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Mechanisms underlying memory impairment in schizophrenia

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ABSTRACT

Background. The purpose of this experiment was to investigate mechanisms underlying commonly-observed verbal memory impairments in schizophrenia, and especially the hypothesized encoding deficit.

Methods. A verbal memory task was administered to 38 patients with schizophrenia and 38 normal controls. Three functions involved in long-term memory – encoding, early phase of storage, retrieval – were investigated. First, non-organizable lists were compared to semantically-organizable lists in a free recall task, in order to vary encoding conditions. Superficial encoding (measured by a 'sequence' index) and deep encoding (measured by a categorization index) were assessed. Secondly, early storage was investigated by varying the delay between learning and recall. Lastly, cues were provided for organizable lists (semantic cues) and non-organizable lists (recognition sheet), in order to vary retrieval conditions.

Results. An analysis of variance revealed an interaction between type of list (organizable, non-organizable) and group, showing that patients used organization less than controls. A further analysis showed that deep encoding was impaired. Also, although the propensity to use superficial encoding was unimpaired, its efficiency was less. The analysis of variance revealed no interaction with delay or with either type of cue. A correlation was found between deep processing and memory performance in both groups.

Conclusions. A major deficit in encoding appeared in the patient group, with a lesser use of deep encoding and a lesser efficiency of superficial encoding. On the other hand, the early phase of storage and the retrieval function seemed unaffected. Overall memory performance appeared to be related to the depth of encoding.

INTRODUCTION

Memory deficits have received growing attention in the field of schizophrenia research (McKenna *et al.* 1995, for a review). Studies by Goldman-Rakic (1991) and Park & Holzman (1992) have shown a link between prefrontal dysfunction and memory deficit in schizophrenia. However, the perturbations in cognitive processes underlying these memory deficits remain unclear. Memory can be subdivided into many different components, often dichotomous (e.g. declarative *v.* procedural memory, explicit *v.* implicit memory, long-term *v.* short-term memory). Further, one can distinguish multiple cognitive functions involved in memory (e.g. encoding, rehearsal, retrieval, recall, recognition, etc.) that can be assessed by tools from the paradigms of cognitive psychology. These permit a more focused approach to the investigation of which memory functions are specifically impaired in patients.

The cognitive approach has been used to investigate recall *versus* recognition in schizophrenic patients. Recall refers to the ability to retrieve actively the information sought from memory stores, whereas recognition involves determining whether a particular stimulus has previously been learned. Some studies found impaired recall along with normal recognition in

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patients relative to controls (Koh, 1978; Beatty *et al*. 1993). A similar pattern of impairment has also been observed in patients with frontal lobe lesions (Jetter *et al*. 1986). However, other studies have found recognition deficits in schizophrenic patients (Gold *et al*. 1992), especially when more severely disturbed patients were assessed (Calev & Monk, 1982; Calev *et al*. 1983).

A greater memory deficit in schizophrenic patients than in controls has been reported when a delay intervened between learning and recall stages. This appeared in both verbal (Calev *et al*. 1983; Sengel & Lovallo, 1983; Beatty *et al*. 1993) and visuospatial performance (Park & Holzman, 1992; Keefe *et al*. 1995). As regards verbal memory however, all these storage deficits were found in tasks with delays of at least 30 min.

It has often been argued that deficits in recall in schizophrenic patients result from an inability to encode information in an organized way (Koh, 1978). Indeed, it has been shown that lists of words organizable in semantic categories, but presented in a random order, were not recalled better by schizophrenic patients than were non-organizable lists (Gold *et al*. 1992). In addition, providing the name of the categories as a cue for the recall of such lists was not helpful (McClain, 1983), suggesting that the information had not been semantically encoded. On the other hand, the presentation of the items category by category, a process that compels organized encoding, led to a significant improvement in free recall in these patients (Gold *et al*. 1992). Moreover, providing such a cue led to a significant improvement in recall when semantic encoding was controlled (Calev *et al*. 1983; McClain, 1983; Sengel & Lovallo, 1983). The deficit at the encoding has been born out by evidence showing less organization in free recall in schizophrenic patients than in controls (Calev *et al*. 1983, 1987; Calev, 1984*a*, *b*).

In order to determine more accurately which of the cognitive processes underlying memory are perturbed in schizophrenic patients, three long-term memory functions can be separately considered: encoding, storage and retrieval. The results of all the above-mentioned studies show a deficit in encoding. A deficit in storage has also been found in some cases. On the contrary, no clear deficit in retrieval has been identified. To our knowledge, however, all three functions have never been studied at the same time in the same sample of schizophrenic patients, which would enable better assessment of the differential contribution of each of them to the memory deficit.

The purpose of the present study was first to confirm that a major deficit in encoding occurs in a verbal memory task in schizophrenic patients. We then wished to determine more accurately the mechanisms through which this encoding deficit occurred, and specifically, to investigate the ability to carry out superficial *versus* deep processing of the items. Superficial processing of the list was assessed by analysing the use of sequences by patients during recall. Deep processing, on the other hand, was assessed by the ability to encode organizable lists according to semantic properties. To investigate deep processing, both non-organizable lists and semantically-organizable lists were presented. A lesser benefit from the organization in the schizophrenic sample, showing a deficit in deep encoding, was expected. Furthermore, we hypothesized that overall memory performance would be directly related to the efficiency of deep encoding.

To investigate the storage function, delayed recall was compared to immediate recall. We expected an interaction between group and delay, revealing a deficit in the storage function in the schizophrenic sample. It should be noted that since our delay was short, only the early phase of storage was investigated. Lastly, the retrieval function was investigated by providing cues. As regards organizable lists, semantic cues were given after free recall. As regards non-organizable lists, a recognition task was administered after free recall. Recognition provides a maximal cue for remembering the items, since no retrieval function is necessary. It was predicted that the benefit from the semantic cue or from the recognition sheet would not be greater in the schizophrenic group, showing that the retrieval function was unaffected.

METHOD

Participants

Thirty-eight in-patients meeting DSM-IV criteria for schizophrenia were included in the schizophrenic sample (gender, 26 M, 12 F; age, mean = 34·4, S.D. = 10·3; years of education,

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mean = 12·5, S.D. = 2·8). They were recruited from the Schizophrenia Research Unit (SRU) at the New York State Psychiatric Institute and Creedmore Psychiatric Center. All were on antipsychotic medication and were at fixed doses at testing.

Thirty-eight normal controls matched for gender, age and years of education were recruited from a pool of normal volunteers from the Mental Health Clinical Research Center at the New York State Psychiatric Institute and from advertising (gender, 24 M, 14 F; age, mean = 37·7, S.D. = 9·7; years of education, mean = 13·0, S.D. = 1·9). They were screened to rule out any current or recent psychiatric history, alcohol abuse or drug addiction.

Materials

Six equivalent lists of 16 substantive, highly frequent (Thorndike & Lorge, 1994) monosyllabic or bisyllabic words were constructed. Two of the lists were organizable in four different semantic categories, with four words in each category. The sixteen words of these organizable lists were randomized, with the requirement that two items of the same category never follow one another. One of the non-organizable lists and one of the organizable lists was used for immediate free recall. One of each was also used for delayed free recall. The two remaining non-organizable lists were used for the recognition task. Two recognition sheets were prepared, each including the 16 words of the recognition list mixed with 16 distractors equivalent in length and frequency. Lastly, a stem completion sheet was prepared to assess implicit memory. It displayed the first three letters of 20 of the words presented in the two non-organizable lists used for free recall.

Procedure

Free recall

Subjects were given a sheet displaying a list of 16 words, and told that they had 30 s to learn it. They were required to read the words aloud at least once, so that the experimenter could make sure that all the words had been processed. Then, either immediately or after a 1-min delay, they were given a sheet with 16 empty spaces, and required to write down as many words as they could remember from the list, in any order and without any time limit. In the delayed condition, subjects were asked to read out loud a passage of a book for 1 min. This procedure was repeated for the four lists; one practice non-organizable list was given before the first run. The attribution of each list to the immediate or delayed condition was counterbalanced among subjects. The order of administration of the four conditions (non-organizable immediate, non-organizable delayed, organizable immediate, organizable delayed) was counterbalanced as well. Subjects were not warned of the possible organization in semantic categories during the learning stage. The number of correctly recalled words in each list was tallied. The number of perseverations (recall of a word from a former list) and intrusions (erroneous recall of a word that had not been presented) was also recorded. A 'sequence index' was computed for the recall of each of the four lists, defined as the proportion of items recalled in their order of presentation out of the total number of recalled items. It reflected the propensity to learn the words of the list by heart, which indicates superficial encoding. In addition, a 'categorization index' was computed for the recall of the two semantically-organizable lists, defined as the number of items following an item of the same semantic category in the recalled list divided by the number of such possible associations. It reflected the propensity to encode words according to their semantic properties, which indicates deep encoding (Koh, 1978). The efficiency of these strategies was then assessed by the total number of items recalled, either sequentially or according to the category.

Semantic cued recall

After the free recall of the organizable lists, subjects were given a sheet providing the name of the four semantic categories in the list, followed by four empty spaces. They were asked to use it as a cue to recall the words of the list a second time.

Implicit recall

After the recall of the four lists, subjects were given the stem completion sheet. They were instructed to complete as quickly as possible each string of three letters by the first English word that would come to their mind. They were not told that each stem could be completed by a word that had been previously learned. Time

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was recorded to put pressure on the subjects and encourage them to write down the first available word. The number of stems completed by a word that was actually in the previous learned lists was recorded.

Recognition

The last two non-organizable lists were learned in the same conditions as the free recall. The attribution of the two lists to the immediate or delayed conditions was counterbalanced among subjects, as well as the order of condition (immediate recognition, delayed recognition). After learning, subjects were given the recognition sheet and required to check the words that they recognized from the previously-learned list. The measures were the number of correctly recognized words and the number of false alarms (erroneous recognition of words that had not been presented in the learning phase). In addition, in order to get a measure of accuracy in recognition independent of response bias, the index of accuracy Pr derived from the Two-High Threshold theory (Corwin, 1994) was computed for both immediate and delayed recognitions.

Short-term memory

The forward digit span and backward digit span of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1981) were administered to assess short-term memory. Increasingly long series of digits had to be repeated, either in the same or in reverse order.

Data analysis was carried out by means of the SPSS for Windows program (SPSS, 1995). Pearson product-moment coefficient was used for correlations. An alpha level of 0·05 was used for all statistical tests.

RESULTS

The number of recalled words in the different conditions of recall (e.g. free recall of non-organizable lists, free recall of organizable lists, cued recall of organizable lists, either in immediate or delayed recall) for both groups is shown in Fig. 1.

As a first step, a variance analysis was conducted on the total number of recalled words. It involved Diagnosis (schizophrenic patients *versus* normal controls) as a between-subject factor and Condition of recall (free recall of non-organizable lists, free recall of organizable lists, cued recall of organizable lists) and Delay (immediate, delayed) as within-subject factors. Main effects for Diagnosis ($F(1, 74) = 54{\cdot}6$, $P < 0{\cdot}0001$), Condition of recall ($F(2, 148) = 121$, $P < 0{\cdot}0001$) and Delay ($F(1, 74) = 56{\cdot}8$, $P < 0{\cdot}0001$) were revealed. No Diagnosis × Delay interaction appeared. The Condition of recall × Delay interaction was significant ($F(2, 148) = 5{\cdot}82$, $P < 0{\cdot}01$) as well as the Diagnosis × Condition of recall interaction ($F(2, 148) = 13{\cdot}7$, $P < 0{\cdot}0001$). This latter result led us to conduct separate analyses of recall performance in both free recall and cued recall conditions.

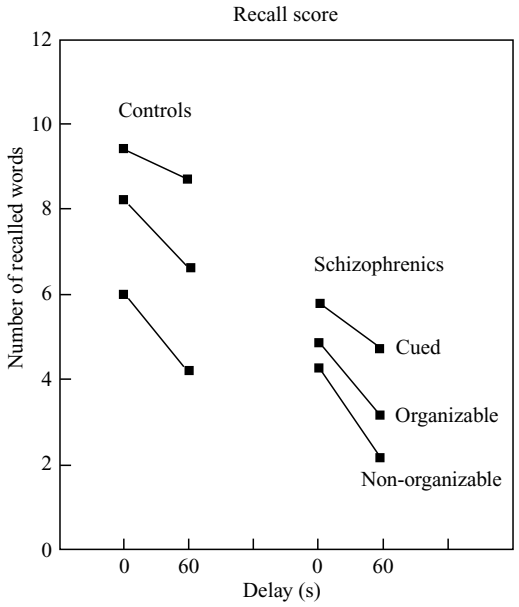


FIG. 1. Number of recalled words in the different conditions of recall (free recall of non-organizable lists, free recall of organizable lists, cued recall of organizable lists) and delay (immediate recall, delayed recall) in normal controls and schizophrenic patients.

Free recall

(*a*) *Number of recalled words*

Superficial processing (*sequential recall*)

A first analysis of the recalled words as a function of their position in the list was carried out on the two immediately-recalled lists (one non-organizable and one organizable). The lists involved in delayed recall were not considered since the recency effect concerns immediate memory. The organizable and non-organizable lists were separately analysed because organization was expected to affect sequential recall. The 16 items of the lists were grouped into couples of

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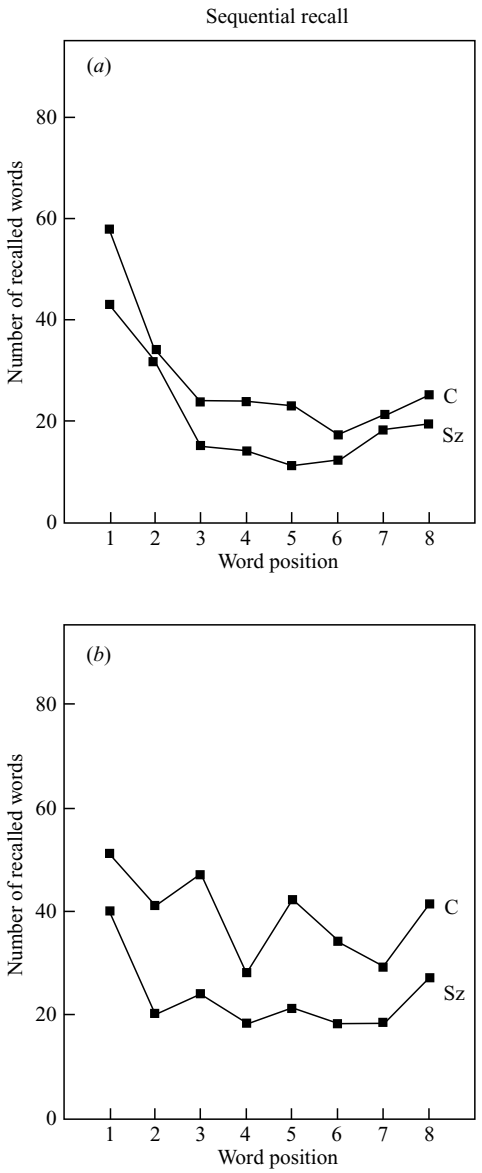


FIG. 2. Number of recalled words in: (*a*) non-organizable; and (*b*) organizable lists as a function of their position in the list in normal controls (C) and schizophrenic patients (Sz).

items, leading to eight word positions. Results are illustrated by Fig. 2.

The overall shapes of the curves indicate that both primacy effect (i.e. better recall of the first words of the list) and recency effect (i.e. better recall of the last words of the list) were observed in the same way in schizophrenic group as in normal controls. This suggests that superficial sequential processing of the items was carried out in the normal way. It can be observed that the organization of the list into semantic categories did not disturb the curve of sequential recall in schizophrenic patients, suggesting that organization was not used by this group. On the other hand, organization of items clearly affected the shape of the curve in controls. Accordingly, there was a significant interaction between Organization and Position in controls ($F(7, 259) = 2{\cdot}54$, $P < 0{\cdot}02$), whereas the interaction was not significant in patients.

Deep processing (*categorization*)

A variance analysis was carried out with Diagnosis as a between-subject factor, and Organization (non-organizable lists, organizable lists) and Delay as within-subject factors. Main effects of Diagnosis ($F(1, 74) = 40{\cdot}6$, $P < 0{\cdot}0001$), Delay ($F(1, 74) = 82{\cdot}4$, $P < 0{\cdot}0001$) and Organization ($F(1, 74) = 72{\cdot}9$, $P < 0{\cdot}0001$) were revealed. There was no significant Diagnosis × Delay, Organization × Delay or Diagnosis × Organization × Delay interaction. The Diagnosis × Organization interaction, however, was significant ($F(1, 74) = 16{\cdot}8$, $P < 0{\cdot}0001$), showing that schizophrenic patients benefited from the organization of the list less than controls. This last result is illustrated by Fig. 3*a*. Table 1 shows the scores on the other measures yielded by the free recall task.

(*b*) *Indices of strategy*

Superficial processing (*sequential recall*)

A variance analysis on the sequence index in the four lists revealed no main effect for Diagnosis. However, the sequence index was lower in the organizable list than in the non-organizable list for immediate recall in controls (11·5% *v.* 29·2%, $F(1, 37) = 8{\cdot}31$, $P < 0{\cdot}01$). In contrast, it remained steady in schizophrenic patients (23·6% *v.* 28·4%, $F(1, 37) = 0{\cdot}65$, NS). The difference between patients and controls in the organizable list (11·5% *v.* 23·6%) was significant ($F(1, 74) = 4{\cdot}90$, $P < 0{\cdot}05$). This confirms the observation (see Fig. 2) that schizophrenic patients keep a sequential strategy of encoding even when organizable lists are to be learned.

Deep processing (*categorization*)

A variance analysis on the categorization index in immediate and delayed conditions revealed a

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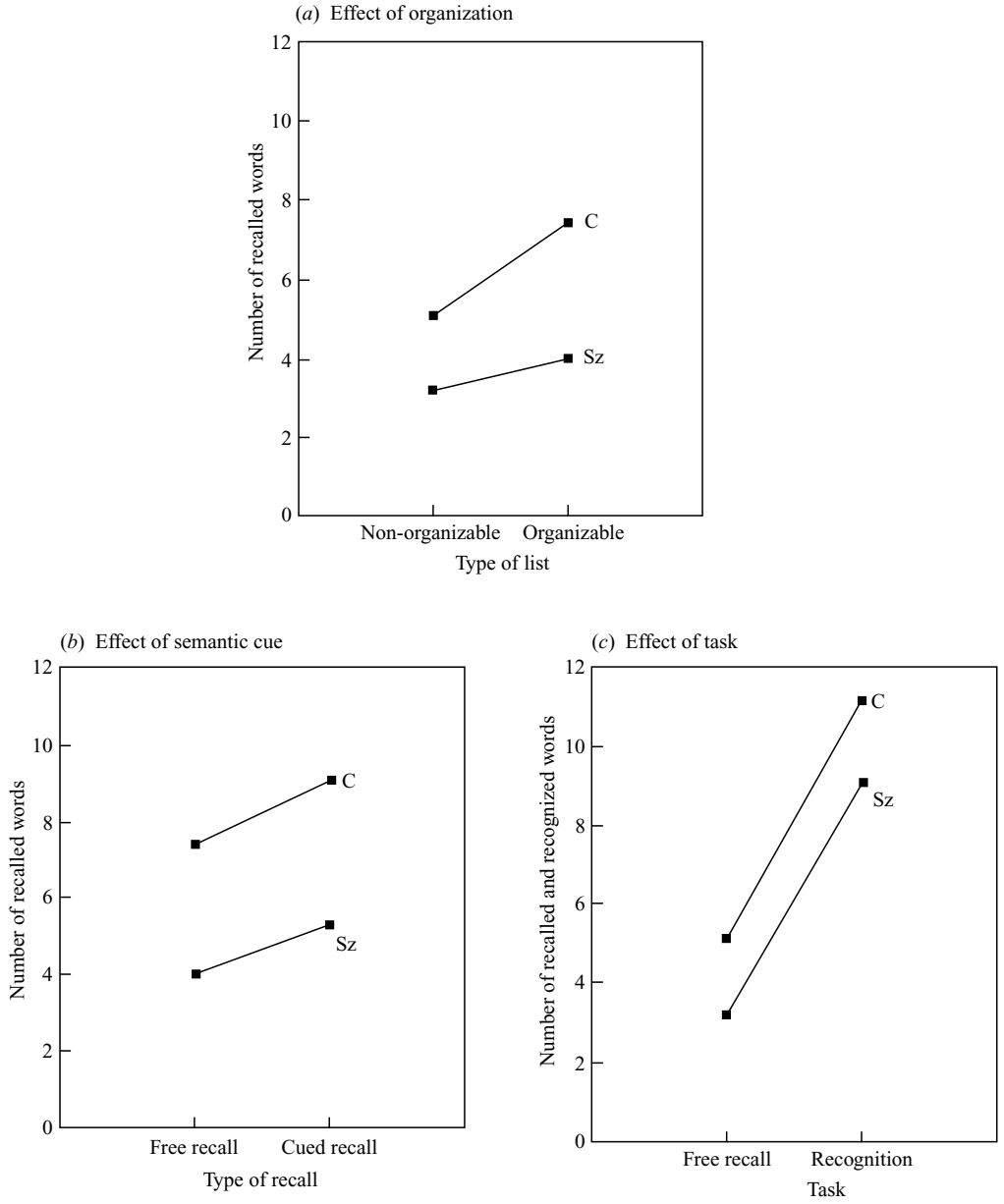


FIG. 3. (*a*) Number of recalled words as a function of the type of list (non-organizable, organizable) in normal controls (C) and schizophrenic patients (Sz). (*b*) Number of recalled words as a function of the type of recall (free recall, cued recall) in the organizable lists in normal controls and schizophrenic patients. (*c*) Number of recalled and recognized words as a function of the task (free recall, recognition) in the non-organizable lists in normal controls and schizophrenic patients.

main effect for Diagnosis ($F(1, 74) = 6{\cdot}9$, $P < 0{\cdot}05$), showing that schizophrenic patients had a lower percentage of categorization than controls. This result corroborates the interpretation of a lesser utilization of organization in encoding.

(*c*) *Measures of strategy efficiency*

Superficial processing

A variance analysis was carried out on the number of items involved in sequential recall

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(i.e. recalled in their order of presentation). A main effect for Diagnosis was revealed ($F(1, 74) = 8{\cdot}47$, $P < 0{\cdot}005$). Thus, even though the propensity to use the sequential strategy was not impaired in schizophrenic patients, they were less efficient than controls in that they were able to recall smaller or fewer sequences of words.

Deep processing

Variance analyses were conducted on the number of categories recalled in the organizable lists (only the categories within which at least two consecutive items were recalled were considered, since it was assumed that the other ones were not identified as categories) and the mean number of recalled items within these categories. Main effects for Diagnosis emerged on both variables (categories recalled: ($F(1, 74) = 23{\cdot}6$, $P < 0{\cdot}0001$; items per category: $F(1, 74) = 21{\cdot}7$, $P < 0{\cdot}0001$). No Diagnosis × Delay interaction appeared in either variable.

Table 1. *Means scores on free recall measures in schizophrenic patients and normal controls* (*number of perseverations and intrusions; mean sequence index and number of words sequentially recalled; mean categorization index*, *number of categories recalled and number of recalled items per category in the organizable lists*)

Measures	Schizophrenic patients ($N = 38$)	Normal controls ($N = 38$)	Significance level
Perseverations	2·03 (1·94)	1·53 (1·61)	NS
Intrusions	2·16 (3·20)	1·84 (1·85)	NS
Mean sequence index	0·19 (0·18)	0·18 (0·12)	NS
Mean number of words in sequence	0·97 (0·82)	1·57 (0·95)	$P < 0{\cdot}005$
Mean categorization index	0·40 (0·36)	0·60 (0·30)	$P < 0{\cdot}05$
Mean number of category recalled	0·72 (0·73)	1·75 (1·08)	$P < 0{\cdot}0001$
Mean number of items by category	1·26 (1·13)	2·33 (0·85)	$P < 0{\cdot}0001$

Table 2. *Correlations between strategy indices in free recall* (*sequence index*, *categorization index*) *and measures of memory efficiency* (*total free recall*, *Pr*) *in schizophrenic patients* (N = 38) *and normal controls* (N = 38)

		Total free recall	Pr (recognition)
Schizophrenic patients	Sequence index	−0·09	−0·14
	Categorization index	0·60***	0·38*
Normal controls	Sequence index	0·13	0·05
	Categorization index	0·49**	0·17

* $P < 0{\cdot}05$; ** $P < 0{\cdot}005$; *** $P < 0{\cdot}0001$.

(d) Role of these strategies in memory efficiency

In order to compare the role of both sequential and categorization encoding strategies on memory performance, correlations were computed in both groups between mean sequence index, mean categorization index and the performance in free recall and recognition. Results are presented in Table 2.

It appears that the mean sequence index was significantly correlated with none of these memory measures in either sample. On the contrary, the mean categorization index showed significant correlations with free recall in the control sample, and with the two memory measures in the schizophrenic sample.

Semantic cued recall

A variance analysis was conducted on the number of recalled items in the organizable lists with Diagnosis as a between-subject factor, and Cue (free recall, cued recall) and Delay as within-subject factors. Main effects of Diagnosis ($F(1, 74) = 63{\cdot}7$, $P < 0{\cdot}0001$), Cue ($F(1, 74) = 61{\cdot}5$, $P < 0{\cdot}0001$) and Delay ($F(1, 74) = 23{\cdot}1$, $P < 0{\cdot}0001$) were revealed (see Fig. 1). The interaction between Cue and Delay was significant ($F(1, 74) = 9{\cdot}76$, $P < 0{\cdot}005$). There was no significant Diagnosis × Delay, Diagnosis × Cue or Diagnosis × Cue × Delay interaction. As expected, the lack of interaction between Diagnosis and semantic cue (see Fig. 3*b*) suggests that the retrieval function, at least with these specific stimuli, was not impaired in patients.

Recognition

The number of recognized words, the number of false alarms and the discrimination index Pr in both groups are shown in Table 3. In order to examine whether the retrieval cue provided by the recognition sheet was more helpful for schizophrenic patients than for controls, a variance analysis was conducted contrasting the number of recognized words in the recognition task with the number of recalled words of the

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Table 3. *Means scores on recognition, implicit memory and short-term memory measures in schizophrenic patients and normal controls*

Task	Measures	Schizophrenic patients ($N = 38$)	Normal controls ($N = 38$)	Significance level
Recognition	Recognized words (immediate)	9·32 (3·06)	11·87 (2·42)	$P < 0·0001$
	Recognized words (delayed)	8·76 (3·61)	10·45 (2·81)	$P < 0·05$
	False alarms (immediate)	2·21 (2·38)	1·37 (1·46)	NS
	False alarms (delayed)	2·89 (2·83)	2·23 (2·03)	NS
	Pr (immediate recognition)	0·45 (0·25)	0·66 (0·17)	$P < 0·0001$
	Pr (delayed recognition)	0·38 (0·26)	0·52 (0·23)	$P < 0·05$
Implicit memory	Stem completion	6·42 (3·49)	6·26 (3·67)	NS
Short-term memory	Forward digit span	6·05 (2·55)	7·71 (2·90)	$P < 0·01$
	Backward digit span	5·37 (2·0)	6·55 (2·64)	$P < 0·05$

two non-organizable lists in the free recall task. Diagnosis was the between-subject factor, Task (free recall, recognition) and Delay were the within-subject factors. Significant effects of Diagnosis ($F(1, 74) = 21·6$, $P < 0·0001$), Delay ($F(1, 74) = 58·9$, $P < 0·0001$) and Task ($F(1, 74) = 346·9$, $P < 0·0001$) emerged. There was no significant Diagnosis × Delay or Diagnosis × Task interaction. The Task × Delay interaction was significant ($F(1, 74) = 8·84$, $P < 0·005$). Follow-up tests showed that neither in the immediate nor in the delayed condition did a significant Diagnosis × Task interaction emerge. In other words, schizophrenic patients did not benefit from the recognition sheet any more than controls did (see Fig. 3*c*). Again, this result suggests, as expected, that their smaller free recall score did not stem from a deficit in the retrieval function.

In order to determine whether the process of recognition *per se* was impaired in schizophrenia, a further variance analysis was conducted on the index of discrimination Pr in immediate and delayed recognition tasks. As expected, a main effect of Diagnosis ($F(1, 74) = 14·5$, $P < 0·0001$) appeared, indicating a deficit in schizophrenic patients in recognition, probably due to the impairment at the encoding. The effect of Delay was also significant ($F(1, 74) = 20·7$, $P < 0·0001$) without interaction with Diagnosis.

Implicit memory

There was no significant difference in patient and control groups on the number of stems completed by a previously learned word (see Table 3), suggesting that implicit memory is not impaired in schizophrenia.

Short-term memory

Both forward digit span and backward digit span were significantly impaired in the schizophrenic group (see Table 3), suggesting a decrement in short-term memory capacity.

DISCUSSION

The purpose of this experiment was to confirm, in a verbal memory task, that the major memory impairment in schizophrenic patients occurs during encoding (Koh, 1978; Calev *et al.* 1983), and then to better determine which underlying processes are involved in this impairment. Our results clearly support the encoding deficit hypothesis: the significant interaction between diagnosis and type of lists (organizable *v.* non-organizable) indicated that schizophrenic patients did not use the semantic properties of the words to encode the information as much as controls. Even when given appropriate retrieval cues patients failed to benefit from organization, which suggests that the items had not been properly encoded in the first place. This failure to take advantage of organization has previously been observed (for a review, see Cutting, 1985; Gold *et al.* 1992). In addition, the categorization index in schizophrenic patients was lower than in controls, which corroborates previous results (Calev, 1984*a*, *b*; Calev *et al.* 1987). Moreover, fewer categories and fewer items per category were recalled by schizophrenic patients. Indeed,

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the categorization index reflects the propensity to use semantic organization during encoding, whereas the number of categories recalled and the number of recalled items per category reflect the efficiency of this strategy. The lower performance of schizophrenic patients on all three measures suggests that the items of the lists were only partially categorized as compared to controls. Finally, patients' sequence index was not significantly lower in organizable *versus* non-organizable lists, suggesting continued use by patients of superficial processing while controls were switching to the more efficient strategy of categorization. Although our experiment focussed on memory processes only, this result may be generalizable to other cognitive functions, and may reflect a tendency in schizophrenic patients not to spot similarities between items, whatever their nature.

As regards superficial processing, the mean sequence index, measuring the propensity to recall the items in their order of presentation, was equivalent in both groups. In addition, the curves of recall as a function of the position of the words in the list were similar in both groups for the non-organizable list. Thus, the propensity of patients to process the list in a sequential way may be unimpaired. However, their smaller number of items involved in the sequential recall indicates that they were not as efficient as controls in carrying out this strategy. This is in agreement with their smaller forward and backward digit spans: schizophrenic patients were not able to retain as long sequences of items as controls.

Taken together, these results suggest that two phenomena are involved in the encoding deficit observed in schizophrenic patients in a verbal memory task. First, there is a deficit in the capacity to maintain a sequence when the lists are processed in an sequential way. This could be interpreted as a decrement in the capacity of the articulatory loop of working memory (Baddeley, 1986), which enables the maintenance of the information by rehearsal. Secondly, patients have a lesser ability, or lesser proneness, to use deeper encoding, i.e. the processing of the semantic properties of the items and their organization into categories. Given that recall has been shown to be a function of the depth of the processing (Craik & Lockart, 1972), the correlations of the categorization index with the memory and recognition scores were not surprising and underscore the importance of organization in memory performance.

On the other hand, results revealed no impairment in the retrieval function. Such an impairment would have been demonstrated by a greater benefit from cues in the schizophrenic group, either from the use of the semantic cue for organizable lists or of the recognition sheet for the non-organizable lists. However, both groups benefitted from the semantic cue in a similar way, which replicated previous results (Calev *et al*. 1983; Sengel & Lovallo, 1983). Likewise, the benefit from the recognition sheet was similar in both groups. Despite this major aid to retrieval, schizophrenic patients still had a significantly lower score than controls, corroborating the interpretation of a deficit at encoding. However, retrieval is a multi-stage process, and we cannot rule out that a retrieval deficit might have appeared with different paradigms.

The lack of interaction between delay and group, whatever the condition, is quite surprising. Previous studies found an interaction with delay in the recall of verbal material (Calev *et al*. 1983; Sengel & Lovallo, 1983; Beatty *et al*. 1993). However, the delay used in these studies was much longer than the 1 min delay used in ours, and comparisons are not possible. It could be that early storage is unaffected in schizophrenia, and that a deficit appears only when a sufficiently long delay intervenes. This deficit with a long delay may reflect the fleetingness of the memory trace due to more shallow encoding in schizophrenic patients.

All the above conclusions concern long-term memory. A further deficit appeared in short-term memory, as reflected by the smaller forward and backward digit spans in the schizophrenic group. Impairment in short-term memory in schizophrenic patients has been controversial in the literature. It has been found in some studies (Gruzelier *et al*. 1988; Beatty *et al*. 1993; Landro *et al*. 1993) but not others (McKenna *et al*. 1990; Franke *et al*. 1993; Goldberg *et al*. 1993); this issue awaits further clarification.

Lastly, it can be observed that the overall memory impairment concerned the tasks that relied on explicit memory, whereas the stem completion task, designed to assess implicit memory, led to equivalent performance in both groups. This is an interesting addition to the

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few, conflicting results on this topic (Heinrichs & Bury, 1991; Clare *et al.* 1993; Randolph *et al.* 1993; Schwartz *et al.* 1993).

We also acknowledge that we cannot rule out an effect of concomitant medications, and in particular neuroleptics and anticholinergics (Frith, 1984). Further studies are needed to clarify to what extent the observed phenomena could be linked to the concomitant medications taken by the patient *versus* their underlying pathology.

CONCLUSION

These results suggest that verbal memory impairment in schizophrenia was not pervasive, but rather affected processes while leaving others unimpaired. Explicit memory was impaired but not implicit memory. Both free recall and recognition were impaired. More specifically, a deficit in encoding clearly appeared in the patients in this study, that was accounted for by two mechanisms: (1) superficial processing of items was less efficient (i.e. smaller sequences of words were able to be maintained in memory); (2) deep processing of items, required for organized encoding, was both less used and less efficient. However, the categorization index was correlated with overall memory performance, indicating that memory performance depended on the use of an efficient encoding strategy. This raises the possibility that schizophrenic patients could improve overall memory performance if they could be led to use better encoding strategies.

Further studies of deficits in schizophrenia could focus on the relationship between specific mnemonic processes and positive, negative, and disorganized symptomatology. Such studies may further our understanding of how the clinical symptoms of schizophrenia are mediated by basic cognitive deficits, which may then permit illumination of the physiological and neuroanatomical bases of these deficits.

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