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The Effect of Right and Left Hemispheric Lesions on Effortful and Automatic Memory Tasks

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The effect of lateralised cerebral damage on two memory tasks—free recall of words and memory of their temporal order—was investigated under intentional, incidental, and "true incidental" learning conditions. Ten Right Brain Damaged patients (RBD), 10 Left Brain Damaged patients (LBD), as well as 15 age-matched and 15 younger control individuals, participated in this study. It was hypothesised that effortful and automatic memory processes involve predominantly the left and right cerebral hemispheres, respectively. Automaticity was defined either by the learning conditions (i.e. incidental–automatic and intentional–effortful) or by the type of task (i.e. temporal-order–automatic and free-recall–effortful) regardless of the learning conditions. In the free recall task the RBD group outperformed the LBD group under all learning conditions. In the temporal order task, the RBD group performed worse than normal controls under all learning conditions while the LBD group performed more poorly than matched controls in the intentional and incidental but not in the "true incidental" learning condition. The results are discussed in terms of the relationship between effortful and automatic memory processes and cerebral lateralisation.

INTRODUCTION

Hasher and Zacks (1979) introduced a distinction between "learned" and "innate" automatic memory processes. Innate automatic memory processes, unlike learned ones, are unaffected by either subject variables (e.g. age or ability) or task variables (e.g. instructions or practice). According to Hasher and

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Zacks (1979), memory for temporal order is one of the tasks that fulfil the criteria of innate automatic memory processes. Some studies have supported Hasher and Zacks' claim by demonstrating invariance in performance over age and/or instructional conditions (Audy, Sullivan, & Gross, 1988; Azary, Audy, & Gross, 1989; Perlmutter, Metzger, Nezworski, & Miller, 1980). By contrast, other studies have reported results that are at odds with Hasher and Zacks' claim (Kausler, Lichty, & Davis, 1985; Kausler, Salthouse, & Saults, 1988; McCormack, 1981; Naveh-Benjamin, 1990; Vakil & Tweedy, 1994).

Right brain damaged patients (RBD), as opposed to left brain damaged patients (LBD), were impaired on automatic tasks whether defined as overlearned skills (e.g. a signature) (Luria, Simernitskaya, & Tubylevich, 1970) or as information learned under incidental learning conditions (Luria & Simernitskaya, 1977). These and other studies led Luria and his colleagues to conclude that effortful and automatic processes are controlled by the left and right hemispheres, respectively (Luria et al., 1970; Simernitskaya, 1974; Luria & Simernitskaya, 1977).

Automaticity has been defined in the literature in different ways. According to Hirst and Volpe (1982, 1984) and Luria and Simernitskaya (1977), the *learning conditions* determine whether information is processed automatically or effortfully. Under incidental learning conditions information is processed automatically, whereas under intentional learning conditions information is processed effortfully. This occurs regardless of the type of information that is presented. According to Hasher and Zacks (1979), specific *types of information*, that is, memory for temporal order, frequency of occurrence, and spatial location are processed automatically regardless of the learning conditions.

In previous studies on memory for frequency of occurrence and spatial location, we found that free recall of items was more impaired following LBD than RBD (Vakil et al., 1991; Vakil, Soroker, & Biran, 1992). By contrast, memory for frequency of occurrence was found to be more impaired following RBD (Vakil et al., 1991). On the memory of spatial location, the learning condition had a differential effect on the groups examined. RBD patients were more impaired than LBD patients under the incidental learning condition, whereas the reverse was found under the intentional learning condition (Vakil et al., 1992). The present study investigates the effect of lateralised brain damage on free recall and on the third task claimed by Hasher and Zacks (1979) to be an ''innate'' automatic memory task—that is, memory for temporal order.

Memory for temporal order is one of the most intriguing aspects of memory, and different researchers have viewed it from various theoretical perspectives. The main contention of the ''temporal order hypothesis'' of amnesia is that impaired memory for temporal order is the source of the amnesic memory deficit (Huppert & Piercy, 1976, 1978; Williams & Zangwill, 1950). Hirst (1982) and Hirst and Volpe (1982, 1984) extended the theory, suggesting that temporal order memory deficit in amnesia can be explained in terms of the constructs of the contextual theory of memory. That is, temporal order is considered as only one aspect of contextual information that is impaired in amnesic patients. Janowsky, Shimamura, and Squire (1989) claim that memory for temporal order is a type of source memory, and has been found dissociable from other aspects of memory. Finally, memory for temporal order, spatial location, and frequency of occurrence have been suggested by Hasher and Zacks (1979) to comprise three primary types of innate automatic memory processes.

The location of the specific brain regions subserving memory for temporal order is controversial. Research findings cluster in two general directions, one focusing on left hemisphere involvement and the other on frontal lobe involvement. Several studies have found patients with frontal lobe lesions to be particularly impaired in encoding temporal order information, while demonstrating intact recall of items (Janowsky et al., 1989; Shimamura, Janowsky, & Squire, 1990). On the other hand, laterality studies have attributed processing of temporal order to the left hemisphere (Carmon & Nachshon, 1971; Efron, 1963; Gutbord, Cohen, Maier, & Meier, 1987; Hammond, 1982). Note, however, that the latter studies examined differences between the hemispheres in the ability to *perceive* temporal order, while the studies with frontal lobe patients examined the ability to *recall* temporal order information. Some studies have tested patients with frontal lobe lesions restricted either to the left or right cerebral hemisphere. Milner's (1971) study demonstrates the complexity of the matter. Patients with left and right temporal lobe lesions were impaired only in the recognition of verbal and non-verbal material, respectively. By contrast, patients with left and right frontal lobe lesions were impaired only in recency judgement of verbal and non-verbal material, respectively. With the use of a more active task requiring self-ordering of data, patients with left frontal lesions were impaired in ordering both verbal and non-verbal material (Petrides & Milner, 1982). The series of studies by Milner and her colleagues suggests that the pattern of performance by different laterality groups is very much dependent on the particular temporal order task required, as well as on the specific instructions given to the participants (McAndrews & Milner, 1991; Milner, 1971; Petrides & Milner, 1982).

In the present study we investigated the effect of lateralised cerebral damage on free recall of words and on the memory of their temporal order, under intentional, incidental, and ''true incidental'' learning conditions. It is hypothesised that effortful memory processes are controlled by mechanisms of the left cerebral hemisphere, while automatic processes are controlled by the right hemisphere (Luria & Simernitskaya, 1977; Luria et al., 1970; Simernitskaya, 1974; Vakil et al., 1991, 1992). In this hypothesis predictions are made depending on the two definitions of automaticity presented earlier, i.e. whether it is determined by the ''learning conditions'' or by the ''type of information''. Both approaches would consider free recall learned under intentional conditions to be processed effortfully. Thus, it is predicted that in addition to the age effect (young better than older participants), LBD patients will be more impaired than RBD patients. Also, according to both approaches, temporal order learned under incidental conditions is processed automatically. Accordingly, RBD patients are predicted to perform more poorly than LBD patients. Free recall of information learned under incidental conditions is processed automatically or effortfully, by the definition of ''learning conditions'' or ''type of information'', respectively. Thus, an advantage of the RBD group over the LBD group would be interpreted as supporting the second definition, and vice versa. Memory for temporal order under intentional learning conditions is processed effortfully according to the ''learning conditions'' definition, and automatically according to the ''type of information'' definition. Thus, an advantage of the RBD group over the LBD group would be interpreted as supporting the first definition, and vice versa.

A distinction between incidental and ''true incidental'' learning instructional conditions has been introduced in the literature on testing of spatial location (Mandler, Seegmiller, & Day, 1977) and frequency of occurrence (Hasher, Zacks, Rose, & Sanft, 1987). In the incidental condition, participants expect to receive a nonspecific memory task. In the true incidental condition, the participants do not expect any memory task whatsoever. Based on the aforementioned distinction, in the present study we anticipate an advantage of LBD over RBD that is more pronounced under the ''true incidental'' as compared to incidental learning condition.

METHOD

Participants

Participants were recruited for the study from among a population of patients admitted to the Loewenstein Hospital for rehabilitation after a stroke. To be included, patients had to meet the following criteria:

1. Brain damage was the result of a CT-proven, single, nonhemorrhagic infarction.
2. The neurologic representation was compatible with a unilateral hemispheric involvement.
3. Negative history of previous stroke or other neurological disease, psychiatric disorder, or alcoholism.
4. Intellectual and linguistic functioning at a level enabling adequate responsiveness to the task requirements. It is important to emphasise that in all patients language comprehension was preserved. Production difficulties (either nominal, paraphasic, or motor in nature) were of mild to moderate severity and in no case affected message intelligibility in any significant manner.

A total of 10 RBD patients (5 males and 5 females) and 10 LBD patients (6 males and 4 females) participated in the study. RBD patients averaged 61.1 years of age, and had an average of 10.6 years of education. The LBD patients averaged 53.3 years of age, and had an average educational level of 9.9 years. Individual patient data are presented in Table 1. Two groups of healthy participants served as normal controls. The first group comprised 15 (9 males and 6 females) age-matched participants, ranging in age from 46 to 70 years ($M = 59.4$ years) and having a mean educational level of 12.5 years. To test the age invariance of Hasher and Zacks' (1979) innate-automaticity formulation, an additional group of younger healthy participants was recruited. This second control group consisted of 15 (7 males and 8 females) participants, ranging in age from 16 to 37 years ($M = 26.7$ years) and having a mean educational level of 13.9 years. The two patient groups and the age-matched control group were not significantly different either on age, $F(2, 32) = 1.95$, $P > .10$, or on educational level, $F(2, 32) = 2.19$, $P > .10$.

TABLE 1
Clinical Data

Patient	*Age*	*Sex*	*H*	*Ed*	*HP*	*HA*	*Neglect*	*Aphasia*
1a. Main Clinical Data of the Right Brain Damaged Group								
BS	62	M	R	16	++	–	+	–
CS	54	M	R	12	++	–	–	–
TY	84	F	R	12	+	–	+	–
GN	45	F	R	12	++	–	+	–
PH	75	F	R	12	–	+	+	–
DS	57	M	R	8	++	+	+	–
MG	64	F	R	8	++	+	+	–
MZ	57	F	R	8	++	–	–	–
BE	55	M	R	12	++	–/e	+	–
BY	58	M	R	6	++	+	+	–
1b. Main Clinical Data of the Left Brain Damaged Group								
AE	43	F	R	12	–	–	–	Motor, mild
EI	69	F	R	12	++	+	–	Motor mainly
ZN	66	M	R	6	+	+	–	Amnestic
AM	53	M	R	10	–	–	–	Conduction
HS	32	M	R	10	++	–	–	Motor
SSh	55	M	R	8	+	–	–	Dysgraphia
LS	65	F	Lc	10	+	+	+*	Amnestic
GM	50	M	R	15	–	–	–	Conduction
ZY	43	M	R	8	++	–	–	Motor
MS	57	F	R	8	++	+	–	Unclassified

H = Handedness (Lc = Converted left hander); *Ed* = Education (years);
HP = Hemiplegia (++)/Hemiparesis (+); *HA* = Hemianopsia (e = extinction upon bilaterial simultaneous stimulation); * = Right-sided neglect.

Lesion Analysis. Reconstructions of the lesions from follow-up CT scans are presented in Figs. 1a and b for the RBD and LBD groups, respectively. To achieve optimal visualisation of infarct boundaries, follow-up scans, performed at least six weeks after onset, were used (Elscint 2400 CT Scanner; Slice width 10mm; Inter-slice distance 10mm). For each patient, all slices that demonstrate the infarct are shown. This provides a clear notion of the three-dimensional extent of the lesion, and enables identification of the brain areas involved. Approximately parallel slice reconstructions from different patients are displayed in vertical columns. CT-scan information was unavailable for patient MS. In all but one patient, the damaged area is confined to the territory of the middle-cerebral artery. Patient ZN of the LBD group is exceptional in having a demonstrable lesion in the posterior-cerebral-artery area. To obtain a rough estimate of the frontal extent of lesions, we measured the maximal antero-posterior (AP) linear dimension of the lesion area in the bi-commissural plane of each patient. The AP extent of the lesion anterior to the anterior commissure (divided in each patient by the distance from the anterior-commissure to the frontal-pole, to yield a normalised measure) was 0.54 ± 0.23 and 0.30 ± 0.24 in the RBD and LBD groups respectively. The task requirements precluded participation of LBD patients with significant language disturbances (see Table 1b). This is probably the reason why lesion extent (total area as well as the frontal involvement) in the LBD group is generally smaller than that of the RBD group, as may be seen in the CT reconstructions (Figs. 1a and b).

Tests and Procedure

Three lists of 12 high-frequency Hebrew nouns (more than 50 per 200,000 words) (Balgure, 1968) were used. Participants were tested individually on three tasks, with a 15-minute break between tasks, in which they were either engaged in a discussion with the examiner, read magazines, or went to the cafeteria.

True Incidental Learning of Words and of Temporal Order. A list of 12 words was read to the participants once (note: by definition, the ‘‘true incidental’’ condition cannot be tested on more than a single trial). Immediately after each word presentation, participants were asked to judge whether the word was feminine or masculine (Hebrew nouns have a gender). Following the presentation of the entire list, participants were asked to recall as many words as possible. Immediately thereafter, they were given a written list of the same 12 words, the word order being different from what had originally been heard. Participants were asked to rewrite the words in their original order.

Incidental Learning of Temporal Order During Intentional Learning of Words. Unlike the previous task, prior to the 12-word list presentation, participants were instructed to remember as many words as possible. The list

A. Right hemisphere damage

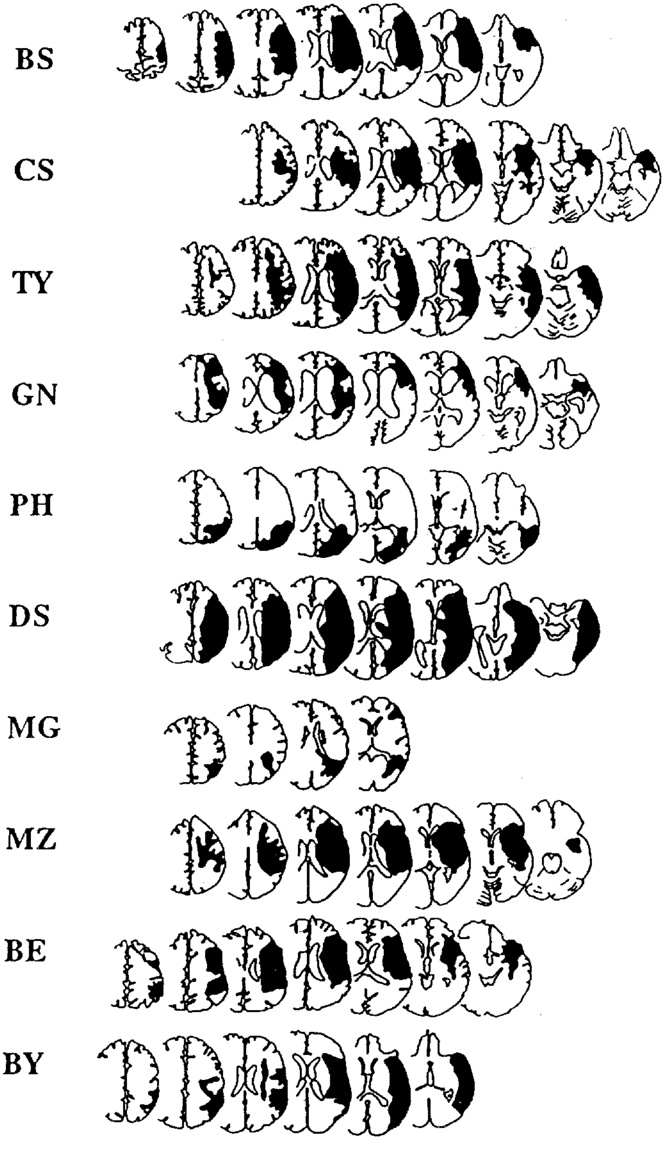

FIG. 1a. CT reconstructions from right brain damaged patients.

B. Left hemisphere damage

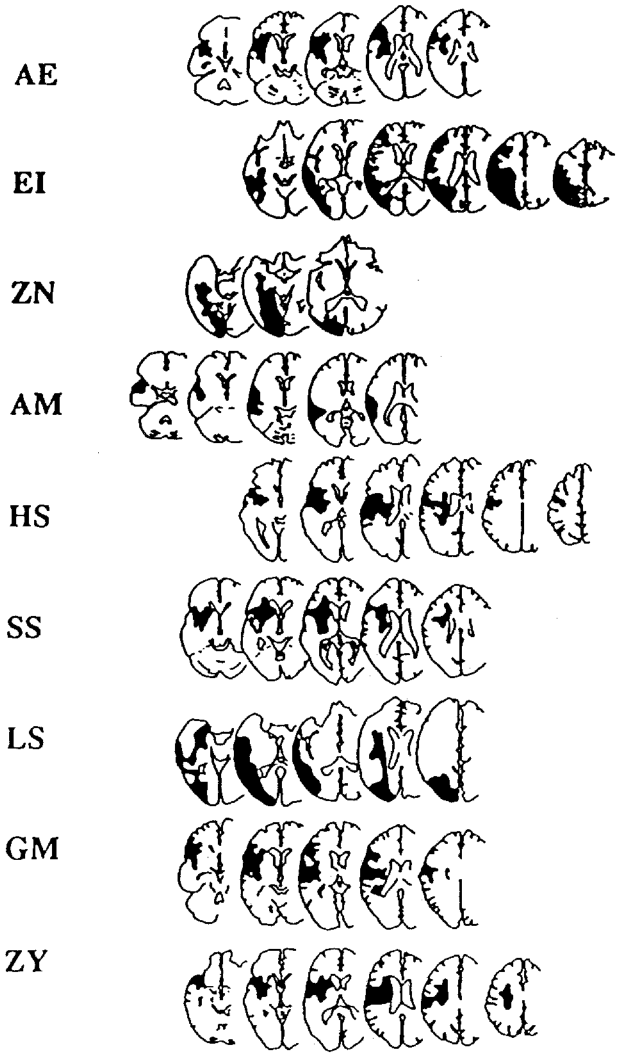

FIG. 1b CT reconstructions from left brain damaged patients.

was read three times, followed by a free recall test at each trial. Subsequent to the recall task, two temporal ordering tasks were given: participants were first asked to recall the words in the order in which they were presented, and were then asked to rewrite the words in their original order (as in the previous condition).

Intentional Learning of Words and of Temporal Order. The procedure in this task was identical to the previous one, except that in this task, participants were explicitly told that their memory for the words, as well as for their order, would be tested.

Testing was in the order in which the tasks are described here, as the true incidental condition must be presented first, and the intentional condition must be presented last. The assignment of the specific word list to a task was counterbalanced.

RESULTS

Free Recall

Free recall was tested following three learning conditions: (1) true incidental learning; (2) intentional learning—words only; and (3) intentional learning—words plus temporal order. Free recall was tested in a single trial in the true incidental learning condition (to preserve the ''true incidental'' nature of the task), and in three trials under both intentional learning conditions. Thus, the learning condition effect on free recall could be assessed by comparing only recall in the first trials of the three learning conditions. In addition, both intentional learning conditions were compared on the three learning trials. Table 2 presents the mean number (and standard deviations) of words recalled in each learning condition in trials 1 to 3 by each group of participants.

In analysis of the free recall test of the first trial, a mixed-design ANOVA was applied to analyse the effects of Group (LBD, RBD patients, young and old controls) and Learning Condition (true incidental, intentional—words only, and intentional—words plus temporal order), the former being a between-subjects factor and the latter being a within-subject factor. The Group main effect was significant, $F(3, 46) = 16.99$, $P < .001$. A follow-up analysis using the Duncan procedure revealed that all the groups differed significantly from each other, with one exception: the RBD group did not differ significantly from the older group. Overall, the young control group recalled the most words and the LBD group the least, with the RBD and old groups in between. The main effect of Learning Condition also reached significance, $F(2, 92) = 3.24$, $P < .05$. As can be seen in Table 2, overall, the most words were recalled when participants were instructed to recall just the words, and the least words were recalled under the true incidental learning condition. The interaction between the two factors did not reach significance.

TABLE 2
Mean Number (and Standard Deviations) of Words Recalled in Trials 1 to 3 by Each Group in the Three Learning Conditions

	Groups			
Trial	*Young* ($n = 15$)	*Old* ($n = 15$)	*RBD* ($n = 10$)	*LBD* ($n = 10$)
True Incidental				
First	6.20 (1.08)	4.93 (1.34)	5.10 (.738)	3.00 (1.49)
Words Only				
First	6.87 (1.51)	5.67 (1.80)	5.40 (2.27)	3.70 (1.34)
Second	9.60 (1.50)	7.13 (2.07)	7.20 (1.14)	4.50 (1.90)
Third	10.60 (1.45)	9.40 (1.35)	8.20 (1.32)	5.20 (2.10)
Total	27.07 (4.15)	22.20 (4.41)	20.80 (4.02)	13.40 (4.93)
Words Plus Temporal Order				
First	6.27 (1.49)	5.13 (1.96)	5.50 (1.84)	2.50 (1.43)
Second	9.13 (1.89)	7.00 (1.81)	6.60 (1.78)	4.30 (2.36)
Third	10.47 (1.69)	9.27 (1.44)	7.50 (2.01)	4.70 (2.21)
Total	25.87 (4.27)	21.40 (4.29)	19.60 (4.97)	11.50 (5.19)

Mixed-design ANOVA was applied to analyse the effects of Group, the two intentional Learning Conditions, and the three Learning Trials. The main effect for Group was significant, $F(3, 46) = 22.94$, $P < .001$. A follow-up analysis using the Duncan procedure presented the same pattern as before: that is, all the groups differed significantly from each other, with the exception of the RBD group, which did not differ significantly from the older group. Overall, the young control group recalled the most words and the LBD group the least, with the RBD and old groups in between. The main effect of Learning Trials was also found to be significant, $F(2, 92) = 140.94$, $P < .001$. As can be seen in Table 2, there is an overall increase in the number of words recalled from trial to trial. Overall, more words were recalled when the participants were instructed to recall just words than when instructed to recall words and order, $F(1,46) = 6.97$, $P < .01$. The only interaction that reached significance was Group $\times$ Learning Trials, $F(6, 92) = 5.67$, $P < .001$. As can be seen in Table 2, the learning rate of the LBD was not as steep as that of the other groups.

Memory for Temporal Order

For the analysis of memory for temporal order, a Pearson product-moment correlation was calculated for each participant, comparing the order recalled and the order in which the words were originally presented (Tzeng, Lee, & Wetzel, 1979). The participants were asked to perform two temporal ordering tasks: the first was to recall the words orally in the original order; second, participants were given a written list of the same 12 words, in an order different from that originally heard, and were then asked to rewrite the words in their original order. As the first measure of temporal order was dependent on the number of words recalled, the basis for comparison varied greatly between and within groups. The rationale for presenting the list three times was to prevent this problem, but it was apparently not successful. Not only was memory for temporal order confounded by the amount of words recalled, but also, in some instances (particularly in the patient groups) very few words were recalled, making calculation of the temporal order score impossible. Presenting the list of words in the second temporal order task ensured the independence of memory for temporal order and free recall task performance. Thus, only the second measure was submitted for statistical analysis. Means (and standard deviations) of the temporal order scores (i.e. Pearson's r values) of the four groups under the three learning conditions are presented in Table 3.

As the list of words was presented just once in the true incidental learning condition, while in the incidental (i.e. intentional recall of words) and intentional conditions (i.e. recall of words and temporal order) it was presented three times, two separate analyses were conducted. Note that due to this, performance on the temporal order task under the incidental learning condition cannot be directly compared with the other two conditions (see Table 3). In the true incidental learning condition, analysis of variance revealed a significant effect for Group, $F(3, 42) = 4.75$, $P < .01$. A follow-up analysis using the Duncan procedure indicated that the young control group differed from both patient groups, but not from the older control group. Although the two patient groups did not differ significantly from each other, the older group differed from the RBD, but not from the LBD group. As can be seen in Table 3, in this condition only, the RBD group was the least accurate in its memory for temporal order, and was even inferior to the LBD group.

TABLE 3
Means (and Standard Deviations) of the Temporal Order Scores (i.e. Pearson's r Values) of the Four Groups in the Three Learning Conditions

	Groups			
Learning Condition	*Young* ($n = 15$)	*Old* ($n = 14$)	*RBD* ($n = 9$)	*LBD* ($n = 8$)
True Incidental	0.552 (.195)	0.479 (.234)	0.263 (.161)	0.317 (.219)
Incidental	0.836 (.159)	0.750 (.189)	0.601 (.257)	0.506 (.309)
Intentional	0.945 (.058)	0.892 (.095)	0.559 (.213)	0.387 (.328)
Total	2.333 (.28)	2.111 (.34)	1.423 (.36)	1.210 (.67)

Mixed-design ANOVA was applied to analyse the effects of Group (LBD, RBD patients, young and older controls) and two Learning Conditions (incidental and intentional). The main effect for Group was significant, $F(3, 42) = 16.61$, $P < .001$, but not the main effect for Learning Condition. The Group $\times$ Learning Condition interaction did reach significance, $F(3, 42) = 3.26$, $P < .05$. In order to analyse the source of the significant interaction, two simple analyses of variance were conducted comparing the groups separately for each learning condition. The groups were significantly different in the incidental learning condition, $F(3, 44) = 5.53$, $P < .005$. A follow-up analysis using the Duncan procedure revealed that the control groups did not differ from each other (i.e. young vs. old), and neither did the patient groups (i.e. RBD vs. LBD). The young control groups differed from both patient groups, but the older control group differed only from the LBD group. The groups were also significantly different in the intentional learning condition, $F(3, 43) = 27.33$, $P < .001$. A follow-up analysis using the Duncan procedure revealed that the control groups did not differ from each other (i.e. young vs. old), but they differed from both patient groups. In addition, the RBD group was significantly different from the LBD group. Thus, unlike the findings under the incidental learning condition, in which the patient groups did not differ from each other, in the intentional learning condition the RBD group performed significantly better than the LBD group. In addition, a paired-samples t-test was conducted for each group in order to test the effect of the learning condition. As can be seen in Table 3, both control groups performed better under the intentional learning condition, $t(14) = 2.57$, $P < .05$, and $t(13) = 4.11$, $P < .001$, for the young and old control groups respectively. The patient groups show an opposite trend, performing better under incidental than intentional learning conditions, but this difference did not reach significance for either patient group.

DISCUSSION

The main premise of this study was that effortful memory processes are controlled predominantly by mechanisms of the left cerebral hemisphere, while automatic processes are controlled by the right hemisphere (Luria & Simernitskaya, 1977; Luria et al., 1970; Simernitskaya, 1974; Vakil et al., 1991, 1992; but see Goldberg, 1995 for a different conclusion).

In the present experiment, two alternative definitions of automaticity were evaluated: ''learning conditions'' (Hirst & Volpe, 1982, 1984; Luria & Simernitskaya, 1977) and ''type of information'' (Hasher & Zacks, 1979). The advantage of the RBD over the LBD group in free recall, regardless of the learning conditions, (learning conditions affected all the groups similarly), is in accordance with our previous findings (Vakil et al., 1991, 1992) and with other reports in the literature in which memory of verbal material was tested (Milner, 1971). Thus, there is no support for the claim that learning conditions determine whether information is processed effortfully or automatically (Hirst & Volpe, 1982, 1984; Luria & Simernitskaya, 1977). The age effect found here (i.e. young better than older participants) is consistent with previous reports in the literature (for review see Light, 1991). Free recall performance was better when learning instructions focused the participants' attention on the words only, as compared to words plus their temporal order. This finding argues against the claim that temporal order is an innate automatic process as, by Hasher and Zacks' (1979) definition, these processes are not supposed to interfere with a parallel effortful process.

As opposed to the free recall task, in the temporal order task the younger and older control groups did not differ significantly from one another in any learning condition. These results are in accordance with Hasher and Zacks' (1979) claim that innate automatic processes are not affected by age. It is important to note that studies concerning the effect of age on memory for temporal order are inconsistent. Some have reported lack of such an effect (Perlmutter et al., 1980) while others have found an age effect (McCormack, 1981).

In the free recall task the RBD group performed consistently better than the LBD group. However, the pattern of results in the temporal order task is more complicated. Under the true incidental learning condition, the LBD group did not differ significantly from the elderly control group, while the RBD group performed significantly more poorly. When compared directly the two patient groups were not significantly different from each other. Note that although verbal material was presented, the LBD group was not more impaired than the RBD group. These results are consistent with a previous study by Cappa, Papagno, and Vallar (1990) showing that RBD patients, unlike controls and LBD patients, do not spontaneously use temporal order as a retrieval strategy (recency effect) in a free recall task, although it involves verbal material. Unlike Milner's (1971) conclusion that involvement of the left and right hemisphere in memory processing is primarily determined by whether the stimuli presented are verbal or non-verbal, the present results, like our previous results (Vakil et al., 1992), indicate that learning conditions also play a role in determining which hemisphere is involved.

In the other two learning conditions (i.e. incidental and intentional), follow-up analyses of the interaction of group and learning condition revealed the following: when the patient groups are compared to each other under the intentional learning conditions of temporal order, the RBD group was significantly better than the LBD group. However, under the incidental learning condition, patient groups were not significantly different from each other. When patient groups are compared to the control groups, both control groups improved from the incidental to the intentional learning conditions, while the patient groups showed an opposite trend, but this trend did not reach significance. The trend of these results can be explained by the fact that intentional learning is the last condition to be tested. Possibly interference effects extracted from previous tasks on the subsequent one were more disruptive to the patients performance than to that of the control participants.

The performance of the control groups is at odds with the Hasher and Zacks' (1979) theory as learning instructions are not expected to have an effect on innate automatic processes such as memory for temporal order. The lack of advantage of memory for temporal order in the RBD group under the intentional as compared to the incidental condition was not predicted, and it is not clear why such results were received. Although LBD group performance is in the opposite direction of the normal trend, it does accord with the ''learning conditions'' prediction that LBD patients are mostly impaired in intentional-effortful processes. Nevertheless, the LBD group was impaired when compared to normals on memory for temporal order under the incidental learning condition, which is contrary to the ''learning conditions'' prediction. Mandler et al. (1977) suggested applying the ''true incidental'' learning condition in experiments of this sort, due to the concern that in a recall task, although spatial location is learned incidentally, participants might use spatial location information as a learning strategy and then process the information intentionally. Strategy application may possibly explain our unexpected finding that the LBD group was impaired relative to normal controls in the incidental learning condition. Mandler et al.'s original suggestion (1977) referred to spatial location; however, temporal order might also be applied as a recall strategy, and therefore may involve intentional-effortful processes, thus being sensitive to LBD as well. Our findings that the LBD group was not impaired as compared to the control group in the true incidental condition, but was impaired under the incidental learning conditions, lend further support to the distinction between these two learning conditions suggested by Mandler et al. (1977).

How consistent are the present findings with our previous findings (Vakil et al., 1991, 1992) concerning the effect of lateralised hemispheric damage on innate automatic processes? The three studies contribute neuropsychological support to Hasher and Zacks' (1979) distinction between automatic and effortful tasks, as lateralised hemispheric damage affected both types of tasks differently. Consistent with other reports in the literature, the LBD group performed least well on the free recall of words, regardless of learning condition (Milner, 1971). However, the learning conditions affected the three automatic tasks differently. They interacted with the lateralisation effect in the temporal order and spatial location tasks but not in the frequency task. In the first two tasks, the LBD group was inferior to the RBD group under the intentional learning condition and superior to the RBD group under the true incidental learning condition (Vakil et al., 1992). Unlike the latter results, on the frequency task the RBD group was inferior to the LBD group in the intentional as well as the incidental learning conditions (Vakil et al., 1991).

The general conclusion that can be drawn from the three studies is that the left cerebral hemisphere is predominantly involved in effortful processes, while the right cerebral hemisphere, under certain conditions, is involved in automatic processes. Specifically, the right hemisphere is predominantly involved in memory of frequency of occurrence under intentional and incidental learning conditions, and memory of spatial location and temporal order under true incidental conditions. As concluded in our previous study (Vakil et al., 1992), none of the alternative definitions of ''automaticity'' is sufficient in and of itself to explain the pattern of findings obtained in studies of automaticity and hemispheric lateralisation.

It is of interest to note that in the present study, lesion extent was generally greater in the RBD group as compared to the LBD group (for reasons pertinent to patient selection as explained in the method section). Moreover, on average the RBD group had more extensive frontal lobe lesions than the LBD group. Thus, the finding that in spite of their more extensive lesions the RBD group outperformed the LBD group in the free recall task but not in the temporal order task, becomes even more telling. This differential impairment of the two patient groups in different aspects of memory using the same stimuli indicates that the type of impairment is related more to the side rather than to the size of the lesion. If lesion sizes were the critical factor, the group with the larger lesions (i.e. RBD) should have been more impaired than the LBD group across all the tasks.

Further research is required to determine what types of memory tasks are processed effortfully, regardless of learning instructions (e.g. free recall), and what type of tasks are processed automatically or effortfully depending on learning instructions (e.g. spatial location and memory for temporal order).

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