



# The effect of electroconvulsive therapy (ECT) on implicit memory: skill learning and perceptual priming in patients with major depression

Eli Vakil<sup>a,\*</sup>, Leon Grunhaus<sup>b</sup>, Ifat Nagar<sup>a</sup>, Esther Ben-Chaim<sup>a</sup>, Ornah T. Dolberg<sup>b</sup>,  
Pinhas N. Dannon<sup>b</sup>, Shaul Schreiber<sup>b</sup>

<sup>a</sup>Department of Psychology, Bar-Ilan University, Ramat-Gan, 52900, Israel

<sup>b</sup>Chaim Sheba Medical Center, Tel-Hashomer, Israel

Received 9 July 1999; received in revised form 21 December 1999; accepted 14 February 2000

## Abstract

While explicit memory in amnesics is impaired, their implicit memory remains preserved. Memory impairment is one of the side effects of electroconvulsive therapy (ECT). ECT patients are expected to show impairment on explicit but not implicit tasks. The present study examined 17 normal controls and 17 patients with severe major depressive disorder who underwent right unilateral ECT. Patients were tested in three sessions: 24–48 hours prior to, 24–48 hours following the first ECT, and 24–48 hours following the eighth ECT. The controls were tested in three sessions, at time intervals that paralleled those of the patients. Implicit memory was tested by the perceptual priming task — Partial Picture-Identification (PPI). The skill learning task used entailed solving the Tower of Hanoi puzzle (TOHP). Explicit memory was tested by picture recall from the PPI task, verbal recall of information regarding the TOHP, and by the Visual Paired Association (VPA) test. Results showed that explicit questions about the implicit tasks were impaired following ECT treatment. Patients' learning ability, as measured by the VPA task, was only impaired in the first testing session, prior to ECT treatment, reflecting the effect of depression. In addition, groups only differed in the first session on the learning rate of the skill learning task. Perceptual priming was preserved in the patients' group in all sessions, indicating that it is resilient to the effect of depression and ECT. The results are interpreted in terms of the differential effect of depression and ECT on explicit and implicit memory. © 2000 Elsevier Science Ltd. All rights reserved.

**Keywords:** ECT; Implicit memory; Skill learning; Depression

## 1. Introduction

In recent years there has been increasing interest in the residual learning capabilities of amnesic patients [12]. Acquisition of new skills such as mirror reading [5] and solving a visuospatial task such as the Tower of Hanoi puzzle (TOHP) [4], have been reported to be preserved in amnesic patients. Priming effect has also been found preserved in amnesic patients [13]. A prim-

ing effect is said to have occurred if stimuli from the study phase are identified either more accurately, or at a faster rate, than the new stimuli. In pictorial priming tasks, such as Partial Picture-Identification (PPI), participants are asked to identify the object presented in degraded forms of pictures as quickly as possible. Based on the above dissociation between preserved and affected memory faculties, a distinction between explicit and implicit memory has been suggested [12].

Although electroconvulsive therapy (ECT) is widely recognized as a highly effective treatment for severe depression, it is also known to produce transient memory impairment. When prescribed a course of ECT, patients with severe major depressive disorder (MDD)

\* Corresponding author. Tel.: +972-3-531-8269; fax: +972-3-535-0267.

E-mail address: vakile@mail.biu.ac.il (E. Vakil).

manifest anterograde as well as retrograde amnesia [15,20]. Several studies have demonstrated that left and right unilateral ECT causes selective impairment of verbal and nonverbal memory, respectively [1,18]. These findings are consistent with previous reports of patients suffering from lateralized hemispheric damage [11]. Most of the studies demonstrating intact skill learning and the priming effect of amnesia, tested patients who were already amnesic. Only a few studies have addressed the question of whether a skill or priming task, learned prior to the onset of amnesia, will also be preserved after ECT induced amnesia. Squire, Cohen and Zouzonis [16] have tested patients prescribed ECT, before and during the course of treatment, with a skill learning task (i.e., mirror reading). The results showed that in contrast to depressive patients not treated with ECT, the ECT patient group developed intact learning and retention of the skill over time. In other words, patients treated with ECT showed neither retrograde nor anterograde amnesia to skill learning, but did demonstrate impaired explicit memory. When tested during the course of treatment, intact priming effect and impaired explicit memory (i.e., lack of anterograde amnesia) [17], was found in patients prescribed ECT.

Certain difficulties in these studies [16,17] prevent conclusive findings about the effect of ECT on implicit memory. In the study on skill learning [16], the control group only consisted of depressed patients. Since depressed patients might themselves be impaired as compared to normal controls, if a group of normal controls is not included in the study, it is difficult to reach conclusions concerning the effect of ECT on skill learning. An additional problem is that the second testing session was held on the day after the first treatment and the third testing session was conducted an average of 16 days after the last ECT treatment. Thus, the lack of effect of ECT on skill learning in the second testing session may possibly be due to the fact that a single ECT treatment is insufficient to cause the impairment. The lack of effect in the third testing session may possibly be due to the fact that the patients had sufficient time (i.e., 16 days) to recover from the ECT effect. Regarding the study on priming [17], since patients were not tested prior to the ECT treatment, the possibility that ECT could cause retrograde amnesia of priming was not investigated.

In the present study a group of normal individuals, matched for age and sex with the patient group, served as the control group. It is important to note that in previous studies [16,17], patients were heterogeneous, with some receiving bilateral ECT and some receiving right unilateral ECT. Only patients receiving right unilateral ECT were included in the present study. The first testing session was given one day prior to the first ECT treatment. This enabled measurement of retro-

grade amnesia for all tests administered. In addition, a comparison of the control group to the patient group at this stage, prior to the administration of ECT, would reflect the pure effect of depression on the different memory tasks. The second session was given one day after the first ECT treatment, and the third session was given one day after the eighth session. This time schedule enabled us to test the effect of ECT at its initial and final phases. Another aspect unique to this study is that it tested the same patient group for the two types of implicit memory (i.e., skill learning and perceptual priming) along with explicit memory. Such a design enables a more reliable comparison of the differential effect of ECT on the different memory tasks within the same sample of patients. As mentioned above, all patients were prescribed a course of right unilateral ECT. Thus, in order to maximize the sensitivity of the tasks to memory impairment, visuospatial skill learning (i.e., TOHP) and perceptual priming (i.e., PPI) tasks were selected.

## 2. Methods

### 2.1. Subjects

Seventeen patients (eight males and nine females) diagnosed with MDD according to the DSM-IV criteria, referred for electroconvulsive therapy (ECT) at Sheba Medical Center, participated in this study. Patients were diagnosed by consensus of two clinicians. To be included, patients had to score >17 points on the 17-item Hamilton rating scale for depression

Table 1  
Demographics of the ECT patient group<sup>a</sup>

Patient	Sex	Age	Education	HRSD-1	HRSD-2
1	M	44	16	24	23
2	M	68	8	22	19
3	M	42	9	31	24
4	M	53	17	22	10
5	F	36	12	24	20
6	F	62	2	27	12
7	F	47	16	24	18
8	F	37	11	37	19
9	F	40	12	19	14
10	F	37	11	18	1
11	M	61	11	30	15
12	F	71	12	22	6
13	M	77	8	19	28
14	M	57	18	31	23
15	F	49	9	31	16
16	F	45	15	23	22
17	M	49	17	19	14

<sup>a</sup> HRSD-1=Hamilton rating scale for depression (first measure); HRSD-2=Hamilton rating scale for depression (second measure following the sixth ECT).

(HRSD) [7]. Psychotropic drugs were discontinued 2–5 days before the beginning of the ECT procedure. During the administration of ECT the use of psychotropic drugs was restricted.

Table 1 shows detailed demographic information of ECT patients. The administration of the HRSD was repeated following the sixth ECT. It is important to note that the treatment was not yet completed by the sixth ECT, which might be the reason the HRSD scores are still relatively high. Trained individuals performed the ratings. The patients' ages ranged from 36 to 77 years ( $M = 51.50$ ), and education ranged from 2 to 18 years of schooling ( $M = 12.0$ ). The control group consisted of 17 individuals, matched with the ECT group for age and education level. It included eight males and nine females, whose ages ranged from 32 to 74 years ( $M = 50.20$ ), and education ranged from 2 to 19 years of schooling ( $M = 12.5$ ). The groups did not differ significantly either in age [ $t(32)=0.32$ ,  $P > 0.05$ ], or educational level [ $t(32)=0.32$ ,  $P > 0.05$ ]. Based on the clinical interview the participants in the control group had no history of and were never treated or hospitalized for psychiatric illness. Participants in both groups had no history of CNS disease, alcoholism or drug use. The Human Research Committee at the Sheba Medical Center and the Ministry of Health approved this research project. All patients and controls signed an informed consent for participation in the research study, and in addition, patients signed an informed consent for receiving ECT, as required by Israeli law.

## 2.2. Procedure

The ECT procedure was conducted according to the protocols approved at Sheba Medical Center. These protocols require all patients undergo complete medical, psychiatric, and laboratory examination. In addition, patients over the age of 50, are required to undergo EKG's and chest X-rays. Where indicated, additional consultations were requested. ECT is performed in a specialized ECT suite under the supervision of a senior anesthesiologist. Patients were anesthetized with methohexital (0.75 mg/kg) and succinylcholine (1 mg/kg). All patients received continuous oxygenation; monitoring of  $pO_2$ , blood pressure and pulse rate, were examined routinely. Electrode placement was right unilateral in all cases.

In all patients the seizure threshold was determined during the first ECT session by finding the minimum amount of electrical energy that would induce at least a 25-s seizure. In subsequent treatments, electrical parameters were set to provide stimulation 2.5 times above seizure threshold. ECT equipment used in this project was a MECTA SR-1 machine that delivers a bi-directional quadratic brief-pulse of electricity. ECT

was performed twice a week. Seizure duration was monitored in all patients through the cuff method, whenever seizure length was below 25 s restimulation was performed.

## 2.3. Tests and procedure

Patients were tested individually in three sessions: 24–48 hours prior to, 24–48 hours following the first ECT, and 24–48 hours following the eighth ECT. They were tested in the hospital during morning hours. The controls were tested in three sessions, at time intervals paralleling those used for the patients. Participants were tested on explicit and implicit memory tasks.

### 2.3.1. Implicit memory tests

**2.3.1.1. Skill learning task: Tower of Hanoi Puzzle (TOHP).** This task is based on a computer program designed for the PC computer. For this task, participants are seated in front of a computer screen. Three pegs are presented on the screen, numbered from 1 to 3. Initially, four disks are arranged on the left-most peg, with the largest disk at the bottom and the smallest disk at the top. Participants are told that the goal is to move the disks from the left-most peg (i.e., number 1) to the right-most peg (i.e., number 3) using a minimum number of steps. They are also told that they may move only one disk at a time, they may not place a large disk on a small disk, and they may use the middle peg as well. The optimal solution for four disks requires 15 moves. In order to move the disks, one must first press the number (1, 2, or 3) reflecting the original position of the peg to be moved and then press the number of the peg to which one chooses to move the disk. The computer automatically registers the number of moves per solution. At each one of the three sessions, participants completed the puzzle four times.

**2.3.1.2. Priming task: Partial Picture-Identification (PPI).** This task is based on a computer program designed for the PC computer. Although originally composed in Hebrew [22], similar forms of this test can be found in the literature [8]. This type of test has been found to induce perceptual priming [2,8]. Participants were told they would first see an X on the screen that would focus their attention. Then, they would see fragments of a picture gradually appear on the screen. They were instructed that their task was to attempt to identify the picture as quickly as possible. The number of fragments of the gestalt continued to increase until the participant, when deciding to respond, pressed a computer key, which consequently suspended the process. The participants then gave their answer verbally.

A participant that identified a picture incorrectly was informed and the gradation process continued until the correct picture was identified. Percent exposure (PE) to correct identification, ranging from 0 to 100, was automatically recorded by the computer. Following correct identification of the picture, the full picture was presented on the screen for 1 s. This procedure was repeated five consecutive times at each one of the three sessions. During each trial the participant was exposed to ten pictures, five were repeated at each trial and five were new at each trial, yielding five repeated pictures and 25 new pictures, for a total of 30 pictures. Priming is said to have occurred when the PE required for the repeated pictures is significantly lower than that of the non-repeated pictures.

### 2.3.2. Explicit memory tests

**2.3.2.1. Visual Paired Associates (VPA).** This is a subtest of the Wechsler Memory Scale — Revised WMS-R [23]. This subtest consists of a set of six different colors paired with six nonsense shapes. Each card (10 × 14 cm) contains one pair. As required by standard administration [23], the same set was repeated consecutively at least three times, each time in a different order. At this point, if the participant has successfully learned all six pairs, the repetition stops. If not, the list of pairs is repeated until all six pairs are learned or until six trials have been administered. Following each set of six cards, six testing cards consisting only of shapes are presented. The participants are presented a folder with eight different colors and are asked to point to the color pair associated with the presented test card shape. An additional matching test trial was repeated half an hour after completion of the first set of trials.

In addition to the standard explicit memory test (i.e., VPA), adding an explicit component to each of the implicit tasks also assessed memory. The explicit component of the skill learning and priming tasks was carried out upon completion of each of these tasks, in the third session. The explicit component was added only after standard administration of tasks in the third session, in order to preserve the implicit nature of these tasks.

**2.3.2.2. Skill learning (TOHP) — six point interview.** Upon completion of the TOHP, participants were asked six questions regarding the learning session and the task (e.g., what is the task called? how many pegs were in the task?). Accordingly, scores ranged from 0 to 6.

**2.3.2.3. Priming task (PPI).** Participants were asked to recall as many of the 30 pictures they had been exposed to during administration of this task. Accordingly, scores ranged from 0 to 30.

## 3. Results

The SPSS (Statistical Package for Social Sciences) software was used for all the statistical analyses [14]. In the case of mixed design analysis of variance, which include the analyses of between as well as within subjects variable, the Repeated Measures option under the General Linear Model, was applied.

### 3.1. Implicit tasks

#### 3.1.1. Skill learning task: Tower of Hanoi Puzzle (TOHP)

The task consists of four repeated trials, at each session, that measure learning. Performance of this task was analyzed using the number of moves per solution as the dependent measure. Fig. 1 presents the number of moves required to solve the TOHP by the groups as a function of learning trials at the three testing sessions. The number of moves required to solve the TOHP was submitted to a mixed-design ANOVA to analyze the effects of group (ECT and control), learning trials (1–4) and session (1–3). The former is a between subject factor and the latter two are within subject factors. All three main effects reached significance. Overall, the control group required less moves than the ECT group to solve the TOHP [ $F(1,32)=3.31$ ,  $P < 0.05$ ]. There was a significant overall improvement from trial to trial [ $F(3,96)=2.96$ ,  $P < 0.05$ ], and from one testing session to another [ $F(2,64)=3.93$ ,  $P < 0.05$ ]. The interactions Session × Learning, and the triple interaction, Group × Session × Learning reached significance [ $F(6,192)=2.38$ ,  $P < 0.05$  and  $F(6,192)=1.82$ ,  $P < 0.05$ , respectively]. By analyzing the group's learning rate separately for each session, these significant interactions were interpreted. In the first session, the group and learning main effects did not reach significance, but the interaction between them did [ $F(3,96)=2.19$ ,  $P < 0.05$ ]. As shown in Fig. 1, the control group, but not the patient group, showed improvement from trial to trial. In the second session, both the group and learning main effects reached significance, [ $F(1,32)=6.70$ ,  $P < 0.05$  and  $F(1,32)=3.79$ ,  $P < 0.05$ , respectively], but not the interaction between them. In the third session, the learning main effect was the only one to reach significance [ $F(1,32)=3.29$ ,  $P < 0.05$ ].

#### 3.1.2. Priming task: Partial Picture-Identification (PPI)

The data was analyzed in two steps. For the first

step, the PE required for identification of pictures in their first presentation, (i.e., first trial of the first session) was analyzed in order to check for possible base-

line differences between the groups (ECT and control) in perceptual identification of pictures. Indeed, the PE baseline (i.e. identification of unprimed pictures) of the

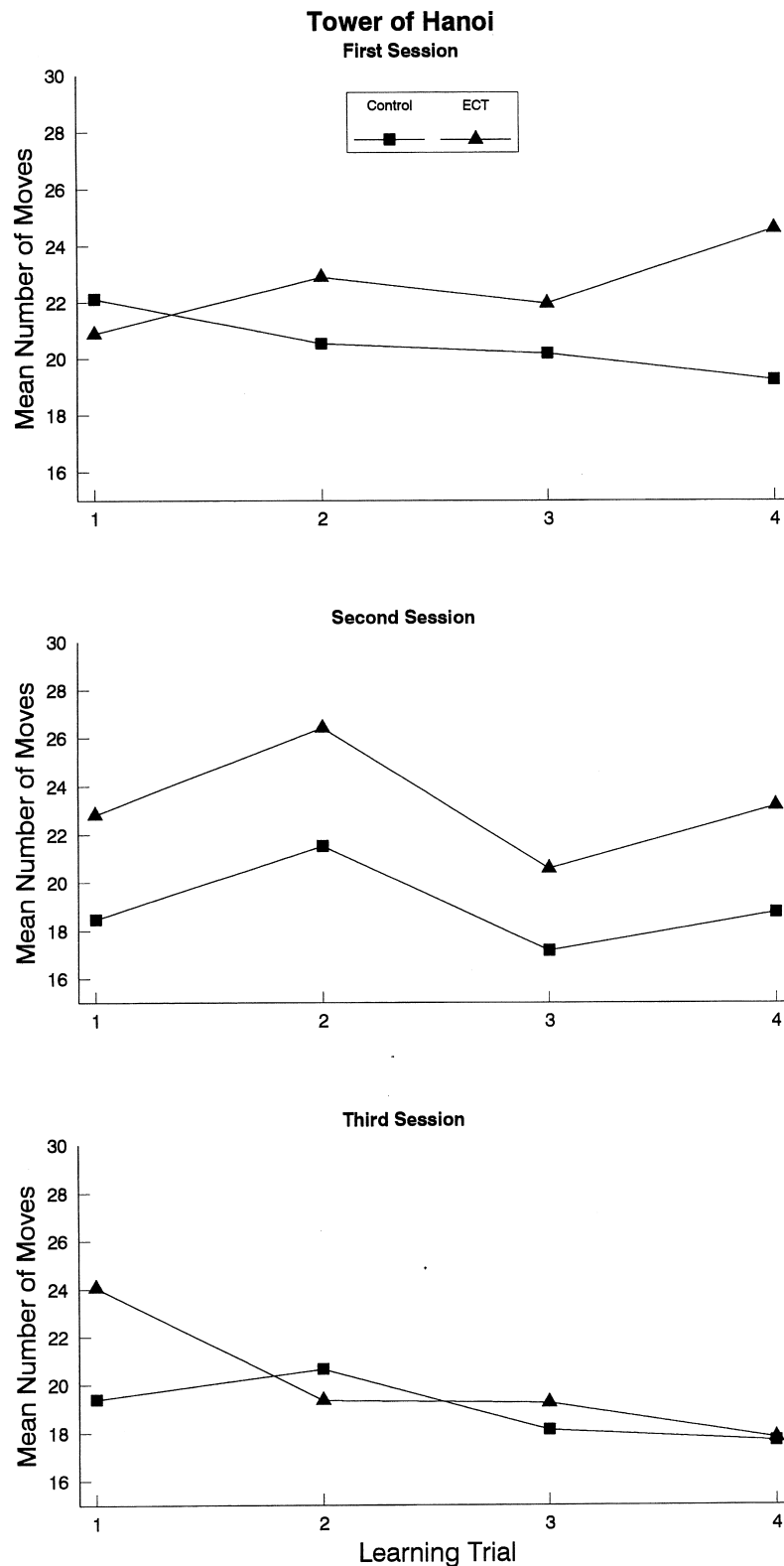


Fig. 1. Mean number of moves required to solve the TOHP by the groups as a function of learning trials in the three testing sessions.

ECT group ( $M = 50.21$ ,  $SD = 12.08$ ) was significantly higher than that of the control group [ $M = 38.59$ ,  $SD = 8.25$ ,  $t(32) = 3.27$ ,  $P < 0.01$ ]. To correct for this

group's baseline difference, a proportion score was derived as follows: the ratio of the PE of pictures over the baseline PE of the new pictures (Fig. 2). During

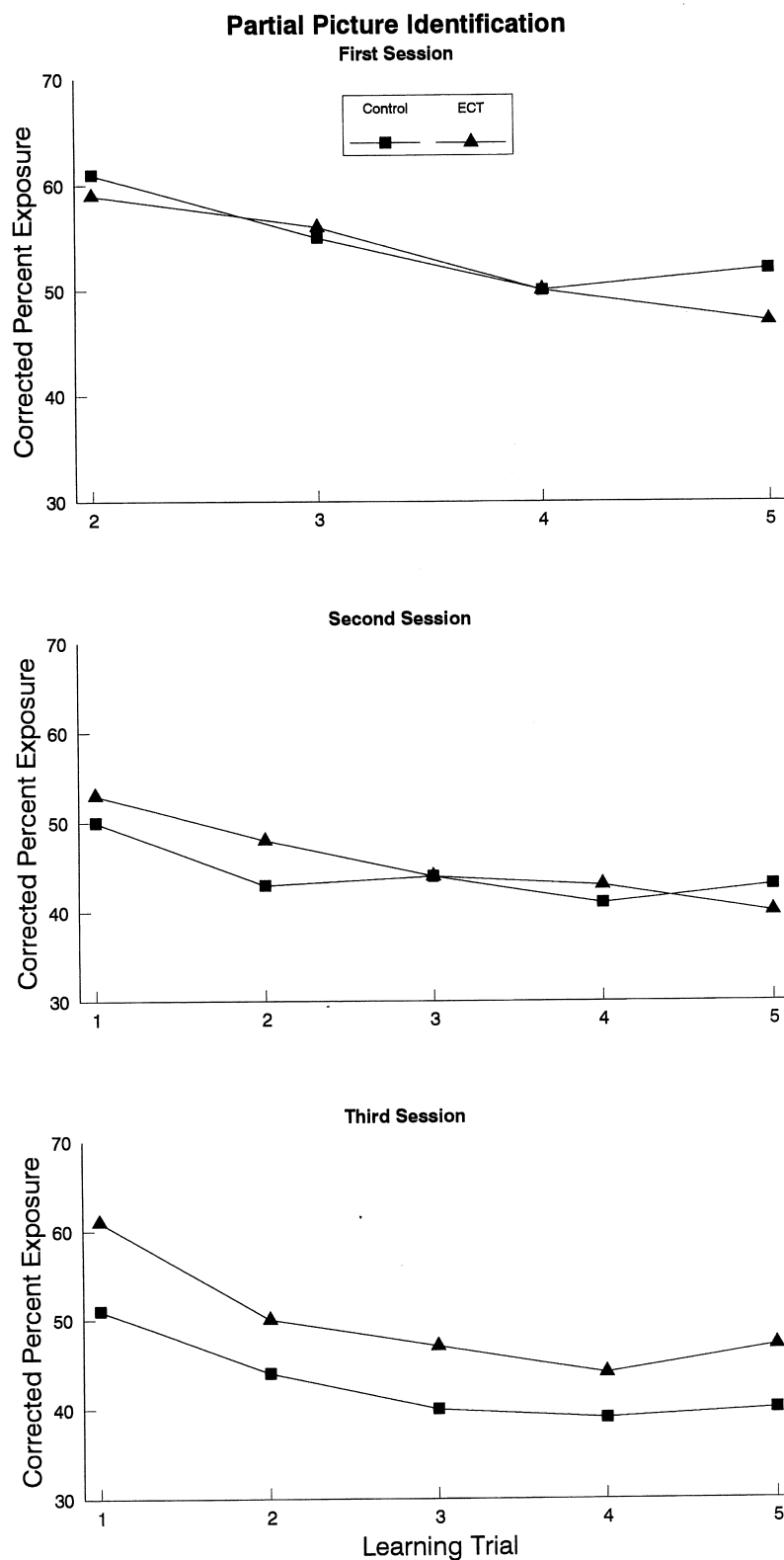


Fig. 2. Mean proportional scores of the groups on the PPI task as a function of learning trials in the three testing sessions.

the second step of analysis the proportional score was submitted for analysis. First, the group's learning over trials was analyzed separately for each session. In the first session only four learning trials were analyzed, as compared to five in the second and third sessions, because the first trial was used as the baseline measure. In the three sessions, neither group nor Group  $\times$  Learning interaction reached significance. Significant learning effect was observed in the three sessions [ $F(3,96)=15.90$ ,  $P < 0.001$ ,  $F(4,128)=11.94$ ,  $P < 0.001$ ,  $F(4,128)=21.15$ ,  $P < 0.001$ , respectively].

The mean proportional score at each session, over groups and learning trials, was calculated ( $M = 0.54$ ,  $SD=0.09$ ,  $M = 0.49$ ,  $SD=0.12$ ,  $M = 0.46$ ,  $SD=0.17$  for sessions 1–3, respectively) in order to analyze the change over sessions. The results reveal a significant change over sessions [ $F(2,66)=9.27$ ,  $P < 0.001$ ]. Follow-up analyses indicate that the performance in the first session was significantly ( $P < 0.01$ ) inferior to that in the second and third sessions, which did not differ from each other.

### 3.2. Explicit tasks

#### 3.2.1. Visual Paired Associates (VPA)

The task consists of three repeated trials in each session to measure learning and a fourth trial half an hour later, to measure delayed memory. Accordingly, the learning and delayed memory results were analyzed separately.

The results of the learning task were submitted to a mixed-design ANOVA to analyze the effects of group (ECT and control), learning trial (1–3) and session (1–3). The former is a between subject factor and the latter two are within subject factors. The learning main effect reached significance; there was a significant increase overall in number of pairs learned from trial to trial [ $F(2,64)=21.43$ ,  $P < 0.001$ ]. The group main effect and the Group  $\times$  Learning trials interaction did not reach significance [ $F(1,32)=2.09$ ,  $P > 0.05$ , and  $F(2,64)=0.14$ ,  $P > 0.05$ , respectively]. Overall, more pairs were learned from session to session [ $F(2,64)=0.70$ ,  $P < 0.001$ ]. The Group  $\times$  Learning  $\times$  Session interaction reached significance [ $F(4,128)=2.44$ ,  $P < 0.05$ ]. As shown in Fig. 3, this interaction is due to the steeper learning rate of the control group compared to the ECT group in the first session. In the other two sessions the groups did not differ, possibly due to the ceiling effect of the control group.

In addition to the group and session effects, delayed memory was measured by comparing the performance on the third and fourth trials. The session's main effect was the only factor that reached significance [ $F(2,64)=14.04$ ,  $P < 0.001$ ], indicating that the number

of pairs correctly recognized in trials three and four, increased from session to session.

Additional measures of explicit memory were derived from the implicit tasks. The groups differed significantly on the explicit component of each of the implicit tasks. Skill learning (TOHP) — six-point interview: the mean score of the control group was 5.58 compared to 3.23 for the ECT group. This difference in performance reached significance [ $t(32)=6.25$ ,  $P < 0.001$ ]. Priming task (PPI): the mean number of pictures correctly recalled by the control group ( $M = 13.71$ ) was significantly higher than the number of pictures correctly recalled by the ECT group [ $M = 9.29$ ,  $t(32)=2.52$ ,  $P < 0.02$ ].

### 3.3. Correlations

Pearson product moment correlations were conducted between the memory measures, age and the measures of depression. As illustrated in Table 2, age and the initial depression level as measured by the HRSD, are significantly correlated with the explicit memory (i.e., VPA) but not with the implicit memory tasks.

## 4. Discussion

Patients receiving ECT are an ideal experimental group for the study of retrograde amnesia. Unlike other amnesic groups, when retrograde amnesia is tested, there is no certainty about the information acquired prior to the onset of amnesia. In contrast, with these patients there is full control of the information exposed to the patient prior to the ECT treatment. However, the disadvantage pertaining to

Table 2  
Intercorrelations between the memory measures with age and the measures of depression<sup>a</sup>

	HRSD1	HRSD2	D-HRSD	Age
VPA1	−0.47*	−0.24	−0.13	−0.39*
VPA2	−0.48*	−0.19	−0.18	−0.47*
VPA3	−0.54*	−0.23	−0.18	−0.39*
TOHP1	0.14	0.22	−0.11	−0.22
TOHP2	0.22	0.30	−0.12	−0.01
TOHP3	0.21	0.15	0.02	−0.02
PPI1	0.13	−0.06	0.15	0.09
PPI2	−0.05	0.14	−0.17	−0.03
PPI3	−0.03	0.14	−0.15	−0.08

<sup>a</sup> HRSD-1=Hamilton rating scale for depression (first measure); HRSD-2=Hamilton rating scale for depression (second measure following the sixth ECT); D-HRSD=The difference between the two HRS measures; VPA=Visual Paired Association; TOHP=Tower of Hanoi Puzzle; PPI=Partial Picture Identification. The numbers in these three tests indicate the session number. \* $P < 0.05$ .

the study of these patients is that they are diagnosed with severe MDD, which is known to affect memory [3]. Thus, comparison of performance

before and after ECT treatment is not simple [6]. On the one hand, ECT affects memory, but as it alleviates the depression, memory deficits caused by

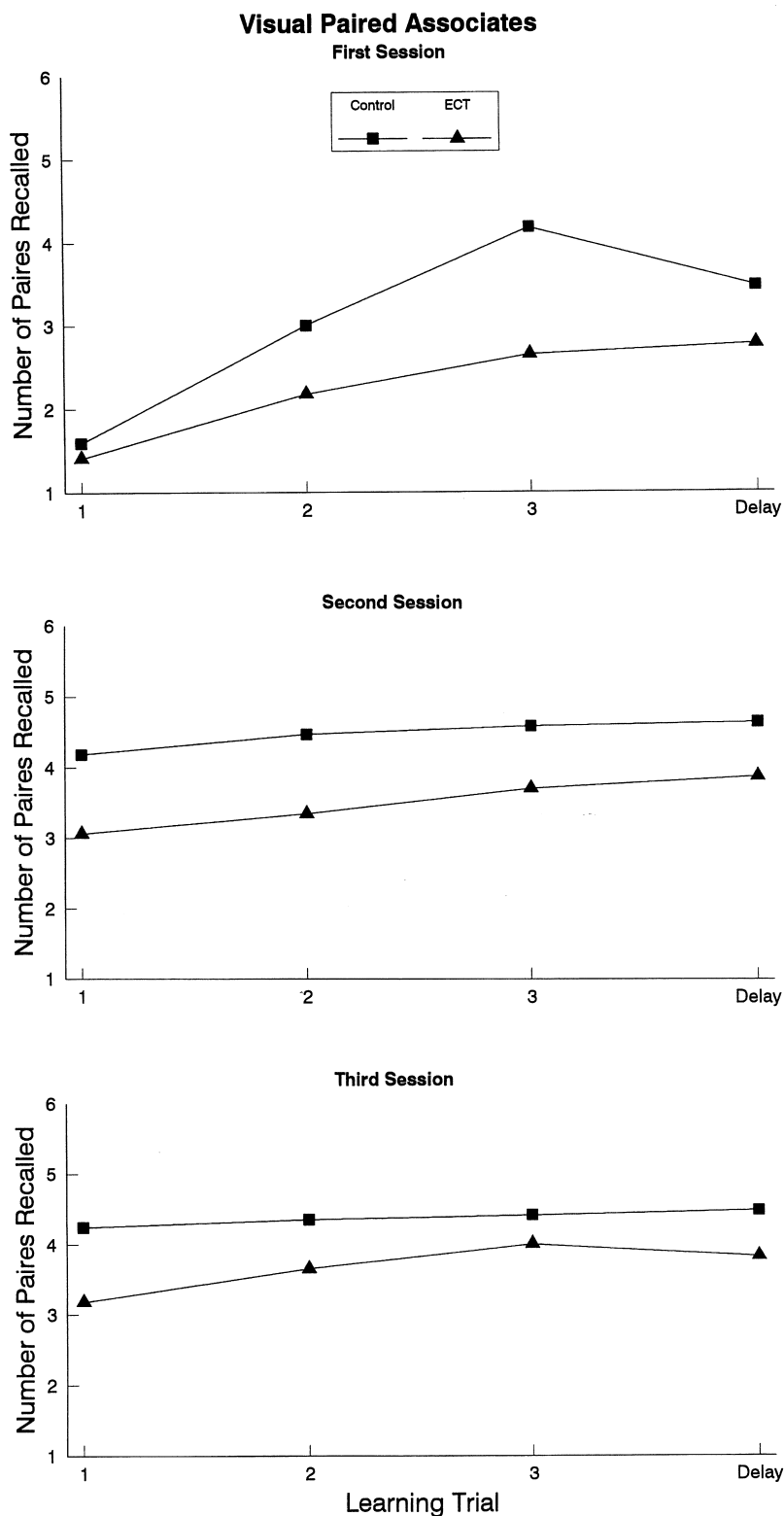


Fig. 3. Mean number of pairs correctly recognized by the groups as a function of learning trials at the three testing sessions.



depression might also improve [15,19]. Some researchers have demonstrated that the characteristics of memory impairment due to depression are different from those due to the ECT. More specifically, patients with major depression have difficulties with immediate memory and with the acquisition of new material but have intact delayed memory. Following ECT, immediate memory and acquisition of new material is preserved, but delayed memory is impaired [19].

Seventeen patients with severe MDD, subscribed right unilateral ECT, participated in this study. The possible confounding effects of other parts of the ECT procedure rather than the effect of electroconvulsive therapy *per se* include; the effect of the psychotropic drugs given to the patients and the effect of repeated administration of general anaesthetic. As mentioned earlier in the method section, psychotropic drugs were discontinued 2–5 days before the beginning of the ECT procedure. Regarding the effect of the anesthesia, the general anesthetic in the ECT procedure is a short acting barbiturate that is effective for less than 10 minutes. Thus, it is safe to assume that it did not have an effect on the patient's performance of tasks administered 24–48 hours later.

Retrograde and anterograde amnesia were tested on skill learning, perceptual priming, and explicit memory. It is important to note that all memory tasks (i.e., within-subject design) were administered on all participants. Consistent with previous studies, explicit questions about the skill learning task [16] and the perceptual priming task [17] were found to be impaired in patients following the ECT treatment. As in previous studies, so as not to interfere with the implicit tasks, the explicit tasks were only administered once in the third testing session upon completion of the ECT treatment and following the implicit tasks. Because these explicit tests were conducted during the third session (i.e., following the 8th ECT treatment) it is reasonable to attribute the resulting memory deficit to the ECT effect rather than to depression, which is assumed to be alleviated by this stage.

An additional explicit test used was the VPA. This test was conducted, along with the implicit tasks, during the three testing sessions. Patient group learning ability was only impaired in the first testing session. Performance in the first session, prior to the ECT treatment, reflects the pure effect of depression on learning, as previously demonstrated [19]. In not one of the sessions was delayed memory sensitive to the group effect. The results on the VPA test should be interpreted cautiously because it might reflect a ceiling effect in the second and third testing sessions. As a result of this study's findings, we recommend the use of a different explicit test at each session, or a more complex task, in order to avoid ceiling effect as a con-

sequence of repeated presentation. The significant correlation between the initial depression measure, prior to the ECT treatment, and the performance on the VPA test, further indicates the relations between depression and explicit memory.

As reflected by the Group by Learning trials interaction, the groups differed on learning rate of the skill learning task (i.e., TOHP) only at the first testing session, prior to the ECT. These results differ from those reported by Squire et al. [16], where the groups did not differ on the learning rate of the skill learning task (i.e., mirror reading) either before or after the ECT treatment. Our interpretation of this discrepancy in the results, is that depression, rather than ECT treatment, impaired the learning rate of skill learning. Because the controls in the study conducted by Squire et al. [16] only consisted of depressed patients, indeed even prior to the ECT treatment, there was no initial difference between the groups. Yet, in the present study, the control group consisted of normal individuals who demonstrated a better learning rate than the depressed patients (i.e., the patient group prior to the ECT treatment). These findings amplify those of Steif et al. [19] regarding the effect of depression on learning rate in explicit memory. This study demonstrates that the same group of depressed patients has an impaired learning rate for the explicit memory and for the skill learning task. In the third session, upon completion of the ECT treatment, the groups were not significantly dissociable. Findings in the second session (following the first ECT treatment) demonstrated that overall, the control group needed less moves than the ECT group to solve the TOHP. This finding is difficult to interpret because the patients are in an intermediate stage. On the one hand, depression is not alleviated. Yet, on the other, ECT treatment has not yet been completed. It is therefore difficult to unconfound these two effects.

The present study expands upon two aspects of the findings in the previous study on ECT and priming [17]. First, it demonstrates that ECT does not cause either anterograde or retrograde amnesia in the priming effect. Second, it illustrates depression does not interfere with the priming effect. Because the ECT group was slower than the control group in perceptual identification of the pictures presented, a proportional score was derived that reflects the priming effect more purely than the raw score of PE. It is probable that the slower perceptual identification reflects an impaired motor speed in the ECT group, rather than a perceptual deficit. It is important to note that in this study we administered the perceptual priming task (i.e., PPI) in a way (i.e., five repeated trials) that enabled us to measure the learning rate of the priming effect. During a standard administration, priming effect is measured following a single exposure of stimuli. In such a case, it could have been argued that priming is not sensitive

to depression because it lacks a learning measure, which was demonstrated to be sensitive to depression [19]. Our study demonstrated that even when a learning measure of the priming effect is present, neither depression (i.e., first session) nor ECT (i.e., second and third sessions) impaired priming.

The correlation pattern between initial (i.e., prior to the ECT treatment) depression level as measured by the HRSD and memory measures (Table 2), indicates that overall explicit but not implicit tasks are associated with depression. Although in the present study patients with depression (i.e., at the first testing session, prior to the ECT) differed on learning rate of the skill learning task (i.e., TOHP). This discrepancy might suggest that although overall depression affects performance on the skill learning task, the severity of depression, as measured with the HRSD, is not associated with task performance level. Consistent with previous reports in the literature, age is also associated with explicit [9], but not implicit memory, neither priming [10] nor skill learning [21].

An interesting dissociation emerged in this study between the two types of implicit memory, skill learning and perceptual priming. Patients with major depression (i.e., tested in the first session prior to ECT treatment) demonstrated impaired learning rate on the skill learning task (TOHP) just as on the explicit task, but the learning rate of the perceptual priming task was intact. Because the priming and skill learning tasks differ in various aspects (e.g., PPI is a perceptual task, TOHP is a problem solving task), it is necessary to conduct additional studies using different tasks, before our interpretation of the results can be conclusive.

## Acknowledgements

This study was supported by a grant from the Leslie and Susan Gonda (Goldschmied) Foundation, Los Angeles, California, USA.

## References

- [1] Bernet S, Cohen BD, Silverman AJ. Changes in verbal and non-verbal learning following a single left or right unilateral electroconvulsive treatment. *Biological Psychiatry* 1975;10:538–47.
- [2] Biederman I, Cooper EE. Priming contour-deleted images: evidence for intermediate representations in visual object recognition. *Cognitive Psychology* 1991;23:393–419.
- [3] Bulbena A, Berrios GE. Cognitive function in the effective disorders: a prospective study. *Psychopathology* 1993;26:6–12.
- [4] Cohen NJ, Eichenbaum H, Deacedo BS, Corkin S. Different memory systems underlying acquisition of skill learning and declarative knowledge. In: Olton DS, Gamzu E, Corkin S, editors. *Memory dysfunctions: an integration of animal and human research from preclinical and clinical perspectives*. New York: Annals of New York Academy of Sciences, 1985. p. 54–71.
- [5] Cohen NJ, Squire LR. Preserved learning and retention of pattern-analyzing skill in amnesia: dissociation of knowing how and knowing that. *Science* 1980;210:207–9.
- [6] Firth CD, Stevens M, Johnson EC, Deakin JFW, Lawer P, Crow TJ. Effects of ECT and depression on various aspects of memory. *British Journal of Psychiatry* 1983;142:610–7.
- [7] Hamilton M. Development of rating scale for primary depressive illness. *British Journal of Social and Clinical Psychology* 1967;6:278–96.
- [8] Hirshman E, Snodgrass JG, Mindes J, Feenan K. Conceptual priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 1990;16:634–47.
- [9] Kausler DH. *Learning and memory in normal aging*. San Diego: Academic Press, 1994.
- [10] Light L. Memory and aging: four hypotheses in search of data. *Annual Review of Psychology* 1991;42:333–76.
- [11] Milner B. Disorders of memory after brain lesions in man. Preface: material specific and general memory loss. *Neuropsychologia* 1968;6:175–9.
- [12] Schacter DL. Implicit memory: history and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 1987;13:501–18.
- [13] Shimamura AP. Priming effects in amnesia: evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology* 1986;38A:619–44.
- [14] SPSS Inc. *Statistical Package for Social Sciences* 1999.
- [15] Squire LR. ECT and memory loss. *American Journal of Psychiatry* 1977;134:997–1001.
- [16] Squire LR, Cohen NJ, Zouzonis JA. Preserved memory in retrograde amnesia: sparing of recently acquired skill. *Neuropsychologia* 1984;22:145–52.
- [17] Squire LR, Shimamura AP, Graf P. Strength and duration of priming effects in normal subjects and amnesia patients. *Neuropsychologia* 1987;25:195–210.
- [18] Squire LR, Slater PC. Electroconvulsive therapy and complaints of memory dysfunction: a prospective three-years follow-up study. *British Journal of Psychiatry* 1983;142:1–8.
- [19] Steif BL, Sackeim HA, Portnoy S, Decina P, Malitz S. Effects of depression and ECT on anterograde memory. *Biological Psychiatry* 1986;21:921–30.
- [20] Sternberg ED, Jarvik ME. Memory functions in depression. *Archives of General Psychiatry* 1976;33:219–24.
- [21] Vakil E, Agmon Ashkenazi D. Baseline performance and learning rate of procedural and declarative memory tasks: younger versus older adults. *Journal of Gerontology* 1997;52:229–34.
- [22] Vakil E, Sigal J. The effect of level of processing on perceptual and conceptual priming: control versus close-head injured subjects. *Journal of International Neuropsychological Society* 1997;3:327–36.
- [23] Wechsler D. *The Wechsler Memory Scale — revised*. San Antonio: The Psychological Corporation, 1987.