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Comparison Between Three Memory Tests: Cued Recall, Priming and Saving Closed-Head Injured Patients and Controls

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ABSTRACT

Twenty closed-head injured (CHI) patients and 20 matched controls were tested with three different memory tasks: cued recall, word stem completion (WSC), and saving. Saving is defined as the advantage of relearning of a list of word pairs, in terms of the number of learning trials to the criterion of one errorless trial, over the original learning of the same list. It was predicted that CHI patients' explicit memory (i.e., cued recall), but not implicit memory (i.e., WSC), would be impaired. The question addressed in this study is whether the memory of CHI patients will be impaired when memory is tested with a saving task, with 2 weeks delay between original learning and relearning. The findings confirm impairment of CHI patients in explicit memory, although the learning rate is preserved. Implicit memory is preserved in CHI patients only when based on reactivation of preexisting knowledge, but not when dependent on forming new associations. Finally, the CHI patients, even after 2 weeks delay, demonstrated a significant saving in relearning old, as compared to new, pairs of words. The clinical contribution of this study is the delineation of those aspects of memory that are impaired and those that are preserved in CHI patients. The theoretical implications of the finding that memory could be preserved in CHI patients when measured by saving, are discussed in terms of the relationship between implicit memory and saving.

Over a century ago, Ebbinghaus (1885) introduced "saving" as a measure of memory performance. Ebbinghaus' classical saving procedure consists of two sessions. In the original learning session, a list of nonsense syllables is learned to the criterion of one errorless recall trial of the list. In the relearning session, the same list is relearned to the same criterion as in the original learning session. Saving is measured as the ratio between the number of trials required for relearning of the list and the number of trials required in the original learning. The lower this ratio is, the higher the saving score. Thus, "saving" is defined as the advantage of relearning over the original learning. Saving was used as a sensitive memory measure not only in the classical list-learning paradigm but also in much broader areas. For example, Bahrick (1979) demonstrated saving in Spanish–English vocabulary relearning. Kolers (1976) has shown saving of mirror reading after a 1-year delay between original learning and relearning.

It is important to note that relearning of the previously studied material does not require explicit reference to the prior learning episode. Saving has been shown for items that were not accessible via recall or recognition (Groninger & Groninger, 1980; Nelson, 1978). Groninger and Groninger reached their conclusion by demonstrating the effect of saving over long delay intervals of 2, 3, or 4 weeks on items not retrieved in recognition.

The dissociation between impaired and preserved memory task performance in amnesic

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patients has been proposed to reflect different memory systems – explicit versus implicit (Schacter, 1987). According to Schacter, explicit memory requires intentional retrieval of information. By contrast, implicit memory does not require conscious, intentional retrieval of information, but is expressed by facilitating performance on a previously experienced task.

The similarity between the definitions of saving and implicit memory led several researchers to conclude that the saving paradigm introduced by Ebbinghaus (1885) can be viewed as an implicit measure of memory. For example, Parkin and Streete (1988) state clearly that implicit memory is measured ‘‘in terms of the *saving* between initial and second presentation’’ (p. 362). Thus, on the one hand, saving test of memory could be considered an explicit task because of participants' awareness that they are involved in a memory test. On the other hand, it could be viewed as an implicit memory test (Parkin & Streete, 1988) due to the fact that participants were not requested explicitly to recall previously learned material at the relearning stage.

Explicit memory, as measured by recall and recognition, is one of the most prominent residual deficits seen in patients who have sustained closed-head injury (CHI; Baddeley, Harris, Sunderland, Watts, & Wilson, 1987; Levin, 1989; Vakil, Blachstein, & Hoofian, 1991). Regarding implicit memory, several studies have reported that as in amnesic patients, priming is preserved in CHI patients (Mutter, Howard, Howard, & Wiggs, 1990; Vakil, Biederman, Liran, Groswasser, & Aberbuch, 1994). In a more recent study, Vakil and Sigal (1997) have reported that perceptual but not conceptual priming was preserved in CHI patients.

In a previous study saving was tested in CHI patients using Ebbinghaus' paradigm (Vakil, Cohen, Frenkel, Groswasser, & Aberbuch, 1996). Saving was calculated as the advantage of relearning over original learning defined by the number of trials to criterion (see MacLeod, 1988). The results show that overall the control group recalled more words than the CHI group, but the groups did not differ on the overall amount of saving measure. These results further supported the similarity between implicit memory and saving.

The purpose of the present study is to follow up on the previous study and to address two of its weaknesses. The first weakness is that saving was the only memory test used, thus precluding the possibility of comparing performance with other memory tests. Therefore, CHI patients in the present study, in addition to saving, will be tested on priming and cued recall, to enable a direct comparison of performance on these tasks. The second weakness is that saving was tested using Ebbinghaus' paradigm. There are two major reasons for replacing Ebbinghaus' saving paradigm in the present study: first, several researchers have noted difficulties with this paradigm. For instance, they expressed concern that the saving score, that is, the number of trials required for an errorless trial, could be dependent on a single difficult pair of associations (Estes, 1995; Nelson, 1971; Slamecka, 1985). A second reason for deviating from Ebbinghaus' paradigm is to enable direct comparison between tasks by applying a procedure resembling as much as possible that used with the priming and cued recall tasks. Nelson (1971) and MacLeod (1988) developed the saving paradigm used in the present study, which will be described in detail in the METHOD Section. One of the advantages of this saving paradigm as compared to that of Ebbinghaus' is that it enables testing memory at the level of a single item rather than a whole list.

Saving could be considered as an explicit memory task because participants know that their memory is being tested. However, given that participants' attention at the relearning stage is not directed to the previous learning experience and they are not requested explicitly to recall previously learned material, this task could be viewed as an implicit task of memory. Based on the literature reviewed, it is expected that CHI patients' memory will be impaired when tested with an explicit task (i.e., cued recall), but will be preserved when measured with an implicit task (i.e., repetition priming). The question addressed in this study is whether the memory of CHI patients will be impaired or preserved when tested with a saving task that has characteristics of both explicit and implicit tasks.

METHOD

Participants

Two groups participated in the present study: a control group (nonbrain damaged) and a CHI group. The control group consisted of 20 volunteers (19 males and 1 female) ranging in age from 19 to 41 years ($M = 28.70$). Their education ranged from 12 to 15 ($M = 13.05$) years of schooling. The CHI patients were recruited for the study from a population of patients attending the Neuropsychologoical Unit for Treatment and Rehabilitation (Israel) for rehabilitation. All patients suffer from traumatic head injury, mostly resulting from motor-vehicle accident. This group was composed of 20 patients (19 male and 1 female) ranging in age from 20 to 42 years ($M = 28.35$). Their education ranged from 10 to 15 ($M = 12.75$) years of schooling. This group is a representative sample of CHI patients at different stages of their rehabilitation. The groups did not differ significantly either on age, $t(38) = .17$, $p > .05$, or educational level, $t(38) = .73$, $p > .05$. Table 1 provides a more detailed description of the patient group including the length of coma, the Glasgow Coma Scale score, and time after onset. Participants in both groups were proficient in Hebrew, and had no history of mental illness, alcoholism or drug use.

Table 1. Demographics of the CHI Patient Group.

Patient	Age	Gender	Educ	TAO	Coma	GCS
SR	29	Female	14	110	1	**
SS	30	Male	13	90	9	7
BH	24	Male	9	47	5	4
AG	27	Male	13	92	7	9
SB	24	Male	12	45	1	9
AS-1	26	Male	12	95	1	**
DD	27	Male	12	88	7	7
SG	23	Male	14	35	1	**
SC	25	Male	13	70	1	**
ES	25	Male	14	43	10	7
ZY	41	Male	14	147	12	6
YB	31	Male	14	84	1	**
ET	20	Male	12	26	1	**
ES	20	Male	12	58	1	7
TK	28	Male	12	55	6	6
AC	25	Male	12	42	5	7
BD	41	Male	12	36	1	**
AS-2	24	Male	14	39	14	*
ZT	42	Male	12	152	1	*
MT	35	Male	15	45	4	12

Note. Educ = education (years); TAO = time after onset (months); Coma = length of coma (days); GCS = Glasgow Coma Scale, on admission to hospital.
* GCS score could not be registered because patient was connected to respirator upon admission to hospital.
** GCS score not available in the medical record.

Tests and Procedure

All participants were tested on a ‘‘saving’’ and a ‘‘priming’’ task. A cued recall task was added to each one of these tasks. The testing was conducted in three sessions per participant. Two of these sessions, 2 weeks apart, were dedicated to the saving task. The priming task was administered in a separate session. For half of the participants, the priming task was administered 1 week prior to the two saving sessions. For the other half of the participants, the priming task was administered 1 week following the second saving session.

One hundred-and-four high frequency Hebrew words (more than 50 per 200,000 words; Balgure, 1968) were used to construct two lists of 26 pairs of words. These two lists were used in a counterbalanced fashion for each participant for the saving and the priming tasks. Based on a pretest, each pair included words chosen with a low association between them. Each pair of words was printed side by side on a card of 10 cm × 15 cm. On each card, the word on the right was used as the cue and the word on the left as the target.

Saving Task

Acquisition. This task is based on the paradigm developed by Nelson (1971) and MacLeod (1988) and was modified to meet the needs of the present study. In order to familiarize the participant with the task, a four-item list of letter-letter pairs was presented. Cue letters were then presented one by one, and the participant responded verbally with the target letter. Following this four-item warm-up task, a 26-pair word list was presented at an 8-s rate. The first three and last three pairs were used only to counteract the primacy and recency effect. Thus, the core list consisted of the 20 pairs of words in the middle. Participants were told that this is a memory task, and asked to read the words aloud. Additionally, in the initial trial only, they were asked to rank the degree of association between the words in each pair on a 1 to 5 scale, from no association to high association, respectively. Following presentation of the list, participants were asked to count backwards from 20 to 0, in order to counteract the recency effect. At test the cue words, appearing in their original size as in learning, were presented in random order, one at a time on a card of the same size as in learning. Participants were asked to say the target word that was presented along with the cue word. This procedure was repeated until the fulfillment of one of the two criteria: either one errorless trial or six repetitions. The examiner recorded the number of correct target words recalled at each trial and the number of trials needed to learn the 20 pairs. Participants were not told that they were going to be tested again.

Retention tests and relearning. Two weeks after acquisition participants returned for the second session. Following the warm-up task (i.e., the four-item list of letter-letter pairs), participants had a self-paced, forced-response retention test. In this test, they saw one cue word at a time and had to respond with the target word associated with it in the learning phase in the previous session. For the relearning test (which took place 10 min later) a list of 20 word pairs was presented. Half of the list, 10 word pairs, was drawn from the exact original pairs, chosen randomly for each participant, from the words that he or she did not recall in the retention test. Note that none of the participants recalled correctly more than 15 words out of the full list of the 26 original word pairs. Thus, for each participant at least 10 word pairs were not recalled, which were then used for the relearning test. The other half of the list was constructed of original cue words and new target words. Two trials were administered (to avoid ceiling effect) with this new list, following the same procedure as in the first session.

Priming and Cued Recall Tasks

Acquisition. These tasks were administered in the first session (i.e., before the saving task) for one half of the participants and in the third session (i.e., after the saving task) for the other half. As in the saving task, a 26-pair word list was presented at an 8-s rate. The format of presentation with regard to the size of the letters and cards was identical to that in the saving task. The first three and last three pairs were used only to counteract the primacy and recency effect, so that the core list consisted of the middle 20 pairs of words. As in the saving task participants were asked to read the words aloud and to rank the degree of association between the words in each pair. In order to strengthen learning, the list was presented twice without an intervening test. It is important to emphasize that the pairs of words were not related to each other and had no a priori association (e.g., Chair-Book).

Priming test – word-stem completion (WSC). This task is based on the paradigm developed by Schacter and Graf (1986) and was modified to meet the needs of the present study. Similar to Schacter and Graf, an attempt was made to measure two aspects of priming. The first aspect is based on the learning of new associations, and thus the original cue word was given with the first letter of the target word (e.g., Chair-B – for Book; same-context condition). The second aspect of priming measured is when completion is based on activation of preexisting representations of target words. This is achieved when a new cue word is given with the first letter of the target word (e.g., Door-B – for Book; different-context condition). Priming is evident when correct completion of target words from the study list exceeds the correct completion of new target words (i.e., baseline) that were not presented in the study phase. The advantage of correct completion of target words in the same-context condition versus the different-context condition would reflect implicit learning of new associations.

In order to strengthen the implicit nature of the task, participants were given a list of names of famous people, first name in full and last initial. Participants were asked to complete the last name with the first name that comes to mind (e.g., Elizabeth T – for Taylor). Following this warm-up task a 36-pair word list was presented one pair at a time at an 8-s rate. At test, the cue word and the first letter of each of the target words were presented. The list consisted of 10 original pairs (i.e., same-context condition), 10 pairs with new cue words but old targets (i.e., different-context condition), 10 new pairs of cue and target words that served as a baseline measure, with the remaining six words used as fillers. The instructions to the participants were to complete the target word with the first word that comes to mind.

Cued Recall Task

This task was always presented following the priming task. The same priming task list was presented again. Just as in the saving task, participants were presented with the cue word and asked to say aloud the target word associated with it.

RESULTS

Saving

Learning – Trials 1 to 3

The mean numbers of target words correctly recalled by the two groups in the first three learning trials are presented in Figure 1. Only the first three trials were analyzed in order to avoid ceiling effect. A mixed-design ANOVA was used for the analysis of the number of target words correctly recalled, with group (controls vs. CHI) and learning trials (1–3) as factors; the first is a between-subjects factor, and the second a within-subjects factor. Both main effects, group,

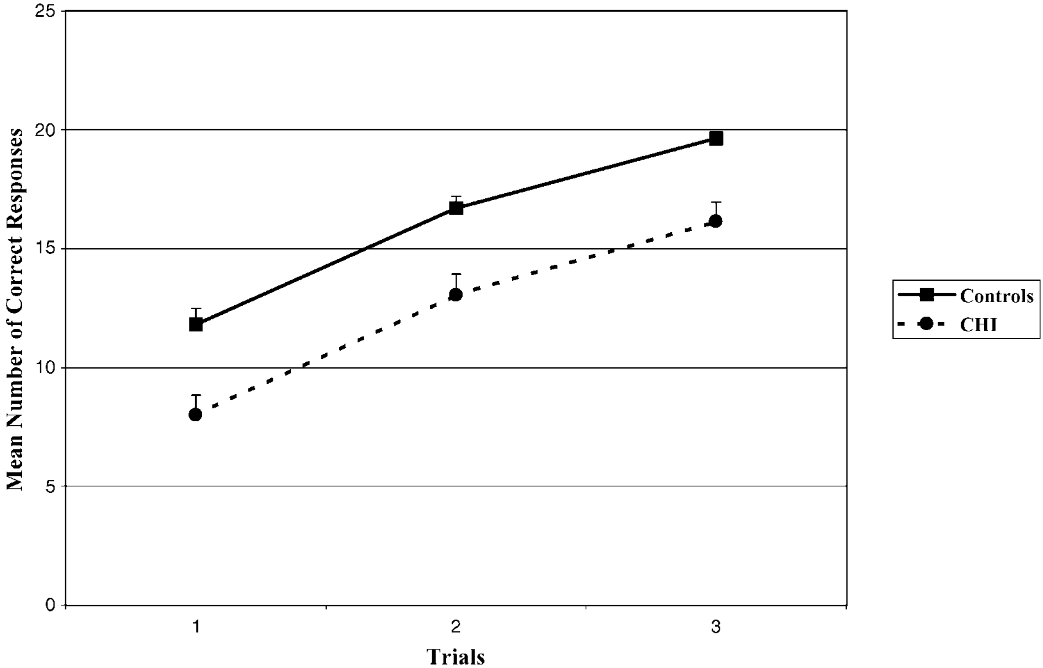

Fig. 1. The mean number (and standard errors) of target words correctly recalled by the two groups in the first three learning trials.

$F(1, 38) = 16.42$, $p < .001$, and learning, $F(1, 38) = 302.09$, $p < .001$, reached significance, but not the interaction between them. As can be seen in Figure 1, both groups improved from trial to trial at the same rate.

Number of Trials to Criterion

The control group needed significantly less trials ($M = 3.05$, $SD = .60$, Range = 2–4) than the CHI group ($M = 4.15$, $SD = 1.27$, Range = 2–6) to reach the criterion of an errorless trial, $t(38) = 3.50$, $p < .002$.

Retention

The control group recalled significantly more pairs after a 2-week delay ($M = 9.95$, $SD = 2.26$, Range = 7–15) than the CHI group ($M = 6.60$, $SD = 2.93$, Range = 2–15), $t(38) = 4.05$, $p < .001$.

Relearning – Trials 1 to 2

The mean number of old and new target words correctly recalled by the two groups in the two relearning trials are presented in Figure 2. A mixed-design ANOVA was used for the analysis of the number of target words recalled, with group (controls vs. CHI), novelty (old vs. new pairs) and learning trials (1–2) as factors; the former is a between-subjects factor, and the latter two are within-subjects factors. Overall, the control group recalled more words than the CHI group, $F(1, 38) = 23.22$, $p < .001$. More words were recalled in the second trial than in the first trial, $F(1, 38) = 321.60$, $p < .001$, and old words were recalled more than new ones, $F(1, 38) = 173.54$, $p < .001$. As can be seen in Figure 2, the significant Learning trials by Novelty interaction, $F(1, 38) = 24.75$, $p < .001$, reflects the steeper learning rate of new as compared to old pairs. It is possible that this interaction is due to the fact that at least the controls reached ceiling in the second learning trial of the old pairs. The Group by Novelty interaction also reached significance, $F(1, 38) = 31.32$, $p < .001$. As can be seen in Figure 2, the difference between the groups in the recall of old pairs is less (8.77%) than the difference between the groups in the recall of new pairs (30%).

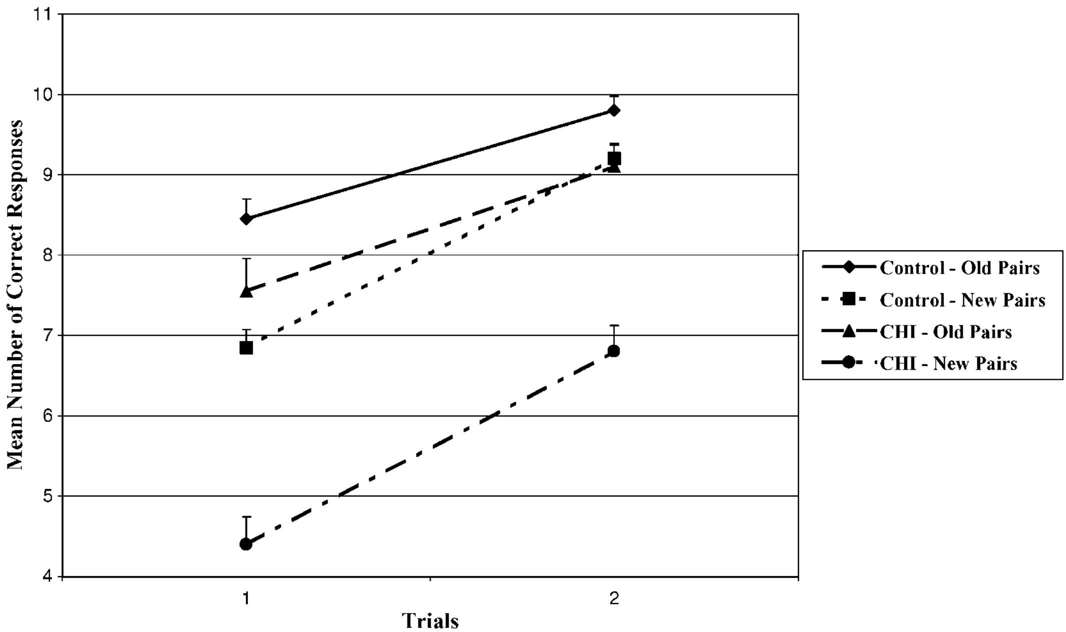

Fig. 2. The mean number (and standard errors) of old and new target words correctly recalled by the two groups in the two relearning trials.

Simple analyses were conducted in order to detect the source of the significant interactions. When old pairs are analyzed separately, the group and learning trial main effects, but not the interaction, reached significance, $F(1, 38) = 5.06$, $p < .05$, and $F(1, 38) = 77.01$, $p < .001$, respectively. A similar pattern was found with new pairs, as the main effects, group, $F(1, 38) = 42.13$, $p < .001$, and learning trial, $F(1, 38) = 443.09$, $p < .001$, but not the interaction, reached significance.

Saving is viewed as the advantage of the relearning of old pairs compared to new pairs. The control group showed an advantage of 24.04% for the first trial and 7.08% for the second trial ($M = 15.56\%$) in relearning of old pairs compared to learning of new pairs. The CHI group showed an advantage of 85.89% for the first trial and 37.113% for the second trial ($M = 61.51\%$) in relearning of old pairs compared to learning of new pairs. The overall advantage of the CHI group compared to that of the controls reached significance, $t(38) = 4.35$, $p < .001$.

Priming

Figure 3 presents the mean number of target words completed correctly by the groups under same-context, different-context, and baseline conditions. Since the groups' baseline performance was identical ($M = .60$ out of 10 words, 16.67%), no correction of performance was required in order to compare the groups' performance on the priming tasks. A mixed-design ANOVA was used for analysis of the number of target words correctly completed, with group (controls vs. CHI), and priming (same- vs. different-context conditions) as factors; the former is a between-subjects factor, and the latter is a within-subjects factor. Both main effects and the interaction reached significance. Overall, the control group completed more words correctly than the CHI group, $F(1, 38) = 5.45$, $p < .05$, and more target words were completed correctly under the same-context than under the different-context condition, $F(1, 38) = 358.05$, $p < .001$. The significant interaction, $F(1, 38) = 10.23$, $p < .005$, indicates that the advantage of same-context

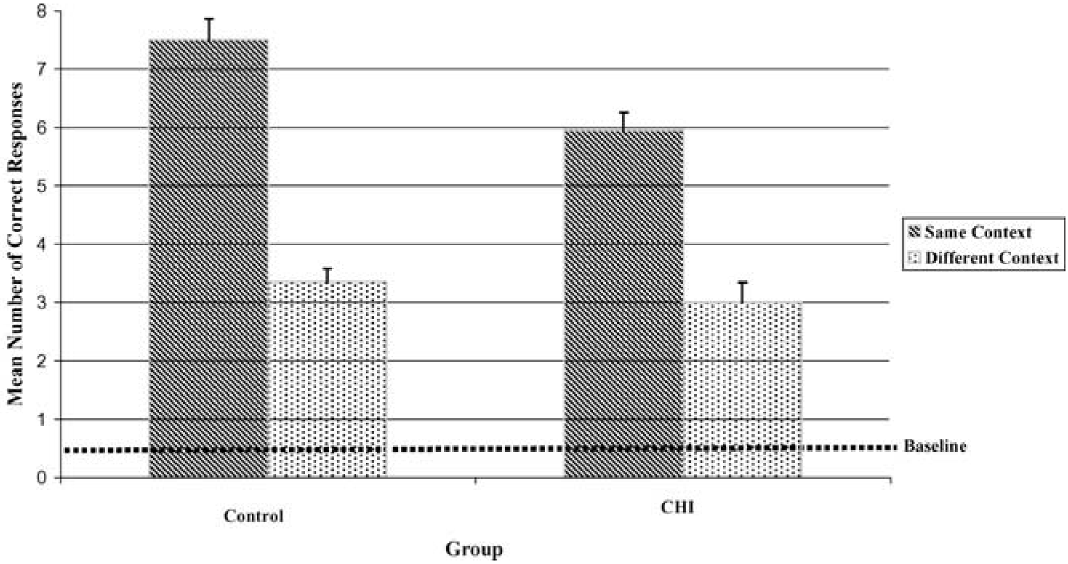

Fig. 3. The mean number (and standard errors) of target words completed correctly by the groups under same-context, different-context, and baseline conditions.

over different-context condition, was not the same for both groups. Follow-up analyses revealed that the groups differed only in the number of target words completed under the same-context condition, $t(38) = 3.26$, $p < .001$, but not under the different-context condition, $t(38) = .84$, $p > .05$.

Cued Recall

In the cued recall task that followed the priming task, the advantage in the number of words recalled by the controls ($M = 5.55$, $SD = 1.73$, Range = 2–9) as compared with the number of words recalled by the CHI group ($M = 4.40$, $SD = 1.35$, Range = 2–7), reached significance, $t(38) = 2.34$, $p < .05$.

Finally, Pearson Correlations were calculated in order to assess the relations between the severity of the patients' head injury to their performance on the different memory measures. Length of coma, Glasgow Coma Scale score, and time after onset were used as different indices of head injury severity. Memory measures that were correlated with the severity measures included the total number of words recalled in the three initial learning trials of the saving task, the total number of words recalled in the two relearning trials of old pairs (saving measure), the total number of new words recalled in the two learning trials, the number of target words correctly completed in the priming task, and the number of words recalled in the cued recall task that follows the priming task. The only correlations that reached significance were between the Glasgow Coma Scale score and the total number of words recalled in the three initial learning trials of the saving task and with the total number of new words recalled in the two learning trials ($r(11) = .697$, $p < .001$, and $r(11) = .883$, $p < .001$, respectively).

DISCUSSION

One of the advantages of the present study is that the same samples of participants (i.e., controls and CHI patients) were tested with three different tasks: cued recall, word stem completion, and saving. Moreover, an attempt was made to apply a similar paradigm to these three different tasks to enable comparison between the tasks.

Consistent with previous reports in the literature (Baddeley, Harris, Sunderland, Watts, & Wilson, 1987; Levin, 1989; Vakil et al., 1991), the overall number of pairs of words recalled immediately and retained over time is impaired in CHI patients as compared with controls. However, contrary to other findings (e.g., Vakil et al., 1991), the CHI patients' learning rate did not differ from that of the control participants. Normal learning of the CHI group was evident on two occasions in this study. First, in the initial phase of the saving task (three trials); and second, in learning of the new pairs (two trials) in the relearning phase of the saving task. A possible reason for this inconsistency is that, unlike previous studies in which learning rate was measured with free recall (e.g., Vakil et al., 1991), in the present study cued recall was used, which might have facilitated learning for the CHI patients. The possibility that deep encoding in the study phase (i.e., ranking the degree of association between the words in each pair) may have contributed to the normal learning rate of the CHI group seems less likely, since the CHI group also demonstrated normal learning rate in the second phase, where deep encoding was not manipulated. Further study is required to determine the variables affecting the learning rate of CHI patients.

In the present study the WSC task was used as the priming task. Previous studies have reported that CHI patients are preserved on this task (Mutter, Howard, Howard, & Wiggs, 1990; Vakil et al., 1994). In the latter two studies, WSC task was administered differently. Unlike in the present study, a single word rather than a pair of words was presented at learning and at test. The paradigm used in this study resembles that used by Schacter and Graf (1986), which enables implicit testing of new associations. The present results are similar to those reported by Schacter and Graf with severely amnesic patients. In both studies, unlike controls, patients' priming effect under same-context condition did not exceed the priming effect found under different-context condition. Thus, as in amnesics, priming is preserved in CHI patients only when based on reactivation of preexisting knowledge (i.e., different-context), but not when it is dependent on forming new associations (same-context). Despite the instructions for implicit memory it is possible that explicit memory is involved in priming of new associations (i.e., same-context). This could explain the advantage of the control group over the CHI group (for discussion, see Schacter & Graf). The other possibility is that in addition to being impaired in conceptual priming, as reported previously by Vakil and Sigal (1997), CHI patients have difficulty in forming new associations even when perceptual priming is involved.

The total number of pairs recalled upon relearning was impaired in CHI patients as compared to controls. However, in saving, measured as the relative advantage of the relearning of old pairs compared to the learning of new pairs, patients' performance was even superior to that of controls (61.51% vs. 15.56%, saving). It is possible that part of the advantage of the CHI group is due to ceiling effect in the controls' performance. However, the advantage already existed in the first learning trial before reaching ceiling level, 24.04% and 85.89% for the control group and the CHI group, respectively. At any rate, it is safe to conclude that the CHI group was not impaired when saving is used as a memory measure. These findings extend the findings of our previous report on saving, in which CHI patients' saving was preserved when tested with Ebbinghaus' paradigm (Vakil et al., 1996).

In conclusion, this study exemplifies the complexity of memory testing and contributes to the delineation of those aspects of memory that are impaired and those that are preserved following closed-head injury. Three different tests of memory were used, explicit, implicit, and saving. The findings confirm the impairment of the CHI patient in explicit memory, although the learning rate is preserved when using a cued recall task. Further support for this conclusion may be derived from the finding that severity of injury (i.e., Glasgow Coma Scale) correlated significantly only with the learning of new pairs of words (i.e., initial three learning trials and two learning trials of new pairs), but not with relearning of old words (i.e., saving) or words completed in the priming task. Priming is preserved in CHI patients, just like in amnesic patients, only when based on reactivation of preexisting knowledge, but not when it is dependent on forming new associations. Finally, the CHI patients, even after the 2-week delay, demonstrated a significant saving in relearning old pairs of words that were not remembered in free recall, as compared to new pairs of words. These findings suggest that despite patients' awareness that they are involved in a memory task, the fact that they were not requested explicitly to recall previously learned material at the relearning stage enabled normal performance on this task. In other words, the crucial stage for determining whether information is processed implicitly or explicitly is the retrieval rather than the encoding stage. Accordingly, just like priming and unlike explicit memory, saving is preserved in CHI patients.

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