unfähig, zusammenhanglose Teile von Wortpaaren zu lernen. Wenn dagegen die Wörter entsprechend ihrer semantischen oder phonetischen Eigenschaften verknüpft waren, ließ das Erlernen bei amnestischen und Kontrollpersonen keine Unterschiede erkennen. Die amnestischen Personen hatten nach 30 Minuten das Gelernte gut behalten, waren aber unfähig, eine zweite, ähnliche Wortpaaraufgabe zu lernen, und zwar zum Teil wegen der großen Zahl von Instruktionsfehlern auf Bogen 1. Ihre Leistungen auf Bogen 2 besserten sich signifikant, so bald die unterscheidenden Charakteristika verstärkt wurden. Die Empfänglichkeit amnestischer Personen gegenüber interferierenden Einflüssen wurde wieder bestätigt, und die Bedingungen, unter denen die Einflüsse gedrosselt werden können, wurden aufgezeigt. Auch die Relevanz der Befunde in Bezug auf die derzeitigen theoretischen Vorstellungen wurde kurz diskutiert.