The effect of semantic categorisation on recall memory in amnesia

Shelley Channon[a,*] and Irene Daum[b]
[a]*Department of Psychology, University College London, UK*
[b]*Department of Neuropsychology, Ruhr University of Bochum, Germany*

Amnesic patients were compared to a healthy control group on recall of word lists containing semantically-related or unrelated words. As expected on the basis of previous literature, the amnesic group performed below the control group on all measures of recall. When total recall scores for each list were used as the index of performance, their scores were not significantly affected by the type of list, unlike those of the control group. Comparison of serial position effects for different parts of the lists revealed that the control group derived greater benefit from semantic relatedness in recall of items from the middle positions. This effect was not shown by the amnesic group, who showed similar U-shaped serial position curves for recall of all three lists, and appeared to use a more passive recall strategy than the control group. The findings are discussed in relation to our current understanding of amnesic deficits.

Keywords: Amnesia, semantic categories, verbal memory, encoding, serial position effects

1. Introduction

It has long been established that amnesic patients are impaired in the explicit recall of material from long-term memory stores, whether the pathology arises from thalamic lesions or Korsakoff's syndrome (e.g. [1]) or from medial temporal lobe damage (e.g. [23]). In the present study, the ability of amnesic patients to make use of semantic information in the encoding and retrieval of word lists was re-visited, to examine strategic aspects of their memory performance using detailed analyses of their recall.

Studies with a range of patient groups have shown that semantically-related words are generally remembered better than unrelated words, at least if the related words are presented in order of category membership or made salient by other means. The overall level of recall may nevertheless be significantly poorer than that shown by normal participants. This effect of semantic relatedness has been demonstrated using the same word lists as in the present study with patient groups including those with unilateral left temporal lobe lesions [9], frontal lobe lesions [12], Parkinson's disease [12], cerebellar lesions [11], and depression [8]. By contrast, work investigating elaborative encoding and retrieval in participants with amnesia arising from diencephalic or medial temporal lobe pathology has produced mixed evidence in relation to capacity to benefit from semantically-related materials.

Impaired capacity to benefit from semantically-related materials might result from difficulties in relation to the encoding/retrieval of the relevant information, or in relation to storage and consolidation. Studies examining encoding/retrieval have compared memory for semantically-related and unrelated materials, or have examined the effects of differing encoding/retrieval instructions on performance. Recall memory is thought to be a more sensitive measure than recognition, which may rely in part on relatively automatic retrieval processes, and may not necessitate the use of elaborative encoding/retrieval strategies. Any impairments in elaborative encoding/retrieval in amnesia may be an intrinsic feature of the disorder, or may reflect the contribution of frontal lobe dysfunction, which is present in some amnesic patients. Recent functional imaging and lesions studies have focused in particular on the role of the prefrontal cortex in the generation and use of organisational strategies that facilitate encoding and retrieval. Functional imaging work has suggested left prefrontal involvement in encoding and predominantly right prefrontal involvement in retrieval (e.g. [15, 26]). Lesion studies have also demonstrated impaired

*Corresponding author: Dr. S. Channon, Subdepartment of Clinical Health Psychology, UCL, Gower Street, London WC1E 6BT, UK.

Behavioural Neurology 12 (2000) 107–117
ISSN 0953-4180 / $8.00

spontaneous strategy use in people with frontal lobe lesions. The provision of semantic cues at encoding or retrieval has been reported to have beneficial effects on their performance (see e.g. [14,16,17,27]).

A series of studies was carried out by Cermak and colleagues examining ability to benefit from semantic encoding in amnesic patients, and they reported some ability to benefit under certain circumstances. Their spontaneous semantic encoding deficit hypothesis postulated that amnesic patients were less likely than control participants to use semantic encoding strategies spontaneously (e.g. [5]), and that they tended to favour phonemic rather than semantic analysis of words [4]. However, when forced to process material semantically, it was argued that amnesic patients should show improved or normal ability to benefit. In relation to this, Cermak and Reale [3] (Experiment 3) found improved recognition memory in Korsakoff patients when required to process materials semantically as compared to physical or phonemic processing. The effect was found to be fleeting, since it was eliminated by a delay in presentation of the recognition list to the amnesic group. Moreover, it was produced only with short word lists (12 words each), and similar levels of processing manipulations using a longer word list (60 words) did not produce the effect. Cermak, Uhly and Reale [11] also found beneficial effects with relatively short word lists for amnesic participants of providing semantic cues at both input and output, but this was restricted to words where the cues used were strong semantic associates of the target words. Improved recall and recognition performance with words presented twice rather than once has also been reported under restricted circumstances in amnesic patients (e.g. [7]), but unlike normal control participants, they did not benefit from semantic versus phonemic encoding.

A series of studies by Mayes and colleagues used matching procedures to equate levels of initial learning, and used additional control conditions such as comparing spontaneous learning with forced encoding procedures. They failed to find support for a semantic encoding deficit in amnesia, arguing that any encoding impairment affected both semantic and non-semantic information equally. For instance, Meudell and Mayes [22] compared list learning in a condition that permitted the use of spontaneous encoding strategies, and in a passive repetition condition that required repetition aloud of each word until the next word was presented. Like the control group, amnesic participants showed poorer recall in the repetition condition than in the free learning condition, suggesting that they do use spontaneous learning strategies beyond passive rehearsal. Moreover, their pattern of errors did not differ from the control group on a recognition experiment using semantic, acoustic or graphemic distractor words. Further evidence contradicting the spontaneous encoding deficit theory was provided by Mayes, Meudell and Neary [21], who failed to find facilitation of performance for amnesic participants when they were forced to encode materials semantically, and similarly did not find facilitation with semantic processing cues during learning or retrieval. A later study [21] demonstrated normal encoding performance in amnesic participants for both semantic items and other kinds of information when each item was exposed for six seconds. Evidence of this type thus failed to support the spontaneous semantic encoding deficit hypothesis, suggesting that processing of semantically-related materials is similar to that of non-semantic materials in amnesia.

Recent theories of amnesia have focused on issues relating to storage rather than encoding of the materials. Thus, Mayes and colleagues have recently contended that the primary deficit in amnesia is characterised by impaired consolidation of long-term memory for complex associations between items, rather than difficulties in encoding/retrieval. Semantically-related materials are thought to be encoded using complex semantic associations to link two or more items and their study context, leading to superior recall over time relative to recall of unrelated materials in healthy individuals. Amnesic participants should therefore show normal benefit from semantically-related versus unrelated materials, but fail to retain such benefit over time compared to controls when assessed by free recall. Their position appears consistent with work by Warrington and Weiskrantz [29], who postulated that amnesic patients were impaired in the use of cognitive mediation, but intact when cognitive mediation was not needed for learning and memory. For instance, they found amnesic patients to be impaired in paired-associate learning; unlike control participants they failed to show a learning advantage for semantically-related materials. Recent work providing support for the consolidation hypothesis was carried out by Isaac and Mayes [18], who compared recall of semantically-related and unrelated words. They exposed the semantically-related words for shorter times than the unrelated words for both groups, and gave the amnesic group longer exposure for both types of words. They found no significant effects on recall of group or group by type of words after a brief (twenty-second) delay, whereas there were significant effects after a three-minute delay. This was

interpreted as evidence of normal initial encoding of both types of words. Forgetting of unrelated words was similar in amnesic and normal groups, whereas forgetting of semantically-related words was faster in the amnesic group. The authors therefore argued that the effects were most likely to operate during initial consolidation of the material rather than encoding or retrieval of the complex associations.

In the present study, recall of semantically-related and unrelated material was studied further in amnesia, comparing semantically-related word lists with differing degrees of organisation. One was presented in random order (similar to the California Verbal Learning Test [13], allowing scope for spontaneous semantic encoding strategies, whereas the other was presented in order of category, removing the need to organise the words. The third list consisted of unrelated words. The randomly ordered semantically-related list required greater effortful encoding than the category-ordered list in order to create complex semantic associative links between the related items. The amnesic group was compared with a matched healthy control group on both immediate list recall, which should involve both STM and LTM processes, and thirty-minute delayed list recall, which should rely solely on LTM processes.

2. Method

2.1. Participants

Thirteen amnesic patients (8 m, 5 f) participated in the study. These consisted of 7 patients diagnosed as suffering from alcoholic Korsakoff's syndrome, 3 post-encephalitic patients with bilateral medial temporal lobe damage, 2 patients with bilateral medial temporal lobe damage from closed head injury, and 1 patient with bilateral thalamic infarcts. In all cases, the lesions were confirmed by radiological MRI or CT evidence. Fifteen control participants also took part in the study (8 m, 7 f). In order to be included in the study, participants were required to have IQ scores of 85 or above, and no history of dementia or other neurological or psychiatric disorder (with the exception of the primary diagnosis for the amnesic group). The two groups of participants did not differ significantly in age (amnesic mean 50.3, SD = 14.4; control mean 50.3, SD = 9.0) or IQ (amnesic mean 98.8, SD = 7.9; control mean 102.0, SD = 6.6), measured on a short German version of the Wechsler Adult Intelligence Scale [10].

2.2. Clinical measures

All participants were assessed on two standardised clinical measures of recall memory, in addition to the experimental measures. These consisted of Story Recall, from the Wechsler Memory Scale (German version) [2] and one nonverbal task, memory for a geometric drawing, the Rey-Osterreith figure [25]. The amnesic group performed significantly more poorly than the control group on each of these measures at the $p < 0.0001$ level: Story Recall immediate (amnesic group mean 5.35, SD = 3.30; control group 11.73, SD = 2.35); Story Recall delayed (amnesic group mean 2.00, SD = 2.53; control group 9.31, SD = 2.40); and Rey-Osterreith Figure delayed recall (amnesic group 25.31%, SD = 27.18; control group 68.67%, SD = 13.26). All the amnesic participants had some degree of immediate Story recall, but seven of the thirteen had no delayed recall of this. All were able to copy the Rey-Osterreith Figure, but six of the thirteen had no delayed recall of this. Eleven of the thirteen amnesic participants were also assessed on the Wisconsin Card Sorting test [24]. Their scores were below average on this task in relation to number of correct sorting categories (mean 3.45, SD 1.81) and number of perseverative errors (mean 8.82, SD 11.16).

2.3. Experimental materials

Three word lists were used, each containing 16 common concrete nouns, matched for word length and frequency, as described by Channon et al. [9], adapted for the German language. The clustered categories list (CC) contained words belonging to 4 superordinate categories (e.g. animals, vegetables etc.), presented sequentially so that all the words belonging to a single category followed each other. The randomised categories list (RC) similarly contained words belonging to 4 categories, but they were presented in randomised order. The uncategorised list (UC) contained words that were not closely related to each other, presented in randomised order.

The word lists and instructions were read to the participants. The procedure was the same for each of the 3 word lists, and order of presentation of the 3 lists was counterbalanced so that every possible order was given to each group, with all participants receiving all 3 lists. Before each list, participants were instructed to listen carefully to the words presented, because they would be asked to remember them later. Sixteen words were then presented serially at 2 sec intervals, total list du-

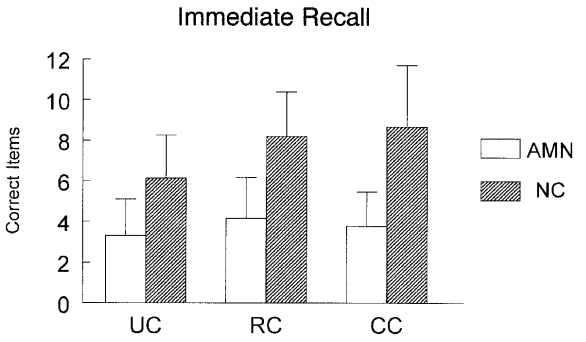

Fig. 1. Mean total scores (and SDs) for immediate recall in amnesic (AMN) and control participants (NC) (UC = uncategorised list, RC = random categories, CC = consecutive categories).

ration 31 secs. Immediately after each list, they were given 2 min to say as many words as they could remember, and these were recorded. After a filled delay of 2 min, the procedure was repeated for each of the remaining 2 word lists. Participants then engaged in other unrelated nonverbal tasks. Delayed recall was assessed after 30 min by asking them to recall as many words as they could from the 3 lists, in any order.

3. Results

The data were analysed using total scores for free recall of each list, and also in terms of serial position effects, primary and secondary memory, and recall organised by study order and by category. A significance level of 0.05 was used throughout.

3.1. Immediate recall of word lists

Mean total scores for recall for the two groups are shown in Fig. 1. ANOVA with one between-participants factor (group) and one within-participants factor (type of list) was used to examine immediate free recall of the three word lists. This showed a significant group × list interaction ($F = 4.14$, $df = 2, 52$, $p = 0.021$); there were also significant effects of group and list ($p < 0.0001$). Comparison for each list separately showed the groups to differ significantly on each of the three lists ($p \leqslant 0.001$). Comparison of the three lists for each group separately showed no significant effect of list for the amnesic group ($F = 1.35$, $df = 2, 24$, $p = 0.277$), and a significant effect of list for the control group ($F = 14.28$, $df = 2, 28$, $p < 0.0001$). T-tests showed that the control participants recalled both the CC and the RC list significantly better than the UC list ($p < 0.0001$); they did not differ significantly on the two categorised lists, CC and RC ($p = 0.411$). Since two of the amnesic group each scored 0 at immediate recall for one of the three lists (UC for one, RC for the other), this analysis was also run removing these two participants; this did not alter the pattern of the findings.

3.2. Use of categories

Since the amnesic group had been shown to recall significantly fewer words than the control group, the words were examined to see whether this deficit was paralleled by a smaller number of reproduced categories on the CC and RC lists. Category reproduction was defined as the number of categories from which at least one word was recalled. Mean scores are shown in Table I. ANOVA for immediate category reproduction from the two categorised lists revealed a significant effect of group ($F = 52.26$, $df = 1, 26$, $p < 0.0001$); neither the group × list interaction nor the effect of list was significant ($p > 0.1$). The amnesic group was poorer than the control group in category reproduction on both measures.

3.3. Serial position effects

The amnesic participants failed to show differential sensitivity to the nature of the list when total recall scores were used to compare performance. However, a more fine-grained analysis was carried out to examine serial position effects, and to see whether retrieval of early, middle and late items was differentially affected by type of list. Each list was divided into four groups of four words in order of presentation (see Fig. 2). ANOVA comparing the two groups with two within-subjects factors (list; serial position) showed a marginally significant group × list × serial position interaction ($F = 2.12$, $df = 6, 156$, $p = 0.054$); the effects of group, list and serial position were all significant ($p < 0.0001$).

Separate comparison for each group showed a significant effect of serial position for the amnesic group ($F = 13.77$, $df = 3, 36$, $p < 0.0001$), and no significant effect of list or list × serial position interaction ($p > 0.1$). T-tests for the three word lists combined showed that the amnesic participants showed a primacy effect such that the first four words were recalled significantly better than the middle two sets of words ($p = 0.004$ and $p < 0.0001$). They also showed a recency effect such that the last four words were re-

Table 1
Mean scores (and SDs) for category reproduction, errors, and primary and secondary memory

Group	Amnesic		Control	
	Mean	S.D.	Mean	S.D.
Categories				
RC immediate	2.08	0.95	3.73	0.46
CC immediate	2.08	0.76	3.60	0.63
RC delayed	0.46	0.66	2.67	0.98
CC delayed	0.38	0.65	2.73	0.80
Errors				
Intrusions	1.46	1.20	0.13	0.35
Extra-list errors immediate	1.38	2.60	0.60	0.63
Extra-list errors delayed	2.00	2.71	1.00	1.36
Primary memory				
UC	1.64	1.03	2.69	0.95
RC	1.82	1.08	3.00	0.82
CC	1.18	0.75	1.69	1.11
Secondary memory				
UC	1.64	1.69	3.54	2.30
RC	1.91	1.51	5.15	2.73
CC	2.45	1.75	6.92	2.93
Recall pairs grouped and not grouped by study presentation				
UC grouped	1.09	1.38	1.83	1.27
not grouped	1.27	1.27	3.42	1.93
RC grouped	0.55	0.82	1.75	1.14
not grouped	2.27	1.62	5.67	2.61
CC grouped	1.27	1.01	2.58	1.24
not grouped	1.36	1.21	5.33	2.87
Recall pairs grouped by category				
RC	1.27	1.56	2.00	2.00
CC	1.45	1.13	3.83	1.85

called better than the middle two sets of words (each $p < 0.0001$).

For the control group, there was a significant list x serial position interaction ($F = 6.52$, $df = 6, 84$, $p < 0.0001$). Comparison across lists for each serial position showed that the effect of list did not reach significance ($p = 0.079$) for primacy, but was significant for the two middle positions ($p < 0.0001$; $p = 0.007$), and was also significant for recency ($p = 0.011$). Inspection of mean scores showed that the effect of serial position was greatest for the uncategorised list, where there were marked differences between the two middle positions and the primacy/recency portions of the list; serial position had less impact on the two categorised lists, especially the CC list.

3.4. Primary and secondary memory

Immediate recall was also classified into primary and secondary memory using Tulving and Colotla's procedure [28] (see Table 1). This was based on the intra-trial retention interval (ITRI), which refers to the number of study list items presented and the number of words recalled between an item's presentation and recall. They classified items with a total ITRI of 7 or less as primary memory, and those with an ITRI of 8 or more as secondary memory. For instance, a word presented 12th/16 in the list in the present study would be classified as primary memory if it was one of the first three words recalled, and as secondary memory if it was recalled later than that. Tulving and Colotla noted that the measure of primary memory derived by this method was very similar to the measure obtained by using the last four items presented, regardless of order of recall. As a result of an administrative error, two participants from each group could not be included because the order of their free recall was not recorded in full. Comparison of the remaining participants for primary memory using ANOVA showed a significant effect of group ($F = 16.07$, $df = 1, 22$, $p = 0.001$) and of list ($F = 6.57$, $df = 2, 44$, $p = 0.003$); the group $\times$ list interaction was not significant ($p = 0.448$). When examined separately for each group, primary memory did not differ significantly between the lists for the amnesic group ($p > 0.1$). For the control group, t-tests showed primary memory scores to be significantly greater on

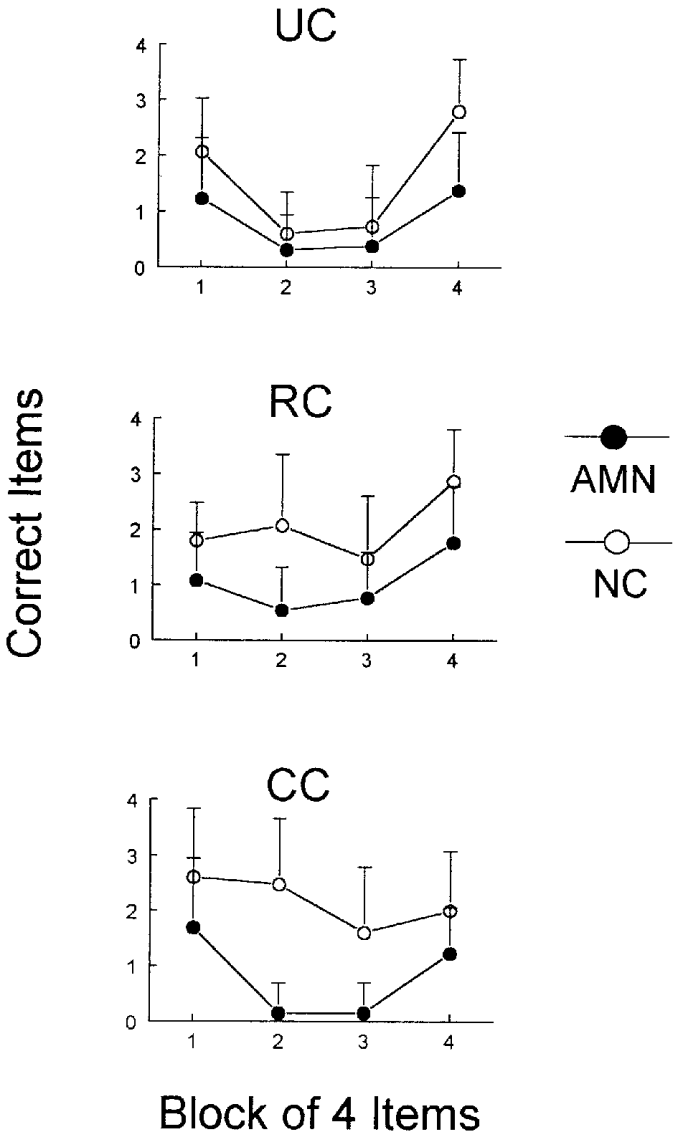

Fig. 2. Mean scores (and SDs) for serial position effects for amnesic (AMN) and control participants (NC) (UC = uncategorised list, RC = random categories, CC = consecutive categories).

the UC list compared to the RC list ($p = 0.005$) and to the CC list ($p = 0.012$); the two categorised lists did not differ significantly ($p = 0.416$). This analysis was also run removing the two amnesic participants who scored 0 for immediate recall for one of the three lists; this did not alter the pattern of the findings.

Comparison of secondary memory for the two groups showed a significant group × list effect ($F = 5.29$, $df = 2, 44$, $p = 0.009$); there were also significant effects of group ($p = 0.001$) and list ($p = 0.003$). Separate comparison for each group again showed no significant effect of list for the amnesic group ($p > 0.1$). The control group showed significantly better secondary memory for the CC list than for the RC list ($p = 0.01$), which in turn was recalled better than the UC list ($p = 0.02$).

3.5. *Effects of study position and category structure on order of recall*

For each list, order of recall was used to determine the number of pairs of words recalled which were presented together at study, and the number of pairs of words recalled which were not presented together at

study. A pair of items recalled in the order A-B were classified as a pair presented together at study if order of study presentation was either A-B or B-A (see Table 1). Any words recalled which were not on the study lists were ignored for the purposes of examining order of recall. As a result of the administrative error described above, two participants from the amnesic group and two from the control group could not be included in the analysis. ANOVA for the pairs presented together at study showed a significant effect of group ($F = 12.72$, $df = 1, 21$, $p = 0.002$); the effect of list did not reach significance ($F = 2.91$, $df = 2, 42$, $p = 0.066$); nor was there a significant group $\times$ list effect ($F = 0.43$, $df = 2, 42$, $p = 0.653$). The control group recalled more pairs of words in order of study than the amnesic group. The control group also remembered significantly more pairs of words which were not presented together at study ($F = 20.88$, $df = 1, 21$, $p < 0.0001$); the group $\times$ list interaction did not reach significance ($F = 2.35$, $df = 2, 42$, $p = 0.107$), but there was a significant effect of list ($F = 7.27$, $df = 2, 42$, $p = 0.002$). Separate analyses of the groups showed no significant effect of list for the amnesic group ($p = 0.143$), and a significant effect for the control group ($p = 0.005$), who recalled most non-ordered pairs for the RC list, then the CC, and then the UC list.

For the two categorised lists, order of recall was also used to determine the number of pairs of words recalled in order of category, and the number of pairs of words recalled which were not in order of category (see Table 1). Words that were not on the study lists were again ignored for the purposes of this analysis. For the CC list, which was presented in order of category, then category order often coincided with order of study presentation, whereas for the RC list, categorised items were never presented together at study. ANOVA for the number of pairs presented in category order showed a significant group $\times$ list interaction ($F = 4.74$, $df = 1, 21$, $p = 0.041$), and significant effects of group ($p = 0.016$) and list ($p = 0.015$). Unsurprisingly, both groups recalled more category pairs in order for the CC than for the RC list; this facilitation was significant for the control group ($p = 0.014$) but not for the amnesic group ($p > 0.1$).

3.6. Errors

The groups were compared on the number of errors they made in list recall (see Table 1). Errors were classified into two types: extra-list errors, i.e. words which did not belong in any of the lists; and intrusion errors, i.e. words recalled from the wrong list. T-tests showed no significant differences between the groups in the number of extra-list errors ($t = 1.13$, $df = 26$, $p = 0.267$). The amnesic participants did make significantly more intrusion errors than control participants ($t = 4.10$, $df = 26$, $p < 0.0001$).

3.7. Delayed recall of word lists

Control participants recalled 2.00 items (SD = 1.77) from the UC list, 4.60 items (SD = 2.41) from the RC list and 5.07 items (SD = 1.67) from the CC list. The amnesic group recalled 0.38 items (SD = 0.77) from the UC list, 0.69 items (SD = 1.03) from the RC list and 0.54 items (SD = 1.13) from the CC list.

Only simple analyses of delayed recall effects were carried out, since the total numbers of words recalled by the amnesic group was very low, such that floor effects limited the value of the comparison. When total delayed recall scores for each list were compared, the pattern of findings was similar to that for immediate recall. There was a significant group x list interaction ($F = 9.06$, $df = 2, 52$, $p < 0.0001$), and significant effects of group and list ($p < 0.0001$). Comparison for each list separately showed the amnesic group to be significantly poorer on each of the three lists ($\leqslant 0.005$). Examination of each group separately showed no significant effect of list for the amnesic group ($F = 0.73$, $df = 2, 24$, $p = 0.490$). For the control group, there was a significant effect of list ($F = 13.64$, $df = 2, 28$, $p < 0.0001$), with best performance on the CC list, followed by the RC and then the UC lists. Intrusion errors were only considered on immediate recall, since at delayed recall participants were asked to remember any words that they could from any of the lists. The groups did not differ significantly in the number of extra-list errors made on delayed recall ($t = 1.26$, $df = 26$, $p = 0.793$).

3.8. Frontal lobe contribution to performance

In view of the limited sample size, it was not possible to examine the effects of each amnesic aetiology separately. Since frontal lobe pathology might potentially contribute to the findings for the Korsakoff's subgroup, these participants were examined separately in comparison with the other amnesic aetiologies combined. Evidence consistent with differences in executive functioning was provided by the WCST, where data were available for six of the seven Korsakoff's and

five of the six non-Korsakoff's. T-tests showed the Korsakoff subgroup to perform significantly worse than the non-Korsakoff subgroup in terms of number of correct sorting categories ($t = 7.24$, $df = 9$, $p = 0.0001$) and number of perseverative errors ($t = 2.61$, $df = 9$, $p = 0.028$). However, Spearman rank correlations examining the relationship between immediate recall of the three lists and WCST performance across the amnesic group were not significant for either WCST categories (CC: $r = -0.02$, $p = 0.961$; RC: $r = -0.22$, $p = 0.516$; UC: $r = 0.21$, $p = 0.54$) or perseverative errors (CC: $r = -0.25$, $p = 0.466$; RC: $r = -0.02$, $p = 0.962$; UC: $r = -0.31$, $p = 0.361$).

When word list performance was examined for the three lists, no significant differences emerged between the subgroups in the patterns of immediate list recall, category usage, or errors. Moreover, examination of the Korsakoff's subgroup alone in relation to list recall showed a similar pattern of performance to the total amnesic group, since they did not perform significantly differently in recall of the categorised and uncategorised lists. However, since the subgroups were small, and the other aetiologies were mixed, this could clearly provide only a tentative exploration of this issue.

4. Discussion

The results showed that, as expected, the amnesic group performed significantly below the level of the control group on all recall measures. These findings replicated previous studies in the literature in demonstrating impairment in primacy, recency and middle parts of the list for amnesic participants. When serial position effects for the three lists were compared, both groups showed primacy and recency effects, but these interacted with list type only for the control group; similar differences were found for analysis of primary and secondary memory. Detailed analysis of the order of recall suggested that semantic relatedness did not influence recall strategy significantly for the amnesic group, but did show the expected effects upon recall for the control group.

When total immediate recall scores for each list were used as the index of performance, there was no evidence that the amnesic group was able to benefit from semantic relatedness, even immediately after list presentation. Unlike those of the control group, their recall scores did not vary significantly in relation to the type of list, despite slight differences in mean scores. This cannot readily be accounted for in terms of scaling differences between the groups, since there was no significant effect of list when the amnesic data were examined independently of the control group. Standard deviations for the amnesic group were larger relative to the mean scores than they were for the control group, suggesting greater variability in performance. The largest difference in mean scores between the patient and control groups was found for the clustered categories list, which offered the greatest opportunity to benefit from both the semantic category structure and the prior organisation of the words. Total recall for the two categorised lists did not differ significantly for the control participants, showing that they were able to make spontaneous use of the semantic category structure in the randomised categories list despite the lack of prior organisation of the words compared to the clustered categories list. The control group means were close to ceiling at immediate recall for usage of all four categories for both the categorised lists. When the groups were compared in their use of the four categories in each of the categorised lists, the amnesic participants were found to recall words from significantly fewer categories. After a thirty-minute time delay, recall performance for the amnesic group was minimal for all three lists. By contrast, the control group retained their superior performance for the two semantically-related lists compared to the unrelated list.

Closer examination of immediate recall of the lists was carried out by classifying the words into four serial positions. This revealed that the amnesic group did show significant primacy and recency effects in recall compared to middle items, although the size of these effects was attenuated compared to those of the control group. The amnesic group also showed similar U-shaped curves for all three lists, and no significant interaction with type of list, in contrast to the control group. For the control group, this U-shaped effect was attenuated particularly for the clustered categories list, where moderately good recall was shown for middle items, as well as those from the beginning and end of the list. Further support for this lack of sensitivity to type of list in the amnesic group was obtained by examining primary and secondary memory using Tulving and Colotla's definition [28], taking into account both list position and number of intervening items recalled. The control group, but not the amnesic group, showed a significant interaction between type of list and primary and secondary memory. Thus, the amnesic participants appeared unable to make effective use of semantic information to aid recall of middle items, even when the category words were clustered together.

Analysis of the order of word recall by the two groups cast further light on the nature of their organisation of the study lists. The control group recalled more pairs organised by order of presentation at study than the amnesic group, and also recalled more pairs not in order of presentation. Whilst type of list did not differentially affect the number of pairs recalled by the amnesic group, the control group recalled more pairs that were not in order of study presentation from the two semantically-organised lists than from the non-semantically-organised list. Since the CC list was presented in clustered order of category, study order frequently coincided with category order for this list, whereas these never coincided for the RC list; a greater number of categorised pairs would therefore be expected by chance from the CC than from the RC list. When the number of pairs organised by category was compared, the control group showed the expected effect and derived significantly greater benefit from the CC list compared to the UC list, whereas the amnesic group did not benefit significantly. These results provide further evidence of failure by the amnesic group to make use of the semantic structure of the lists to organise their recall in relation to the category structures.

The two groups did not differ significantly in the number of extra-list errors made, i.e. words reported which were not on the lists, and these were infrequent for both groups. The amnesic group made more intrusion errors than the control group, i.e. they were more likely to recall words from the wrong list, although these errors were again relatively infrequent. Although the absolute number of intrusion errors was low even for the amnesic group, it represented a relatively substantial proportion of the overall amnesic output, which was also low. Despite the counterbalancing of order of list presentation, the use of three separate lists could have disadvantaged the amnesic group more than the control group because of interference effects. However, recent evidence suggests that interference effects in effortful retrieval processes do not provide a satisfactory explanation of amnesic performance deficits [19].

The failure to demonstrate any beneficial effects of semantic relatedness on immediate recall in amnesia in the present study contrasted with some studies that have reported such effects (e.g. [3,20]). Other studies (e.g. [18]) have reported recall of semantically-related and unrelated words to be similar in amnesia after a brief delay (twenty seconds), but found forgetting of the semantically-related words to be faster after three minutes than that of the control group, whilst forgetting rates for unrelated words were comparable for the two groups. Isaac and Mayes interpreted their data in terms of normal semantic encoding but relatively rapid forgetting of complex associations formed for the semantically-related material in the amnesic group. Unlike some previous studies, the present study did not extend the study time for the amnesic group in order to equate initial levels of learning with those of the control group. Hence, immediate recall of material in the present study was based on far briefer total exposure times for the amnesic participants than those used in some studies, and it may therefore be relatively difficult to detect weak effects of semantic encoding/retrieval. Nevertheless, analysis of the order of presentation and the lack of significant differences between the lists gives little indication that the amnesic group made use of semantic grouping strategies to organise their encoding/retrieval in recalling the semantically-related materials. Differences in the experimental paradigms used may contribute to the variable findings in relation to semantic encoding/retrieval. It is also possible that differences in pathology or the extent of damage in the amnesic participants used in the various studies is an important contributory factor.

Recent evidence suggests that prefrontal cortex rather than medial temporal or diencephalic structures may primarily contribute to the organisational aspects of strategy use (e.g. [14,26]). Semantic organisation of encoding/retrieval of lists of semantically-related stimuli requires a degree of effortful recall which may have been lacking in the amnesic group. Weak performance on the Wisconsin Card Sorting Test for the Korsakoff's subgroup in the present study is consistent with the possibility of frontal lobe involvement for these participants. However, there was no direct evidence that this was linked to their use of encoding/retrieval strategies, since they did not perform worse than the remaining amnesic participants in their pattern of recall or errors, and word list recall was not significantly correlated with WCST performance. Another potential factor in relation to the use of semantic information is that the amnesic participants may have failed to detect the inherent semantic organisation of the two categorised lists. In order to become aware of the semantic relationships between the words, serial comparison of the items would be needed. In the case of the randomised categories list, this requires comparison of quite different parts of the list, whereas fewer resources should be needed to detect the semantic relationships between the consecutively presented categorised items in the clustered categories list. However, there may be a threshold below which impaired capacity to retain information does not

permit adequate serial comparison of the items and retention of the products of this, resulting in inadequate spontaneous semantic analysis. The slight facilitatory effect reported by Cermak and Reale [3] and by Cermak et al. [6] resulted from individually cueing each word for level of processing, rather than making use of semantic relatedness between different list items, as in the present study. De-briefing would have been useful here in assessing their degree of awareness of the differing semantic properties of the lists.

In summary, the present findings replicated previous work demonstrating impairment in amnesic participants in memory for semantically-related and unrelated word lists. Impairments were found when primacy, recency and middle-list effects were examined, and also when primary and secondary memory scores were considered. Detailed inspection of recall strategies using order of recall and serial position effects failed to detect any significant effects of semantic relatedness on performance in the amnesic participants. Semantic encoding ability in amnesia may be limited to analysis of individual items for transient periods of time, with restricted ability to perform and store the necessary comparative operations needed for the encoding of semantically-related materials.

References

[1] A.D. Baddeley and E.K. Warrington, Amnesia and the distinction between long- and short-term memory, *Journal of Verbal Learning and Verbal Behaviour* **9** (1970), 176–189.

[2] W. Boecher, Erfahrungen mit dem Wechslerschen Gedaechnistest (Wechsler Memory Scale) bei einer deutschen Versuchsgruppe von 200 normalen Vpn [Findings using the Wechsler Memory Scale in a German sample of 200 healthy volunteers], *Diagnostica* **9** (1963), 56–68.

[3] L.S. Cermak and L. Reale, Depth of processing and retention of words by alcoholic Korsakoff patients, *Journal of Experimental Psychology: Human Learning and Memory* **4** (1978), 165–174.

[4] L.S. Cermak, N. Butters and J. Gerrein, The extent of the verbal encoding ability of Korsakoff patients, *Neuropsychologia* **11** (1973), 85–94.

[5] L.S. Cermak, M. Naus and L. Reale, Rehearsal and organizational strategies of alcoholic Korsakoff patients, *Brain and language* **3** (1976), 375–385.

[6] L.S. Cermak, B. Uhly and L. Reale, Encoding specificity in the alcoholic Korsakoff patient, *Brain and Language* **11** (1980), 119–127.

[7] L.S. Cermak, M. Verfaellie, S. Lanzoni, M. Mather and K.A. Chase, Effect of spaced repetitions on amnesia patients' recall and recognition performance, *Neuropsychology* **10** (1996), 219–227.

[8] S. Channon, J.E. Baker and M.M. Robertson, Effects of structure and clustering on recall and recognition memory in clinical depression, *Journal of Abnormal Psychology* **102** (1993), 323–326.

[9] S. Channon, I. Daum and C.E. Polkey, The effect of categorisation on memory after temporal lobectomy, *Neuropsychologia* **27** (1989), 777–785.

[10] G. Dahl, *Reduzierter Wechsler-Intelligenztest [Short version of the Wechsler Intelligence test]*, Hain, Meisenheim/Glan, FRG, 1972.

[11] I. Daum, H. Ackermann, M.M. Schugens, C. Reimold, J. Dichgans and N. Birbaumer, The cerebellum and cognitive functions in humans, *Behavioral Neuroscience* **107** (1993), 411–419.

[12] I. Daum, M.M. Schugens, S. Spieker, U. Poser, P.W. Schoenle and N. Birnbaumer, Memory and skill acquisition in Parkinson's disease and frontal lobe dysfunction, *Cortex* **31** (1995), 413–432.

[13] D.C. Delis, J.H. Kramer, E. Kaplan and B.A. Ober, *California Verbal Learning Test Manual*, The Psychological Corporation, San Antonio, 1987.

[14] P.J. Eslinger and L.M. Grattan, Altered serial position learning after frontal lobe lesions, *Neuropsychologia* **32** (1994), 729–739.

[15] P.C. Fletcher, C.D. Frith and M.D. Rugg, The functional neuroanatomy of episodic memory, *Trends in Neuroscience* **20** (1997), 213–218.

[16] F.B. Gershberg and A.P. Shimamura, Impaired use of organizational strategies in free recall following frontal lobe damage, *Neuropsychologia* **13** (1995), 1305–1333.

[17] A. Incisa della Rocchetta and B. Milner, Strategic search and retrieval inhibition: the role of the frontal lobes, *Neuropsychologia* **31** (1993), 503–524.

[18] C.L. Isaac and A.R. Mayes, Rate of forgetting in amnesia: Recall and recognition of word lists at different levels of organisation, *Journal of Experimental Psychology* **25** (1999), 963–977.

[19] A.R. Mayes and J.J. Downes, What do theories of the functional deficit(s) underlying amnesia have to explain? in: *Theories of Organic Amnesia*, A.R. Mayes and J.J. Downes, eds., Erlbaum, Hove, England, 1997, pp. 3–36.

[20] A.R. Mayes, J.J. Downes, M. Shoqeirat, C. Hall and H.J. Sagar, Encoding ability is preserved in amnesia: evidence from a direct test of encoding, *Neuropsychologia* **31** (1993), 745–759.

[21] A.R. Mayes, P.R. Meudell and D. Neary, Must amnesia be caused by either encoding or retrieval disorders? in: *Practical Aspects of Memory*, M.M. Gruneberg, P.E. Morris and R.N. Sykes, eds., Academic Press, London, 1978, pp. 712–719.

[22] P.R. Meudell and A.R. Mayes, Do alcoholic amnesic patients passively rehearse verbal information? *Brain and Language* **10** (1980), 189–204.

[23] B. Milner, Clues to the cerebral organisation of memory, in: *Cerebral Correlates of Conscious Experience*, P.A. Buser and A. Rougeul-Buser, eds., Elsevier, Amsterdam, 1978, pp. 139–153.

[24] H.E. Nelson, A modified card-sorting test sensitive to frontal lobe defects, *Cortex* **12** (1976), 313–324.

[25] A. Rey, L'examen psychologique dans les cas d'encéphalopathie traumatique [The psychological examination in cases of traumatic brain damage], *Archives de Psychologie* **28** (1941), 286–340.

[26] T. Shallice, P. Fletcher, C.D. Frith, P. Grasby, R.S.J. Frackowiak and R.J. Dolan, Brain regions associated with acquisition and retrieval of verbal episodic memory, *Nature* **368** (1994), 633–635.

[27] D.T. Stuss, M.P. Alexander, C.L. Palumbo, L.S. Buckle and J. Pogue, Organizational strategies of patients with unilateral or

bilateral frontal lobe injury in word list learning tasks, *Neuropsychology* **8** (1994), 355–373.
[28] E. Tulving and V.A. Colotla, Free recall of trilingual lists, *Cognitive Psychology* **1** (1970), 86–98.
[29] E.K. Warrington and L. Weiskrantz, Amnesia: a disconnection syndrome? *Neuropsychologia* **20** (1982), 233–248.