Neuropsychiatry, Neuropsychology, and Behavioral Neurology
Vol. 9, No. 3, pp. 171–175

22

Saving During Relearning as an Implicit Measure of Memory in Closed-Head-Injured Patients

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Summary: Memory disturbance is the most prominent residual deficit after closed-head injury (CHI). Recent studies have demonstrated that CHI patients, just like global amnesic patients, show impaired memory when measured explicitly, but not when measured implicitly. Many theorists have concluded that the saving paradigm introduced by Ebbinghaus in 1885 can be viewed as a measure of implicit memory. Thus, it was hypothesized that saving will be preserved in CHI patients. Thirteen CHI patients and 13 control subjects were tested individually on three word lists. Each list was tested in two phases: learning and relearning. There was a different time delay between the two phases for each list: 1 h, 1 day, and 3 days. The groups were compared on explicit-recall and implicit-saving measures of memory. Time delay from learning to relearning did not affect the performance of either group. As expected, 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. However, when saving was measured just on the initial learning and relearning trials, the groups did differ. The results are discussed in terms of the relationship between saving and implicit memory. **Key Words:** Closed-head injury—Saving—Relearning—Memory. **NNBN 9:171–175, 1996**

Despite their very impaired memory, there is growing evidence that amnesics can show preserved memory for skills and procedures such as solving the Tower of Hanoi puzzle, reading mirror-reversed words (1), and, more recently, preserved priming effect for certain kinds of information [see (2) and (3) for reviews]. These findings led to the contemporary view that memory is comprised of two separate systems, explicit and implicit memory. In amnesics, the former is impaired while the latter is preserved. Explicit memory requires intentional retrieval of information. On the other hand, implicit memory does not require conscious, intentional retrieval of information, but is expressed by facilitating performance on a previously experienced task (4).

Memory disturbance is the most prominent residual deficit after closed-head injury (CHI) (5–7). Explicit memory ability of CHI patients has been extensively investigated. By contrast, little is known concerning their implicit memory ability. Mutter et al. (8) found that patients with mild CHI when tested implicitly displayed normal memory; when tested explicitly, their memory was impaired compared to normal control subjects. Vakil and his colleagues have also attempted to address this issue in a series of studies that tested CHI patients on a variety of implicit memory tasks. In these studies, although the CHI patients were impaired when memory was assessed explicitly, their memory was preserved when measured implicitly [cf. (9) re: temporal order judgment; cf. (10) re: frequency judgment; cf. E. Vakil, H. Golan, E.

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Received April 19, 1995; first revision August 22, 1995; second revision December 4, 1995; accepted December 7, 1995.

Grunbaum, et al., unpublished observations. re: contextual information].

According to the previously noted definition of implicit memory, Schacter (4) concludes that the saving paradigm introduced by Ebbinghaus in 1885 (11) can be viewed as an implicit measure of memory. Similarly, Slamecka (12) suggests that the entire literature on priming may be viewed as the study of implicit memory. Parkin and Streete (13), for example, clearly mention that implicit memory (i.e., picture completion) in their study is measured in terms of the *savings* between initial and second presentation" (p. 362). In contrast, the explicit memory is measured by using a recognition task. In the saving paradigm introduced by Ebbinghaus (11), memory is tested by comparing the learning of a list to the relearning of the same list. The critical element in this paradigm that makes it an implicit test is that relearning of the previously studied list does not require explicit reference to the prior learning episode. Furthermore, saving has been shown for items that were not accessible via recall or recognition (14,15).

Groninger and Groninger (14) 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. Although this paradigm has been known and available for over a century, as far as we know, it has not been applied to the study of implicit memory. The theoretical importance of the use of the saving paradigm as an implicit test of memory is its contribution to our understanding of how implicit components are involved in the process of recall–explicit learning.

The purpose of the present study is to test the memory of a CHI group by using the saving paradigm as an implicit measure of memory. It is hypothesized that when explicit but not implicit aspects of memory (i.e., saving scores) are analyzed, CHI patients will be relatively more impaired than control subjects.

METHOD

Subjects

Two groups of subjects participated in the present study: A normal control group (non–brain damaged) and a CHI group. The control group consisted of 13 volunteers (9 men and 4 women) whose ages ranged from 18 to 39 years (mean age = 25.4) and whose educational level ranged from 12 to 14 years of schooling (mean = 12.4). The CHI group included 13 patients (10 men and 3 women) whose ages ranged from 18 to 32 years (mean age = 23.2) and whose educational level ranged from 10 to 12 years of schooling (mean = 11.6). Table 1 provides a more detailed description of the patient group. Patients were recruited for the study from a population of patients admitted to the Loewenstein Hospital (Israel) for rehabilitation after a traumatic head injury. All patients selected for the study passed a screening battery administered by the occupational therapist and the speech pathologist in the hospital department. The battery included tests for aphasia, orientation, and perception. Furthermore, patients referred to the study had been evaluated ≥1 month earlier by an interdisciplinary team in the department to be out of posttraumatic amnesia. Thus, the patients' intellectual and linguistic functioning was at a level enabling adequate responsiveness to the task requirements based on the tests conducted. None of the participants had a history of alcohol, drug abuse, or psychiatric illness.

TABLE 1. *Demographics of the head-injured patient group*

Patient	Age	Sex	H	Ed	TAO	COMA	GCS
VH	20	F	R	12	22	30	4
PC	22	M	R	12	26	24	9
GI	19	M	R	12	40	55	4
ST	22	M	R	12	12	4	6
AM	26	M	R	12	7	10	[a]
AW	32	M	R	10	52	—	—
MR	22	F	R	12	12	7	[a]
GM	26	M	R	12	11	10	7
ZM	18	M	R	10	15	21	7
SH	21	M	R	12	8	14	[a]
SS	24	M	R	12	14	8	[a]
MK	28	M	R	11	8	4	7
BC	21	F	R	12	60	30	4

ED, education (yr); H, handedness; TAO, time after onset (wk); COMA, length of coma in days; GCS, Glasgow Coma Scale, on admission to hospital.

[a] Information not found in medical records.

Test and Procedure

Forty-five high-frequency Hebrew words (16) were used to construct three 15-item presentation lists. Each subject was tested individually on the three word lists. Each list was tested in two phases: *learning* and *relearning*. Each list had a different time delay between the learning and relearning phase: 1 h, 1 day, and 3 days. Altogether, each subject participated in six sessions. The word list assigned to the particular test as well as the order of the tests was counterbalanced. In the learning phase, one of the lists was read to the subject for several consecutive trials, and each trial was followed by a free recall test. The words were read in the same order each time, at the rate of 1 word/s. There was no mention that this list would be relearned at a later stage. In the relearning phase, the same procedure was conducted with the same list used in the learning phase. Explicit recollection of the prior episode was not called for during relearning. To equate CHI group performance to that of the control group, in the learning and relearning phases, each list was read to the CHI group on 10 consecutive trials, but on only 5 for the control group. The words recalled were recorded by the examiner on a recording form.

RESULTS

To confirm the assumption that the CHI group actually suffers from memory impairment, groups were compared on the number of words recalled in the fifth learning trial. Results showed that the CHI group had an average recall of 10.26 words; the control group recalled 13.85 words. These scores were significantly different: $t(24) = 4.36$, $p < .001$. This difference was eliminated when the CHI group was allowed five additional learning trials and reached an average recall of 12.28 words.

Different saving scores that reflect different aspects of the groups' performance were calculated and analyzed. In the first analysis, saving was expressed as the increase in the number of words recalled from the first five learning trials to the relearning phase. The number of words recalled at each of the first five learning and relearning trials was submitted to a mixed design ANOVA to analyze the effect of group (CHI and controls) by saving (learning and relearning) by trials (1 to 5) by delay interval (1 h, 1 day, and 3 days). The first is a between-subjects factor and the latter three are within-subjects factors. Main effect for group was significant: $F(1, 24) = 24.47$, $p < .001$, with the control group recalling more words overall than the CHI group. More words were recalled overall in the relearning than the learning phase: $F(1, 24) = 132.71$, $p < .001$. There was also a significant increase in the number of words recalled overall from trial to trial: $F(4, 96) = 135.95$, $p < .001$. Time delay was the only main effect not to reach significance. Because time delay neither had a significant effect on performance nor significant interaction with the other factors, the results reported from this stage on are collapsed over time delay (i.e., only the average number of words recalled in the three delay intervals was analyzed). The group by trials and group by saving interactions were not significant. Trials by saving and group by trial by saving did reach significance: $F(4, 96) = 27.10$, $p < .001$; $F(4, 96) = 10.89$, $p < .001$, respectively. The mean number of words recalled by the two groups in the learning and relearning trials, collapsed over time delay, are presented in Table 2.

TABLE 2. *Mean number of words recalled (and SDs) by the two groups in the learning and relearning trials, collapsed over time delay*

		Control group ($n = 13$)		CHI group ($n = 13$)	
		Learning	Relearning	Learning	Relearning
Trial 1	Mean	8.05	13.33	6.59	9.56
	SD	1.28	.99	1.58	2.23
Trial 2	Mean	11.26	14.46	8.23	10.85
	SD	1.96	.62	2.33	2.34
Trial 3	Mean	12.36	14.82	9.18	11.39
	SD	1.63	.32	2.59	2.58
Trial 4	Mean	13.56	14.90	9.54	11.90
	SD	1.08	.25	2.69	2.35
Trial 5	Mean	13.85	15.00	10.26	12.10
	SD	1.05	.00	2.78	2.52

CHI, closed-head injury.

Although the insignificant group by saving interaction suggests that overall, both groups saved to the same amount, the significant group by saving by trial indicates that the groups had a different pattern of saving across trials. The different pattern of saving is probably due to the fact that the control group is saving less at the latter trials because of a ceiling effect (see Table 2). For this reason, an additional analysis was conducted in which the groups were compared just on the learning and relearning (i.e., saving) of the first trial. In this analysis, the groups were significantly different: $F(1, 24) = 22.24$, $p < .001$. Overall, more words were recalled at relearning: $F(1, 24) = 214.30$, $p < .001$. The group by saving interaction reached significance as well: $F(1, 24) = 16.74$, $p < .001$, indicating that the control group saved more than the CHI group, from first trial of learning to first trial of relearning.

A different way of expressing saving is by calculating proportional rather than absolute change from the learning to the relearning phase. The most common way is to express saving as percent increase of words recalled in relearning compared to the learning phase (17). This score was calculated for both groups for the total number of words recalled in the first five learning and relearning trials. The formula is: ((Relearning - Learning)/Relearning) $\times 100$. The results show that the CHI group saved 21.56% and the control group saved 18.60% from learning to relearning. This difference was not found to be significant $t(24) = .88$, $p = .39$. Because of the same concern of ceiling effect as above, an additional analysis was conducted in which the formula was applied just to the first trials rather than to the total of all the learning and relearning trials. In this analysis, the CHI group saved 29.36% and the control group saved 39.62% from learning to relearning. This difference was found to be significant: $t(24) = 2.16$, $p < .05$.

Two more proportional saving scores were derived based on a saving formula used by Weiskrantz and Warrington (18). The first is based on the number of words recalled in the first five learning and relearning trials. The formula is: (Relearning - Learning)/(Relearning + Learning). The scores were .124 and .104 for the CHI and control groups, respectively. These scores were not significantly different: $t(24) = .93$, $p = .36$. For the same reason as noted earlier, an additional analysis was conducted just for the first learning and relearning trials. The scores were now .189 and .250 for the CHI and control groups, respectively. These scores were significantly different: $t(24) = 2.14$, $p < .05$.

In Ebbinghaus' studies, saving was calculated as the advantage of relearning over original learning in terms of number of trials to criterion (19). Accordingly, the other saving score based on Weiskrantz and Warrington (18) was not applied to the number of *words* recalled as in the three measures noted. Thus, this time, *learning* was defined as the number of *trials* required for each subject to reach the highest number of words recalled in the learning phase. *Relearning* was defined as the number of *trials* required in the relearning phase to reach the highest number of words, as explained. The modified formula thus is (Learning - Relearning)/(Relearning + Learning). For example, if a CHI patient recalled 14 words in trial 8 and did not improve on trials 9 and 10; and in the relearning phase, the subject has already recalled 14 words by trial 5, the learning score will be eight and the relearning score five. Applying these scores to the previous formula, the scores were .218 and .419 for the CHI and control groups, respectively. These saving scores were significantly different: $t(24) = 2.70$, $p < .02$.

DISCUSSION

As expected, the overall results show that the control group recalled significantly more words than the CHI group. Despite their impaired memory, the CHI group saved overall as much from learning to relearning as did the control group. When just the initial learning and relearning trials were analyzed, the control group was found to save more than the CHI group. These findings raise the possibility that the results obtained are partially due to the ceiling effect in the relearning of the control group.

Previous findings have reported that the saving measure of memory in a normal control group is not affected by the length of the delay interval between learning and relearning (14,15). The findings of the present study amplify these previous findings and demonstrate that, as hypothesized, the delay interval neither affected the control nor the CHI group. In the first measure, *saving* was defined by the increased number of words recalled from learning to relearning. Although overall the groups *saved* the same amount, they differed on the rate of learning from trial to trial, as expressed in the significant triple interaction of group by trials by saving. The groups also differed on the overall total number of words recalled in the learning and relearning phases, which was higher for the control group. Our interpretation of the control group's advantage is that these aspects of the task depend on explicit memory, whereas the overall benefit from the previous exposure (i.e., saving) is the implicit aspect of the task, since subjects were not asked to refer to it at the relearning stage. This interpretation of the findings is in accord with Slamecka's (12) comment that although Ebbinghaus used only an implicit memory index, all the other variables have been reexamined through explicit indices.

As mentioned earlier, in Ebbinghaus' studies, saving was calculated as the advantage of relearning over original learning defined by the number of trials to criterion (19). We have used other scores as well due to various researchers' claims that Ebbinghaus' measure of trials to criterion is relatively insensitive and unreliable, because performance hinges on the difficulty of the most difficult item in the list. Thus, number of items rather than number of trials seems to be a better measure (15,19).

If one looks at tasks that are preserved in amnesia [for review, see (20)] whether procedural [e.g., (1)], priming [e.g., (3)], or, more generally, tasks referred to as implicit measures of memory (4), one finds that in most cases performance was assessed by saving methods. The typical paradigm begins with learning a task, and then saving in relearning at a later stage is viewed as an index of residual learning. This raises two questions: First, perhaps these tasks are preserved simply because memory is assessed by a more sensitive measure (i.e., saving) (15,19). In a study by Groninger and Groninger (14), subjects showed saving after long delay intervals (i.e., 2, 3, or 4 weeks) for items not retrieved via recall or recognition. Second, in studies comparing amnesics to controls on either tasks impaired in amnesics (i.e., explicit) or preserved (i.e., implicit), the comparison is inappropriate since the tasks are not comparable in the ways in which they are assessed. Explicit memory is measured by using recall or recognition; implicit memory is measured by using a saving measure [see, for example, (13)]. Thus, it is possible that the difference does not depend on the particular task, but rather on the way it is measured. This brings us to the present study. Although a typical explicit task (i.e., word list recall) was used in this study, when memory was assessed using a saving index, the groups were not as different as in the explicit measure.

In conclusion, the results of the present study should be viewed just as preliminary findings that raise theoretical as well as more practical-experimental questions. On the theoretical level, it is important to further clarify the relationship between saving and implicit memory. Can implicit memory, by definition, be tested just by saving methods? Or, put differently, are all memory tests measured by saving (e.g., the present study) considered implicit tasks? This question leads to a practical implication—the importance of having both implicit and explicit tasks use compatible memory measures. In most of the current studies a confounding exists since implicit memory is measured by saving and explicit memory is measured by recall or recognition. Further studies using paradigms that better avoid the possibility of ceiling effect in the control group should be carried out with CHI patients and classic global amnesics as well.

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