

The effect of level of processing on perceptual and conceptual priming: Control *versus* closed-head-injured patients

ELI VAKIL AND JULIE SIGAL

Psychology Department, Bar-Ilan University, Ramat-Gan, Israel

(RECEIVED December 15, 1995; REVISED August 19, 1996; ACCEPTED September 13, 1996)

Abstract

Twenty-four closed-head-injured (CHI) and 24 control participants studied two word lists under shallow (i.e., nonsemantic) and deep (i.e., semantic) encoding conditions. They were then tested on free recall, perceptual priming (i.e., perceptual partial word identification) and conceptual priming (i.e., category production) tasks. Previous findings have demonstrated that memory in CHI is characterized by inefficient conceptual processing of information. It was thus hypothesized that the CHI participants would perform more poorly than the control participants on the explicit and on the conceptual priming tasks. On these tasks the CHI group was expected to benefit to a lesser degree from prior deep encoding, as compared to controls. The groups were not expected to significantly differ from each other on the perceptual priming task. Prior deep encoding was not expected to improve the perceptual priming performance of either group. All findings were as predicted, with the exception that a significant effect was not found between groups for deep encoding in the conceptual priming task. The results are discussed (1) in terms of their theoretical contribution in further validating the dissociation between perceptual and conceptual priming; and (2) in terms of the contribution in differentiating between amnesic and CHI patients. Conceptual priming is preserved in amnesics but not in CHI patients. (*JINS*, 1997, 3, 327–336.)

Keywords: Perceptual, Conceptual, Priming, CHI

INTRODUCTION

A priming effect has been found preserved even in severe amnesic patients (for review see Shimamura, 1986). A priming effect is said to have occurred if the 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 (Cermak, Talbot, Chandler, & Wolbarst, 1985), subjects are asked to identify the object presented in degraded forms of pictures, as quickly as possible. Common forms of verbal priming tasks are: word identification, in which the reaction time of word identification is recorded (Jacoby & Dallas, 1981); word-stem completion (WSC), in which the first three letters of a word are given and participants are asked to complete the stem with the first word that comes to mind (Squire et al., 1987); and word-fragment completion (WFC), in which participants must supply a word fitting a given word fragment (e.g.,

“e—p—n” for “elephant”: Rajaram & Roediger, 1993). Priming can be subdivided into two subtypes, *perceptual* and *conceptual*, each based upon the involvement of respective levels of processing (Srinivas & Roediger, 1990; Blaxton, 1992; Challis & Brodbeck, 1992).

The priming phenomenon was first identified in studies of amnesic patients (Milner, 1962; Warrington & Weiskrantz, 1968). It was found that while amnesics were impaired at the explicit retrieval of information, they were capable of implicitly retaining certain information. Some investigators suggested that amnesics' primary impairment may be in the conceptual processing of information, rather than in explicit retrieval (Blaxton, 1989; Srinivas & Roediger, 1990). In support of this claim, Blaxton (1992) found that temporal lobe epileptic patients were impaired on conceptual memory tasks, whether tested explicitly or implicitly. These patients' memory was preserved when perceptual memory was tested either explicitly or implicitly. However, several more recent studies have reported different results; that is, amnesics' memory was impaired when measured explicitly and preserved when measured implicitly, regardless

Reprint requests to: Eli Vakil, Psychology Department, Bar-Ilan University, Ramat-Gan, 52900, Israel. E-mail: vakile@ashur.cc.biu.ac.il.

of whether perceptual or conceptual processing was required (Carlesimo, 1994; Graf et al., 1985; Cermak et al., 1995; Vaidya et al., 1995). One possible explanation of Blaxton's (1992) findings is that the patients who participated in her study were not global amnesics, but patients with unilateral left-side lesions (for discussion see Vaidya et al., 1995).

Although the distinction between perceptual and conceptual priming is not useful in the dissociation between impaired and preserved memory ability in amnesia, it is nevertheless an important distinction. It accounts for many findings in memory studies with normal persons, such as the effect of level of processing on different tasks (Jacoby, 1983; Blaxton, 1989; Srinivas & Roediger, 1990; Challis & Brodbeck, 1992). Further support for the dissociation between perceptual and conceptual priming is derived from studies concerning early-stage Alzheimer's disease (AD), in which AD patients' perceptual, but not conceptual, priming has been found preserved (Butters et al., 1990; Keane et al., 1991; Fleischman et al., 1995; Monti et al., 1996). On the other hand, an opposite pattern has been observed for patients with occipital lesions; that is, impaired perceptual priming and preserved conceptual priming (Keane et al., 1992; Gabrieli et al., 1995).

Memory disturbances in CHI patients have been found in various explicit memory tests. For example, Baddeley et al. (1987) found that CHI patients performed more poorly than controls on paired-associate cued-recall and recognition tasks, and on recall and recognition tests that required participants to recollect category members from a prior study phase; in the Vakil et al. (1991) study, CHI subjects performed more poorly than normal controls on recall and recognition in the Rey Auditory-Verbal Learning Test; and Vakil et al. (1992) found CHI patients recalled fewer details in the Logical Memory subtest of the Wechsler Memory Scale-Revised (WMS-R; Wechsler, 1987) than normal controls. In general, CHI patients have been found to display impaired learning and memory for new material (Baddeley et al., 1987).

Today, the memory deficit in CHI is commonly viewed as particularly affecting conceptual processes involved in memory (Levin, 1989). In other words, it does not include the perceptual properties of inputs, but rather their cognitive referents. Baddeley et al. (1987) concluded that semantic information is maintained after CHI; however, speed of access to semantic memory is impaired. Levin and Goldstein (1986) concluded that although semantic knowledge and its organization is intact in CHI patients, these individuals seem to have a passive approach to learning, and do not actively organize learning material. Further indication that semantic knowledge is preserved following CHI was reported by Schmitter-Edgecombe et al. (1993). In their study, they used a lexical decision task to measure CHI patients' semantic priming ability, and found that although they were slower than normal controls, there was no significant group difference in semantic priming. Vakil et al. (1992) came to a similar conclusion to that of Levin and Goldstein,

when referring to their experimental results. These researchers tested the memory ability of CHI patients on the logical memory subtest of the WMS. Specifically, differential memory ability for important details was studied. Results demonstrated that while normal controls selectively recalled the more important details, CHI patients failed to show this selective differentiation in their recall of the stories. Again, it is proposed that one source for poor memory in CHI is due to the inefficient conceptual processing of information. Goldstein et al. (1990) investigated the effect of level of processing (LOP) on CHI recall performance. Results demonstrated that response latencies for the CHI subjects were longer, overall, than those of control participants. However, CHI participants were disproportionately slower when accessing the semantic information from memory, as compared to physical or acoustic information. The authors concluded that their results support the hypothesis that CHI leads to slower processing, which causes deficient speed of access to semantic memory. In one of their studies, Baddeley et al. (1987) compared CHI and classic amnesic patients. They found that although both groups were impaired in the learning of new material, CHI patients were impaired in the speed of access to semantic memory and in the memory for autobiographical information (personal past events). These abilities were found intact in the classic amnesics. The above differences between the groups may reflect the underlying cognitive and anatomic differences that exist between amnesic and CHI patients. By definition, in global amnesia memory loss is primary; that is, other cognitive functions remain intact. In contrast, CHI injury most commonly leads to multiple cognitive dysfunctions, in which memory impairment may occur as a secondary effect (Baddeley et al., 1987). In addition, injury location differs in CHI and classic amnesic patients; as described earlier, the amnesic syndrome is due to medial-temporal lobe and diencephalic damage. CHI frequently leads to widespread diffuse axonal injury, which disrupts connections within the cerebrum (Ommaya & Gennarelli, 1974), and to lesions in the frontal and temporal lobes (Adams 1975; Levin et al., 1982). More recently, researchers have been emphasizing the cardinal role of the lesions to the frontal lobes as an explanation of the behavioral sequelae typically observed following CHI (Bigler, 1990; for review see Stuss & Gow, 1992).

Although explicit memory has been investigated in the CHI population, there is a dearth of information concerning its implicit memory ability. In a review of the literature, only two experiments were found to address the issue of priming directly. One study (Mutter et al., 1990) found that mild CHI subjects performed as normal controls on the word stem completion (WSC) task, but performed poorly on a cued recall task. The other study was performed by Vakil et al. (1994), who found that CHI patients demonstrated similar priming ability to that of normal controls when tested with a WSC task. It seems, then, that the minimal findings concerning CHI implicit memory ability point to retained priming ability, at least as expressed in the performance on the WSC test. However, no studies directly compared perceptual *ver-*

sus conceptual priming in CHI patients, nor the effect of deep (i.e., semantic) *versus* shallow (i.e., nonsemantic) encoding on the performance of these tasks.

It is assumed that the CHI patients' dysfunctional deep encoding ability will be reflected in their performance on both explicit and conceptual priming tasks. Their perceptual priming ability is not expected to be impaired due to low-level processing demands of perceptual priming. In addition, it is predicted that the CHI group will benefit from deep encoding to a lesser degree than the control group.

METHODS

Research Participants

The sample consisted of two groups: CHI patients and normal controls. The participants in the CHI group sample consisted of 24 patients from both the Recanati National Institute for the Rehabilitation of the Brain-Injured, and from the Rehabilitation Day Center, Loewinstein Hospital, Israel. Subject selection answered to the following criteria: (1) all patients had been unconscious for at least 24 hr (an indication of severity of brain insult: Levin et al., 1982); (2) all patients were at least 1 year postinjury (to ensure stabilization of condition: Levin et al., 1982). See Table 1 for detailed demographic information of CHI patients. The sample

consisted of 19 men and 5 women, whose age ranged from 18 to 46 years ($M = 28.3$); mean level of education in years was 12.3. The control group consisted of 24 normal participants, matched for age and education level of the CHI group. The sample consisted of 20 men and 4 women whose ages ranged from 18 to 41 years ($M = 27.4$); mean level of education in years was 12.6. Differences were not significant for age [$t(46) = .47, p > .05$], or for education level [$t(46) = .37, p > .05$]. Participants in both groups were proficient in Hebrew, and had no history of mental illness, CNS disease, alcoholism, or drug use.

Testing Materials

The target materials consisted of 105 Hebrew words, 72 of which were comprised of 6 exemplars each of 12 different categories (e.g., category name: occupations; exemplars: architect, judge, cook, glass cutter, tailor, policeman). The remaining 33 of the 105 words were high-frequency Hebrew words (more than 50 per 200,000 words: Balgure, 1968). A *category exemplar word list* was derived from a pretest. The purpose of the pretest was to acquire normative data concerning frequency of category exemplars in the Hebrew language. Participants consisted of 324 adults, who were given a questionnaire to fill out. The questionnaire consisted of a list of 24 category names. The participants were asked to write down the first eight members of each category that came to mind. Data were analyzed with regard to the frequency of each category exemplar listed by subjects. Exemplars of 12 category names were applied in this present study (i.e., six exemplars of six categories at each of the two testing sessions). Those category exemplars applied were nonfrequent, that is, they were not among the 10 most frequent exemplars of each category.

Definition of words

This was required in the deep encoding condition at the learning phase. The efficacy of the word definitions was tested in a second pretest. For this pretest, a pool of word definitions was tested on a total of 74 university students. Students were required to guess the word being defined. Definitions chosen for this present experiment belonged to the subgroup of definitions for which at least 85% of students supplied the desired word. Bloom and Fischler (1980) have applied similar cutoffs in their search for appropriate definitions for a similar encoding task.

Partial Word-Identification (PWI)

This task was based on a program that was written for a PC computer. Although it is an original program, similar forms of this test can be found in the literature (Hirshman et al., 1990). This type of test has been found to induce perceptual priming (Hirshman et al., 1990; Biederman & Cooper, 1991). This computer program was designed to enable the gradual appearance of fragments of all letters of a given word. Thirty-

Table 1. Demographics of the CHI patient group

Patient	Sex	Age	Edu	TAO	COMA
D.D.	F	19	11	24	22
Y.L.	M	29	12	72	99
L.L.	M	25	12	23	5
D.S.	M	29	10	55	14
A.O.	M	47	17	20	14
E.B.	M	22	11	55	60
L.H.	M	22	12	34	3
G.M.	M	27	12	19	10
L.R.	M	21	12	33	45
A.S.	F	22	13	37	14
S.M.	F	27	12	29	21
A.B.	M	27	12	73	60
Y.B.	M	36	12	33	2
S.A.	M	29	12	36	60
E.D.	F	27	12	64	45
U.G.	M	44	11	65	7
I.W.	F	19	11	32	45
A.H.	M	41	16	54	1
A.K.	M	25	12	52	21
S.T.	M	23	12	19	16
S.S.	M	25	12	18	9
B.S.	M	21	12	12	13
G.O.	M	36	10	14	4
D.E.	M	37	17	137	30

Edu = education (years), TAO = time after onset (months), COMA = length of coma (days).

nine words were applied in the PWI test, the first three being practice items. Of the remaining 36 words, 18 were new words and 18 were primed (9 from the shallow encoding condition and 9 from the deep encoding condition). These 18 primed words consisted of six exemplars of three of the categories seen in the previous encoding conditions. The new and primed words were presented in random order.

Category production (CP)

This task was comprised of six category names. Three of the category names were names of the three primed categories of the study phase that had not been applied in the PWI priming test. The three remaining category names were new, unprimed categories. Categories were presented in random order. As noted previously, performance on the CP priming test has been shown to reflect a conceptual form of processing (Graf et al., 1985; Srinivas & Roediger, 1990).

Distracter task

The Digit Span subtest of the WMS–R was applied as a distracter task.

Procedure

Participants were individually tested. The testing was conducted in two sessions per participant, and there were at least 5 days between sessions. Each session consisted of a study phase and a testing phase. The study phase was identical in both sessions; however the words applied in the two study phases were different. The 72 words (six exemplars of twelve categories), obtained in a pretest, were divided equally into two blocks of six exemplars of six categories (i.e., 36 words), and each block was used in a different session. In the first session, perceptual and conceptual priming tests followed the study phase, and in the second session a recall test followed the study phase. The same distracter task (i.e., digit span) was administered between study and test phases in both sessions.

Study phase (in both sessions)

Participants were seated in front of a computer screen. They were presented with 42 words, one at a time, on the computer screen. The list consisted of three filler words at the beginning of the list and three at the end of the list. The remaining 36 words consisted of six exemplars of six categories. The words were divided into two lists of 18 words, representing two encoding conditions: *shallow* (i.e., non-semantic) and *deep* (i.e., semantic), so that three exemplars of each category were found in every list. In the shallow encoding condition, participants were asked to count the total number of times that either one of two vowels (*yod* or *vav* in Hebrew) occurred in each word appearing on the screen. Words appeared for 3 s. In the deep encoding con-

dition, participants were read a one- or two-sentence description of an undisclosed word by the examiner. They were then requested to generate the word that was described. If the generated word was correct, the examiner pressed a key to expose the correct answer on the computer screen. If a participant responded incorrectly, he or she was shown the correct answer on the computer screen. If no response was offered by a participant after 10 s following the description, the examiner displayed the answer on the screen. All responses were recorded by the experimenter. In both sessions, the shallow encoding condition was followed by the deep encoding condition. Had the deep encoding condition been presented first, it is very likely that participants would have continued (unintentionally) to more deeply process the words belonging to the shallow encoding condition as well (Blaxton, 1989). At no time were participants told their memory for the words would be tested.

Distracter task

Immediately following Study Periods 1 and 2, the digit-span task was administered. Here, participants were first asked to repeat a series of digits, ascending in difficulty (digits forward), and were then asked to repeat a different series of digits, this time in the opposite order that they had heard (digits backward). After completing this task, the examiner administered the according test.

Priming tests—first session

A partial word-identification test (perceptual priming) and a category production test (conceptual priming) were administered in this phase in counterbalanced order.

Partial word-identification. Participants were told they would first see an “X” on the screen to focus their attention. Then, they would see fragments of a word gradually appear on the screen. They were instructed that their task was to attempt to identify the word as quickly as possible. The increase in number of fragments of the gestalt continued until subjects, when deciding to respond, pressed a computer key, consequently freezing the process. The subjects then gave their answer verbally. If a participant identified a word incorrectly, he or she was so told, and the gradation process was continued until the correct word was identified. Percent exposure (PE) to correct identification was recorded, which ranged from 0 to 100. Following the correct identification of the word, the full word was presented on the screen for 1 s.

Category production. Participants were read six category names (three primed and three new), one at a time. They were requested to say the first eight category exemplars that came to mind for each category name. A new category was attempted after participants either supplied eight

exemplars for the prior category, or failed to produce a new exemplar of that category for 1 min.

Recall (explicit) test—second session

Immediately following the distracter task, participants were requested to recall as many as possible of the words that had appeared on the computer screen since the beginning of the session.

In summary, all participants participated in two sessions. For each session there was a study and a testing phase. The study phase was similar (but with different words) in both sessions: participants performed shallow encoding for the first half of the list and deep encoding for the second. Perceptual (i.e., PWI) and conceptual (CP) priming tests followed the study phase in the first session and an explicit (i.e., free recall) test followed the study phase in the second session. A distracter test (i.e., digit span) was administered between study and testing phases in both sessions.

RESULTS

The CHI and control groups were compared in this study in three memory tasks: free recall, perceptual priming, and conceptual priming. The analysis of the results of each task is reported accordingly in three different sections.

Explicit Memory—Free Recall

Mean words recalled (and *SDs*), as a function of encoding conditions, for control and CHI groups, are presented in Table 2. A mixed design two-way ANOVA was conducted to analyze the effect of Group (control vs. CHI) by \times Encoding Condition (shallow vs. deep), the former being a between-subjects factor, and the latter a within-subjects factor. Both main effects were found to be significant. Since the interaction between them was also significant, main effects should be interpreted cautiously. The group main effect was [$F(1, 46) = 22.91, p < .001$], and the encoding main effect was [$F(1, 46) = 208.98, p < .001$]. The Encoding \times Group interaction was [$F(1, 46) = 20.51, p < .001$]. The significant group main effect suggests that controls had superior recall as compared to CHI participants. Results also suggest that the deep encoding condition facilitated later recall more than did shallow encoding. However, deep encod-

Table 2. Words recalled as a function of encoding condition for controls and CHI patients

Encoding condition	Group			
	Control (<i>n</i> = 24)		CHI (<i>n</i> = 24)	
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
Shallow encoding	1.42	(1.32)	0.79	(1.14)
Deep encoding	7.79	(1.89)	4.13	(2.91)

Table 3. Percent exposure required for the new and old (underwent prior encoding) words for control and CHI groups in the partial word-identification (i.e., perceptual priming) task

Encoding condition	Group			
	Control (<i>n</i> = 24)		CHI (<i>n</i> = 24)	
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
New words	57.95	(5.06)	67.92	(12.33)
Encoded words	52.99	(7.76)	61.06	(12.87)

ing facilitated later recall more for the control group than for the CHI group. This conclusion should be made cautiously since there is a possible floor effect in the shallow encoding condition, particularly for the CHI group.

Perceptual Priming—Partial Word Identification Test

The data were analyzed in three steps. For the first step, to ascertain whether a priming effect did indeed exist, old and new word PEs were compared. The PEs of shallow and deep encoding of words were combined, and, in unison, compared to the PE of new words. Table 3 displays mean PEs (and standard deviations) for control and CHI groups, as a function of new and previously encoded words. A mixed-design ANOVA was conducted to analyze the effect of Group (control vs. CHI) \times Perceptual Priming (new words vs. combined shallow + deeply-encoded words). Results yielded a significant group main effect [$F(1, 46) = 10.68, p < .005$]; that is, overall, the control group required less PE than the CHI group. The significant perceptual priming main effect, [$F(1, 46) = 43.84, p < .001$] indicates the overall effect of priming. The insignificant Group \times Encoding interaction indicates that both groups were equally affected by the perceptual priming. As can be seen in Table 3, it appears that the standard deviations in the CHI group are considerably larger than those of the control group. Thus, the results were reanalyzed using nonparametric tests. A Mann-Whitney test (for independent samples) revealed a group effect in the PE for correct identification of new words [$U(48) = 146.0, p < .005$] and for the combined PE of shallow and deeply encoded words [$U(48) = 177.0, p < .03$]. The CHI groups required more PE than the control group for correct identification. A Wilcoxon matched-pairs signed-ranks test (for related samples) was employed to compare the performance of each group on these two variables. Both groups required significantly more PE for correct identification of the unprimed stimuli [$z(24) = -3.31, p < .001$] and [$z(24) = -3.89, p < .001$], for the control and CHI group respectively. Thus the nonparametric statistical analyses yielded compatible results with the parametric statistical analysis. For the second step, in order to check for possible baseline differences between groups, which may have led to the group effect in the previous analysis, a *t* test was adminis-

Table 4. Proportional percent exposure, as a function of encoding condition for control and CHI patients in the partial word-identification (i.e., perceptual priming) task

Encoding condition	Group			
	Control (<i>n</i> = 24)		CHI (<i>n</i> = 24)	
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
Shallow encoding	0.92	(0.09)	0.89	(0.11)
Deep encoding	0.90	(0.13)	0.91	(0.11)

tered for percent exposure (PE) for correct identification on unprimed words. Indeed, the PE baseline (i.e., identification of unprimed words) of the CHI group was significantly higher than that of the control group, [$t(46) = -3.66, p < .001$]. To correct for this group baseline difference, a proportion score was derived as the ratio of the PE of shallow or of deep encoding of words over the baseline PE of the new words. The third step was conducted to analyze the effect of the different encoding conditions on the perceptual priming task, for both groups. Table 4 displays the proportional mean PEs (and *SD*s), as a function of perceptual and deep encoding conditions, for control and CHI groups. A mixed-design ANOVA, conducted to analyze the effect of Group (control vs. CHI) \times Encoding Conditions (shallow vs. deep), yielded nonsignificant results; that is, no main effects or interaction effects were found.

In other words, groups performed similarly, and encoding conditions yielded comparative performance. In summary, then, CHI patients require a higher PE for correct identification than do normal controls, but when this baseline difference is corrected for, the perceptual priming effect is the same for the two groups. Results also showed that PE is significantly lower for primed words than for new words, equally for both groups. In addition, prior deep encoding did not facilitate PE more than did shallow encoding.

Conceptual Priming—Category Production

As in the analysis of the perceptual priming task, the present data were analyzed in three steps. In the first step, in order to check for possible baseline differences between groups, the groups were compared on the total number of nonfrequent word responses to the three unprimed categories. As can be seen in Table 5, the control group supplied more words than the CHI group, 8.38 and 7.08, respectively, but this difference did not reach significance, [$t(46) = 1.90, p > .05$]; therefore no corrections of raw data were necessary. For the second step, to ascertain whether a priming effect did indeed exist, the number of nonfrequent category members supplied by the subjects in primed categories (categories whose exemplars were applied at study), under both encoding conditions, and in unprimed categories was compared between groups. Notice that for the primed categories, out of all the nonfrequent members, only six were

Table 5. Number of nonfrequent category members of control and CHI groups, as a function of unprimed category in the category production (i.e., conceptual priming) task

Category	Group			
	Control (<i>n</i> = 24)		CHI (<i>n</i> = 24)	
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
Primed category	11.83	(6.20)	10.33	(2.22)
Unprimed category	8.38	(2.34)	7.08	(2.38)

primed. So, in order to appropriately test the overall priming effect, since all nonfrequent members were counted for the unprimed categories, *all* nonfrequent members were counted for the primed categories (including the six primed members). Table 5 displays mean number of nonfrequent category members, as a function of primed and unprimed categories, of control and CHI groups. A mixed-design ANOVA was conducted to analyze the effect of Group (control vs. CHI) \times Category (primed vs. unprimed nonfrequent category members), the former being a between-subjects factor, and the latter being a within-subjects factor. A significant category main effect was found [$F(1,46) = 18.39, p < .001$], indicating the overall priming effect, since more nonfrequent members of the primed categories were generated. The group main effect was close to reaching significance [$F(1,46) = 3.72, p = .06$]. The nonsignificant Group \times Category interaction indicates that both groups reported more nonfrequent category members in the primed categories (whether the particular members were primed or not), to the same extent. As can be seen in Table 5, the standard deviation of the control group for the primed category was, quite unusually, much larger than that of the CHI group. Thus, the results were reanalyzed using nonparametric tests. A Mann-Whitney test (for independent samples) revealed no significant group effect for either the primed or unprimed nonfrequent category members generated. A Wilcoxon matched-pairs signed-ranks test (for related samples) was used to compare the performance of each group on these two variables. Both groups generated more nonfrequent category members in the primed, than in the unprimed categories [$z(24) = -2.95, p < .005$] and [$z(24) = -3.88, p < .001$], for the control and CHI groups respectively. Thus, once again the nonparametric statistical analyses yielded compatible results with the parametric statistical analysis. The third step was conducted to analyze the effect of the different encoding conditions on the conceptual priming task, for both groups. Table 6 displays the mean number of primed words of control and CHI groups, as a function of encoding conditions. Notice that for this analysis, a response was considered as correct only if it matched one of the six nonfrequent category members previously encoded (shallow or deep). For this reason the sum of primed members, following shallow or deep encoding, as presented in Table 6, is less than the total number of the nonfrequent members of

Table 6. Number of primed words of control and CHI groups, as a function of encoding condition in the category production (i.e., conceptual priming) task

Encoding condition	Group			
	Control (<i>n</i> = 24)		CHI (<i>n</i> = 24)	
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
Shallow encoding	1.79	(1.41)	1.38	(1.06)
Deep encoding	2.88	(1.65)	1.50	(1.06)

the primed category reported in Table 5, which includes all nonfrequent members of the primed categories, and not only concerning the six primed members. A mixed-design ANOVA was executed to analyze the effect of Group (control vs. CHI) \times Encoding Condition (shallow vs. deep). Analyses yielded a significant main effect for group [$F(1,46) = 12.14, p < .001$], as well as a significant encoding effect [$F(1,46) = 4.62, p < .05$]. No Group \times Encoding interaction was found, although an interaction tendency did appear [$F(1,46) = 2.91, p < .095$]. In other words, overall, the control group showed a stronger effect of conceptual priming than did the CHI group. Prior deep encoding facilitated words to be primed later more than did shallow encoding. This effect was not significantly different for the two groups, although there was a tendency for controls to benefit more than the CHI patients from prior deep encoding on the later conceptual priming test. The possibility that the CHI and control groups' memory performance might have been influenced differentially by different initial accuracy levels of deep encoding (i.e., generating a word in response to its definition) was investigated. The analyses of the groups' responses suggest that the groups were significantly different in their accuracy in generating the words based on their definitions [$M = 16.88, SD = .95$, for the control group, and $M = 14.96, SD = 2.14$, for the CHI group; $t(46) = 4.02, p < .001$]. However, accuracy levels were not significantly correlated with later performance on priming tasks; that is, memory performance was not influenced by encoding accuracy levels.

In order to assess the effect of the severity of injury, Pearson product-moment correlations were calculated for the CHI group between the length of coma and time after onset, and the different memory measures previously analyzed. The memory measures that correlated with length of coma and time after onset were number of words recalled, proportional percent exposure required to correct identification in the perceptual priming task, and the number of the primed nonfrequent category members in the conceptual priming task. From each one of the above memory measures, two scores were generated—following shallow and deep encoding. None of the correlations with time after onset reached significance. Only two correlations concerning length of coma reached significance. One was a correlation with number of words recalled following deep encoding [$r(24) =$

$-.46, p < .04$]; that is, the longer the coma the fewer words recalled. The second correlation was with the number of nonfrequent deeply encoded category members [$r(24) = .49, p < .02$]. The direction of this correlation is counterintuitive, suggesting that the longer the coma, the more category members were produced. We do not have a reasonable interpretation of this finding. Another manner in which the effect of severity of injury was assessed was by dividing the CHI group into two subgroups—above and below 14 days of coma, which was the median length of coma in the CHI sample—and comparing them on the same memory scores correlated above with length of coma. The two CHI subgroups did not differ significantly on any of the memory measures, with the exception of the number of nonfrequent deeply encoded category members [$t(22) = 3.17, p < .01$]; that is, the same unexpected finding as seen in the correlation results.

DISCUSSION

Memory disturbance is the most prominent residual deficit following head injury (Baddeley et al., 1987; Levin, 1989). Several researchers have demonstrated that poor memory in CHI is due to the inefficient conceptual processing of information (Levin & Goldstein, 1986; Baddeley et al., 1987; Vakil et al., 1992), despite intact semantic knowledge (Baddeley et al., 1987; Schmitter-Edgecombe et al., 1993). In a number of studies with CHI patients, perceptual priming was found preserved, this being similar to findings concerning amnesic patients (Mutter et al., 1990; Vakil et al., 1994). In amnesic patients, conceptual priming has also been found preserved. In contrast to amnesics, it was predicted that CHI patients would show an impairment in performance on a conceptual priming task, due to their difficulties in conceptual processing.

As predicted, CHI patients performed more poorly on recall than did their normal counterparts. Furthermore, CHI and controls recalled the words that had undergone prior deep encoding better than those that had undergone shallow encoding. As in the findings of Goldstein et al. (1990), controls benefited more from deep encoding than did CHI patients on recall performance. In accordance with previous findings (Mutter et al., 1990; Vakil et al., 1994), the phenomenon of perceptual priming did occur in this experiment; that is, all participants identified primed words faster than new words. Once baseline differences between groups were corrected for, CHIs were indeed found to perform similarly to normal controls on the perceptual priming test. As expected, shallow and deep encoding strategies had an equal facilitatory effect on later perceptual priming. These findings are consistent with many other studies that have found no differential encoding condition effects on perceptual priming tests: LOP effects occur in conceptual priming and explicit memory tasks only (e.g., Challis & Brodbeck, 1992).

As predicted, CHI patients performed more poorly than normal controls on the conceptual priming task. This finding supports the hypothesis that CHI patients suffer from an

underlying processing deficit that disproportionately affects the effectiveness of conceptual-processing. Repercussions of this are observed in both conceptual-implicit and explicit test performance. In this context, we would like to point out two findings that require further discussion. First, in the second step of the conceptual priming task analyses, when the overall effect of primed and unprimed categories was analyzed, the advantage of the control group over the CHI group was close, but did not reach significance. However, in the third step of the analysis, when the effect of primed nonfrequent category members was measured, there was a very significant group effect. These two sets of findings do not necessarily contradict one another, although admittedly the first finding was not expected. These results could indicate that the two groups are not necessarily different in the effect of priming, but that the priming effect is not sufficiently selective in the CHI group. In this way, presentation of the words to the CHI subjects may have generated a diffuse activation of category members; as such, they supplied almost the same amount of nonfrequent category members as the control group. However, the CHI group performed poorly as compared to controls when number of primed words among nonfrequent category members was measured; that is, selectivity of words may have been dysfunctional. If this analysis of the results is indeed correct, it would suggest that the CHI group suffers from a deficit at the retrieval stage of processing, rather than at the encoding stage.

The second point that requires further discussion relates to the effect of encoding on later conceptual priming. As predicted, conceptual priming for both groups was better for words that had undergone deep, as compared to shallow, encoding. However, contrary to our prediction, controls did not benefit more from prior deep encoding on the later conceptual priming test, although a tendency for such, albeit nonsignificant, did exist. This finding can also be interpreted along similar lines described concerning our interpretation of the previous point; that is, it indicates that processes involved in the encoding stage are better preserved than those involved in the retrieval stage. However, this approach has difficulty explaining one finding: deep encoding did have a differential effect on the groups in the recall task. Thus, the above interpretation clearly requires further investigation and needs to be addressed more directly in future research in an attempt to resolve such conflicting findings.

In the present study, severity of injury as measured by the length of coma was predictive of the performance on a recall task following deep encoding. The second significant correlation was concerning the reported number of nonfrequent deeply encoded category members. The direction of this correlation is counterintuitive, suggesting that the longer the coma, the more category members were produced. As mentioned above, we do not have a reasonable interpretation of this finding. It is important to note that duration of coma has been considered an index of severity of injury (Teasdale & Jennet, 1974). However, it primarily reflects

damage to the brain stem, rather than damage to frontal lobes or other cortical areas (Bigler, 1990). Thus, it should not be surprising when this measure does not reliably correlate with memory measures sensitive to damage to other areas of the brain such as the frontal lobes.

In summary, these findings add to the understanding of the unique memory impairment following CHI, as compared to amnesia. CHI leads to a memory impairment similar to amnesia in some respects (i.e., impaired explicit memory and preserved perceptual priming). However, it is apparent from this study that the above group differs with respect to conceptual priming; that is, conceptual priming is impaired following CHI, while it is preserved in amnesia. The characteristics of the CHI group's memory ability are very similar to what has been reported concerning AD patients (Butters et al., 1990; Keane et al., 1991; Fleischman et al., 1995; Monti et al., 1996); that is, both conceptual-implicit and explicit memory were found impaired, whereas perceptual priming was preserved. This similarity in the findings reflects both a similarity in the brain areas known ordinarily to be intact in AD and CHI patients (i.e., the occipital lobes), as well as a similarity in the areas known to be damaged in both groups (the temporal and frontal lobes). The role of the medial-temporal and diencephalic brain regions in explicit memory has been demonstrated repeatedly in the last 30 years. Much less is known, however, with regard to the critical areas for priming. Perceptual priming has been shown impaired in patients with occipital lobe damage (Fleischman et al., 1995; Gabrieli et al., 1995) and preserved in patients with an intact occipital lobe, such as AD patients (Keane et al., 1991; Fleischman et al., 1995; Monti et al., 1996). With regard to conceptual priming, Monti et al. (1996) conclude that the deficit observed in AD could reflect damage to frontal, parietal, and temporal association areas, which are ordinarily known to be damaged in these patients. Patients with localized lesions to the dorsolateral prefrontal areas have demonstrated intact conceptual priming (Gershberg & Shimamura, 1993). However, patients with ventromedial frontal or basal forebrain lesions have demonstrated impaired conceptual priming (Keane et al., 1994, as cited in Monti et al., 1996). It should be kept in mind, however, that in most such lesions, the damage extends beyond these specific areas. Finally, because of the nature of damage after CHI, it is difficult to identify the specific brain damaged regions that are critical to conceptual priming. Nonetheless, converging evidence from studies with AD and other patients with more focal lesions indicates that the frontal lobe may play a major role, particularly the ventromedial area. Although in the literature frontal lobe involvement in CHI is documented (Adams 1975; Levin et al., 1982), there was no direct independent indicator of frontal lobe dysfunction for our patient group. Therefore, the conclusion associating conceptual priming and frontal lobe functioning should be made cautiously. This study further validates the distinction between perceptual and conceptual priming, and helps to better characterize the nature of memory impairment following CHI.

REFERENCES

- Adams, J.H. (1975). The neuropathology of head injury. In P.J. Binken & G.W. Bruyn (Eds.), *Handbook of clinical neurology* (pp. 35–65). New York: Elsevier.
- Baddeley, A., Harris, J., Sunderland, A., Watts, K.P., & Wilson, B.A. (1987). Closed head injury and memory. In H.S. Levin, J. Grafman, & H.M. Eisenberg (Eds.), *Neurobehavioural recovery from injury* (pp. 295–319). Oxford, England: Oxford University Press.
- Balgure, R. (1968). List of basic words for school. *The treasure of the teacher*. Tel Aviv, Israel (Hebrew).
- Biederman, I. & Cooper, E.E. (1991). Priming contour-deleted images: Evidence for intermediate representations in visual object recognition. *Cognitive Psychology*, 23, 393–419.
- Bigler, E.D. (1990). Neuropathology of traumatic brain injury. In E.D. Bigler (Ed.), *Traumatic brain injury* (pp. 13–49). Austin, TX: Pro-Ed.
- Blaxton, T.A. (1989). Investigating dissociations among memory measures: Support for a transfer-appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 657–668.
- Blaxton, T.A. (1992). Dissociations among memory measures in memory-impaired subjects: Evidence for a processing account of memory. *Memory and Cognition*, 20, 549–562.
- Bloom, P.A. & Fischler, I. (1980). Completion norms for 329 sentence contexts. *Memory and Cognition*, 8, 631–642.
- Butters, N., Heindel, W.C., & Salmon, D.P. (1990). Dissociation of implicit memory in dementia: Neurological implications. *Bulletin of the Psychonomic Society*, 28, 359–366.
- Carlesimo, G.A. (1994). Perceptual and conceptual priming in amnesic and alcoholic patients. *Neuropsychologia*, 32, 903–921.
- Cermac, L.S., Talbot, N., Chandler, K., & Wolbarst, L.R. (1985). The perpetual priming phenomenon in amnesia. *Neuropsychologia*, 23, 615–622.
- Cermak, L.S., Verfaellie, M., & Chase, K.A. (1995). Implicit and explicit memory in amnesia: An analysis of data-driven and conceptually-driven processes. *Neuropsychology*, 9, 281–290.
- Challis, B.H. & Brodbeck, D.R. (1992). Levels of processing affects priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 595–607.
- Fleischman, D.A., Gabrieli, J.D.E., Reminger, S., Rinaldi, J., Morrell, F., & Wilson, R. (1995). Conceptual priming in perceptual identification for patients with Alzheimer disease and a patient with right occipital lobectomy. *Neuropsychology*, 9, 187–197.
- Gabrieli, J.D.E., Fleischman, D.A., Keane, M.M., Reminger, S., & Morrell, F. (1995). Double dissociation between memory systems underlying explicit and implicit memory in the human brain. *Psychological Science*, 6, 76–82.
- Gershberg, F.B. & Shimamura, A.P. (1993). Intact conceptual priming but impaired cued recall in patients with frontal lobe lesions. *Society for Neuroscience Abstracts*, 19, 1079.
- Goldstein, F.C., Levin, H.S., Boake, C., & Lohry, J.H. (1990). Facilitation of memory performance through induced semantic processing in survivors of severe closed head injury. *Journal of Clinical and Experimental Neuropsychology*, 12, 286–300.
- Graf, P., Shimamura, A.P., & Squire, L.R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 386–396.
- Hirshman, E., Snodgrass, J.G., Mindes, J., & Feenan, K. (1990). Conceptual priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 634–647.
- Jacoby, L.L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning & Verbal Behavior*, 22, 485–508.
- Jacoby, L.L. & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, 110, 306–340.
- Keane, M.M., Clarke, H., & Corkin, S. (1992). Impaired perceptual priming and intact conceptual priming in a patient with bilateral posterior cerebral lesions. *Society for Neuroscience Abstracts*, 18, 386.
- Keane, M.M., Gabrieli, J.D.E., Fennema, A.C., Growdon, J.H., & Corkin, S. (1991). Evidence for a dissociation between perceptual and conceptual priming in Alzheimer's disease. *Behavioral Neuroscience*, 105, 326–342.
- Levin, H.S. (1989). Memory deficit after closed head injury. *Journal of Clinical and Experimental Neuropsychology*, 12, 129–153.
- Levin, H.S., Benton, A.L., & Grossman, R.G. (1982). *Neurobehavioral consequences of closed head injury*. Oxford, England: Oxford University Press.
- Levin, H.S. & Goldstein, F.C. (1986). Organization of verbal memory after severe closed head injury. *Journal of Clinical and Experimental Neuropsychology*, 8, 643–656.
- Milner, B. (1962). *Disorder of memory accompanying bilateral hippocampal lesions*. Paris: Centre Nationale de la Recherche Scientifique.
- Monti, L.A., Gabrieli, J.D.E., Reminger, S., Rinaldi, J.A., & Wilson, R.S. (1996). Differential effect of aging and Alzheimer's disease of conceptual implicit and explicit memory. *Neuropsychology*, 10, 101–112.
- Mutter, S.A., Howard, D.V., Howard, J.H., & Wiggs, C.L. (1990). Performance on direct and indirect tests of memory after mild closed head injury. *Cognitive Neuropsychology*, 7, 329–346.
- Ommaya, A.K. & Gennarelli, T.A. (1974). Cerebral concussion and traumatic unconsciousness. *Brain*, 97, 633–654.
- Rajaram, S. & Roediger, H.L. (1993). A direct comparison of four implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 19, 765–776.
- Schmitter-Edgecombe, M., Marks, W., & Fahy, J.F. (1993). Semantic priming after severe closed head trauma: Automatic and attentional processes. *Neuropsychology*, 7, 136–148.
- Shimamura, A.P. (1986). Priming effects in amnesia: Evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology*, 38A, 619–644.
- Squire, L.P., Shimamura, A.P., & Graf, P. (1987). Strength and duration of priming effects in normal subjects and amnesia patients. *Neuropsychologia*, 25, 195–210.
- Srinivas, K. & Roediger, H.L. (1990). Classifying implicit memory tests: Category association and anagram solution. *Journal of Memory and Language*, 29, 389–412.
- Stuss, D.T. & Gow, C.A. (1992). "Frontal dysfunction" after traumatic brain injury. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, 5, 272–282.
- Teasdale, G. & Jennet, B. (1974). Assessment of coma and impaired consciousness. *Lancet*, 2, 81–84.
- Vaidya, C.J., Gabrieli, J.D.E., Keane, M.M., & Monti, L.A. (1995). Perceptual and conceptual memory processes in global amnesia. *Neuropsychology*, 9, 580–591.
- Vakil, E., Arbell, N., Gozlan, M., & Hoofian, D. (1992). Relative importance of informational units and their role in long-term

- recall by closed-head-injured patients and control groups. *Journal of Consulting and Clinical Psychology*, 60, 802–803.
- Vakil, E., Biederman, Y., Liran, G., Groswasser, Z., & Aberbuch, S. (1994). Head injured patients and control group: Implicit vs. explicit measures of frequency judgment. *Journal of Clinical and Experimental Neuropsychology*, 16, 539–546.
- Vakil, E., Blachstein, H., & Hoofian, D. (1991). Automatic temporal order judgment: The effect of intentionality of retrieval on closed-head-injured patients. *Journal of Clinical and Experimental Neuropsychology*, 13, 291–298.
- Warrington, E.K. & Weiskrantz, L. (1968). A study of learning and retention in amnesic patients. *Neuropsychologia*, 6, 283–291.
- Wechsler, D. (1987). *The Wechsler Memory Scale-Revised*. San Antonio, TX: The Psychological Corporation.