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# Word Recall versus Reading Speed: Evidence of Preserved Priming in Head-Injured Patients

ELI VAKIL, RUTH JAFFE, AND SHIRA ELUZE

*Bar-Ilan University, Ramat-Gan, Israel*

AND

ZEEV GROSWASSER AND SARA ABERBUCH

*Loewenstein Rehabilitation Hospital, Ra'anana, Israel Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel*

This study addressed a number of issues. One purpose was to test whether memory-impaired, head-injured patients show the same pattern of memory task dissociation as reported in amnesics, that is, impaired explicit and intact implicit memory performance. The second purpose of this study was to apply the distinction between the acquisition and retention aspects of memory, which has not, as yet, been investigated adequately in the study of implicit memory. The third purpose was to evaluate the contribution of intra-item and inter-item processes in implicit memory. A group of 18 head-injured (HI) patients and 18 control subjects participated in this study. Subjects read two lists of 15 words seven times: five times consecutively, once after 20 min, and after a 1-hr delay. One list was read in the same order and the other in a different order. Acquisition and retention of the information were measured explicitly (i.e., recall of words) and implicitly (i.e., priming—reading speed). The results indicated that novel information is preserved in HI as in other amnesic patient groups, only when implicit, rather than explicit, measures of memory are used. The effect of contextual manipulation (i.e., order of presentation) was interpreted to suggest similar involvement of intra- as well as inter-memory processes in implicit memory in normal and memory-impaired subjects. 

Memory disorders can be produced by a variety of neurological conditions, including Korsakoff's syndrome (Butters & Cermak, 1980), electroconvulsive therapy (ECT) (Weiner, 1984), Herpes encephalitis (Starr & Philips, 1970), anoxia (Warrington & Weiskrantz, 1978), cerebrovascular accident (CVA) (Volpe & Hirst, 1983), and head injury (Baddeley, Sunder-

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Address correspondence and reprint requests to Eli Vakil, Ph.D., Psychology Department, Bar-Ilan University, Ramat-Gan, 52900, Israel.



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land, Watts, & Wilson, 1987; Levin, 1989). Memory impairment is characterized by impaired ability to learn and acquire new information or to retain information over time (Squire, 1981).

Despite their often impaired recall and recognition, there is growing evidence that amnesics can show preserved indirect memory for skills and procedures, such as solving the Tower of Hanoi puzzle (Cohen & Squire, 1980) and, more recently, preserved priming effect for certain kinds of information (see Shimamura, 1986, and Mayes, 1988, for reviews). Preserved memories, when measured indirectly by their priming effect, were found in amnesics in several paradigms, such as word-stem priming (Graf, Squire, & Mandler, 1984), lexical decision (Cermak, Blackford, O'Connor, & Bleich, 1988), and reading mirror-reversed words (Cohen & Squire, 1980). Most of these paradigms involve information that was familiar to the subjects prior to the priming experience itself. Some studies using novel information have demonstrated normal priming effect in amnesics, but these findings are as yet inconclusive (see Mayes & Gooding, 1989). Such findings are obviously more telling with regard to amnesics' abilities to learn and retain new information over time.

Reading speed has also been used as a priming measure. Musen, Shimamura, and Squire (1990) measured the acquisition and retention of reading speed for passages presented three times. They found that reading speed improved and was retained over time at the same rate for amnesic patients and normal subjects. Mandler (1980) has argued that recognition is mediated by the processing of the item itself, which he terms ''intra-item integration of sensory and perceptual information'' (i.e., spelling, phonemic constitution, pronunciation, etc.) and the verbal context, which he calls ''inter-item elaboration.'' In this approach, the latter is not expected to play a role in the preserved memory process.

Moscovitch, Winocur, and McLachlan (1986) presented (Experiment 2) young, elderly, and memory-impaired subjects with word pairs and sentences and then tested for both recognition and speed reading of old, recombined, and new items. This procedure enabled the experimenters to see whether the preserved priming effect observed in reading speed is affected by changes in the verbal context. The results demonstrated that the memory-impaired group was inferior to the other groups on the recognition task, but performed normally on the speed-reading task. Interestingly, all groups showed the priming effect on the old items, but not on the same items when recombined. In contrast with Mandler (1980), this finding led the authors to conclude that intra-item integration, as well as inter-item elaboration, mediate the priming effect. In other words, contextual changes do affect performance on the priming task.

Mayes, Poole, and Gooding (1991) have also shown preserved priming of novel information in amnesics. In their study, amnesics showed a normal proportional increase in reading speed for lists of words and pronounceable nonwords that were shown several times. Mayes et al. note that since the lists of words were always presented in the same order, it is difficult to conclude whether the increase in reading speed is due to learning the words themselves, or the order in which they were presented. This distinction is very important, since if the latter is correct, we might conclude that amnesics in this study showed preserved learning of novel information. Mayes et al. (1991) define novel information in the following way: ‘‘It is not the components that are necessarily novel, but the association between the components’’ (p. 413).

The contribution of temporal order to recall has already been demonstrated by Pellegrino and Batting (1974), who showed that a word list presented in a fixed order over trials is learned better than a word list presented in random order. Head-injured (HI) patients were shown to have impaired recall of temporal order when measured explicitly but not when measured implicitly (Vakil, Blachstein, & Hoofien, 1991). These findings make the question concerning the Mayes et al. results even more important, with regard to the HI patient population.

The purpose of the present study is to address several issues: Do memory-impaired patients following head injury show the same pattern of dissociation reported in amnesics between memory tasks measured explicitly and implicitly? Furthermore, in the case of HI patients, will the consistency of order facilitate their performance on the explicit task (i.e., word recall) and on the implicit task (i.e., reading speed), despite their impaired memory for temporal order? Based on the above studies (i.e., Pellegrino & Batting, 1974; Vakil et al., 1991), it is predicted that since temporal order judgment is not required explicitly for either word recall or the reading speed tasks, consistency of presentation order will have an equally facilitating effect for both groups on the explicit and implicit tasks. An additional purpose of the present study is to apply the distinction between the acquisition and retention aspects of memory, which has not, as yet, been examined adequately in the study of implicit memory. Finally, an attempt is made in this study to address the question of the contribution of intra-item and inter-item processes in implicit memory that remained unresolved in the Mayes et al. (1991) study.

For this experiment, a memory-impaired patient group (i.e., head injured) and a control group will be tested on lists of words presented in fixed and variable order, to sort out the contribution of the words themselves to the learning process, as compared to their presentation order. Furthermore, the acquisition rate, as well as retention of the information, will be tested. These will be measured explicitly (i.e., recall of words) and implicitly (i.e., priming—reading speed) within the same task.

## METHOD

### *Subjects*

Two groups of subjects participated in the present study: a normal control group (non-brain-damaged) and a HI group. The control group consisted of 18 volunteers whose age ranged

TABLE 1
Demographics of the Head-Injured Patient Group

| Patient | Age | Sex | H | Ed. | TAO | COMA | GCS |
|---|---|---|---|---|---|---|---|
| TY | 22 | M | R | 12 | 5 | 6-D | 6 |
| BO | 20 | M | L | 12 | 9 | 5-D | 11 |
| SS | 21 | M | R | 12 | 31 | 6-H | 9 |
| AJ | 39 | M | R | 12 | 11 | — | — |
| BYA | 32 | M | R | 10 | 12 | 15-D | 8 |
| AS | 26 | M | R | 12 | 33 | 45-D | 4 |
| BYE | 47 | M | L | 10 | 11 | — | — |
| UD | 19 | M | R | 12 | 26 | 7-D | * |
| MS | 30 | M | R | 12 | 25 | 21-D | 5 |
| GZ | 24 | M | L | 12 | 18 | 3-D | 6 |
| AE | 30 | M | R | 8 | 19 | — | — |
| BA | 22 | M | R | 12 | 36 | 14-D | 6 |
| ZA | 55 | M | R | 12 | 10 | — | — |
| CY | 19 | M | R | 12 | 15 | 7-D | * |
| HB | 44 | M | R | 11 | 20 | 5-H | * |
| RI | 45 | M | R | 12 | 11 | 4-D | 5 |
| LI | 37 | M | L | 15 | 13 | 2-D | 7 |
| SD | 40 | M | R | 15 | 42 | 7-D | 7 |

*Note. Ed*, education (years); *H*, handedness; *TAO*, time after onset (weeks); *COMA*, Length of coma, *D*, in days, *H*, in hours); *GCS*, Glasgow Coma Scale, on admission to hospital; * Information not found in medical records.

from 18 to 46 years (mean age = 28) and whose educational level ranged from 10 to 20 years of schooling (mean = 13). The HI group included 18 patients whose age ranged from 19 to 55 years (mean age = 31) and whose educational level ranged from 8 to 15 years of schooling (mean = 11). The groups were not significantly different either on age ($t(34) = 1.23$, $p > .05$) or on educational level ($t(34) = 1.24$, $p > .05$). 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 following a traumatic head injury. All the 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 at least one month earlier by an interdisciplinary team in the department to be out of Post-Traumatic Amnesia (PTA). 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.

## *Stimuli*

Two lists of 15 high-frequency Hebrew words (more than 50 per 200,000 words) (Balgure, 1968) were used. The words in each list were typed in uppercase form, from top to bottom on an 8.5" × 11" sheet of paper. One list was typed on a single sheet (''fixed order''). The other list (''variable order'') was typed seven times on seven separate sheets of paper, each time in a different order, pseudorandomly, so that any sequence of three words was never repeated from trial to trial.

## *Procedure*

Subjects were tested individually. Half of the subjects in each group were given the fixed order list first, and the other half the variable order list. They were asked to read the list (seven times) as fast as they could and to try to recall as many words as possible. They read each list five times in succession, once more after a 20-min delay and then after a 1-hr delay after the final aquisition trial. During the delay interval, subjects were engaged in a discussion with the examiner, read magazines, or went to the cafeteria. The time it took to read the list at each trial was measured (using a stopwatch) and the number of words recalled at each trial was recorded. Thus, a total of 14 measures of reading speed were recorded (i.e., seven for the fixed order and seven for the variable order lists), as well as 14 measures of the number of words recalled for each list. Each word list was used in half the cases as the fixed order list and in the other half as the variable order list.

# RESULTS

## *Recall Analysis*

Figure 1 presents the number of words recalled in each list order by each group as a function of the repeated trials. Two separate analyses of variance were conducted in order to analyze the data, first for the acquisition portion (i.e., trials 1 to 5) and second for the retention portion (i.e., trial 5, 20-minute delay and 1-hr delay).

*Acquisition.* A mixed-design ANOVA was conducted to analyze the effect of group (HI and controls) by trial (1 to 5) by order (fixed and variable), the former being a between-subjects factor and the latter two within-subjects factors. The group main effect was significant, $F(1, 34) = 7.50$, $p < .01$. Control and HI group means were 9.06 and 7.54, respectively. The trial main effect was also significant, $F(4, 136) = 84.24$, $p < .001$. Means for trials 1

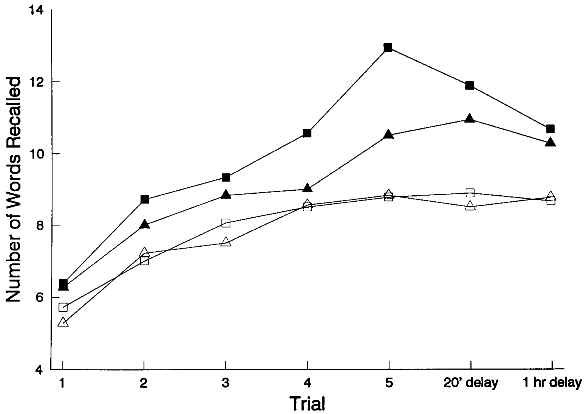


FIG. 1. The number of words recalled in each list order by each group as a function of repeated trials. Solid square, fixed control; solid triangle, variable control; open square, fixed head-injured; open triangle, variable head-injured.

through 5 were 5.92, 7.74, 8.43, 9.15, and 10.26 respectively. In addition, the order main effect was found to be significant, $F(1, 34) = 7.02$, $p < .012$. Fixed order and variable order means were 8.60 and 8.00, respectively. Since most of the interactions between the main effects also reached significance, main effects will not be interpreted at this stage. The significant group by order interaction seen in Fig. 1, $F(1, 34) = 4.24$, $p < .047$, suggests that, while the control group recalled more words on the fixed order than on the variable order list, the HI group showed similar recall on both list orders. As seen in Fig. 1, the significant group by trial interaction, $F(4, 136) = 5.19$, $p < .001$, suggests that the learning rate over trial, for the control group is steeper than for the HI group. The order by trial interaction did not reach significance. The significant triple interaction (group $\times$ order $\times$ trial), $F(6, 204) = 2.30$, $p < .05$, suggests that the control group, as compared with the HI group, showed a steeper learning rate over trials on word recall for the fixed order list than for the variable order list. Interpretation of the above interactions is based on a simple effect analysis conducted for each group separately. The results showed that both main effects, order, $F(1, 17) = 11.54$, $p < .003$, and trials, $F(4, 68) = 60.35$, $p < .001$, as well as the order $\times$ trial interaction $F(4, 68) = 4.64$, $p < .002$, were significant for the control group. On the other hand, the only effect to reach significance for the HI patient group was the trial main effect, $F(4, 68) = 28.37$, $p < .001$.

*Retention.* A mixed-design ANOVA was conducted to analyze the effect of group (HI and controls) by trial (5, 20-min delay and 1-hr delay) by order (fixed and variable), the former being a between-subjects factor and the latter two within-subjects factors. The group main effect was significant, $F(1, 34) = 10.31$, $p < .003$. Means for the control group and the HI group were 11.20, and 8.73, respectively. The trial main effect was also found to be significant, $F(2, 68) = 5.16$, $p < .008$. Means for trials 5, 20-min and 1-hr delay were 10.26, 10.06, and 9.58, respectively. In addition, the order main effect was significant, $F(1, 34) = 5.97$, $p < .020$. Means for the fixed order and the variable order were 10.31 and 9.63, respectively. Since all of the interactions between the main effects also reached significance, the main effects are not being interpreted at this stage. As seen in Fig. 1, the significant group by order interaction, $F(1, 34) = 4.45$, $p < .042$, suggests that the control, but not the HI patient group, recalled more words from the fixed order list than from the variable order list. As also seen in Fig. 1, the significant group by trial interaction, $F(2, 68) = 3.93$, $p < .024$, suggests that the forgetting rate over trials for the control group is steeper than for the HI group (this point will be addressed in the discussion section). The significant triple interaction (group $\times$ order $\times$ trial), $F(2, 68) = 5.42$, $p < .007$, suggests that the control group, as compared with the HI group, showed a steeper forgetting rate over trials in word recall from the fixed order list than from the variable order list. The above interactions were interpreted based on a simple effect analysis conducted for each group separately. Results showed

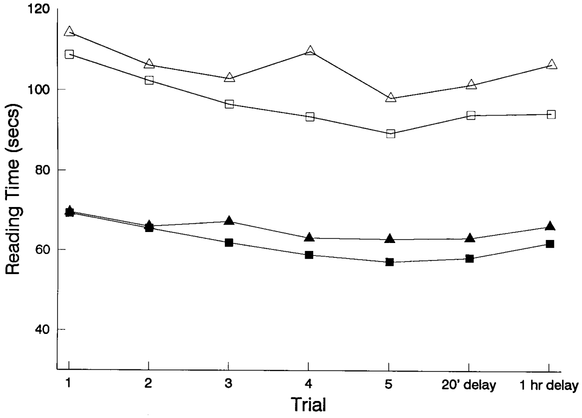


FIG. 2. The reading speed of the words in each list order by each group as a function of repeated trials. Solid square, fixed control; solid triangles, variable control; open squares, fixed head-injured; open triangle, variable head-injured.

that both main effects, order $F(1, 17) = 13.77$, $p < .002$, trials $F(2, 34) = 11.44$, $p < .001$, as well as the order $\times$ trial interaction $F(2, 34) = 11.94$, $p < .001$, were significant only for the control group but not for the HI patient group.

*Reading speed analysis: Raw scores*

Figure 2 presents the reading speed of words in each list order by group as a function of repeated trials. As above, two separate analyses of variance were conducted in order to analyze the data, first for the acquisition portion (i.e., trials 1 to 5) and then for the retention portion (i.e., trial 5, 20-min delay and 1-hr delay).

*Acquisition.* A mixed-design ANOVA was conducted to analyze the effect of group (HI and controls) by trial (1 to 5) by order (fixed and variable), the former being a between-subjects factor and the latter two within-subjects factors. The group main effect was significant, $F(1, 34) = 25.88$, $p < .001$. Control and HI group means were 64.25 and 102.14 sec, respectively. The trial main effect was significant, $F(4, 136) = 20.12$, $p < .001$. Means for trials 1 through 5 were 90.46, 85.05, 82.19, 81.33, and 76.95, respectively. The order main effect was also found to be significant, $F(1, 34) = 5.61$, $p < .024$. Means for the fixed order and the variable order were 80.37 and 86.03 sec, respectively. Both groups showed decreased reading time over the first five trials. Since some of the interactions between the main effects also reached significance, they will not be interpreted at this stage. The group by trial interaction reached significance as well, $F(4, 136) = 2.51$, $p < .044$. This interaction is due to the fact that the decrease in reading time over trials was steeper for the HI group. The order by trial interaction was the only

TABLE 2
Values of $t$ Test Comparisons of Different Trials for Both Control and HI Groups

| | Delayed trial 20 min | 1 hour |
|---|---|---|
| | Control ($n$ = 18) | |
| | Fixed order | |
| First trial | 5.58** | 3.19 |
| | Variable order | |
| First trial | 3.97** | 1.74 |
| | HI ($n$ = 18) | |
| | Fixed order | |
| First trial | 3.36** | 3.09** |
| | Variable order | |
| First trial | 3.17** | 1.36 |

** $p < .001$.

other interaction that reached significance, $F(4, 136) = 2.64$, $p < .036$. As may be seen in Fig. 2, the insignificant group by order interaction suggests that the decrease in reading time was steeper for both group to the same extent on the fixed condition.

*Retention.* In order to evaluate the delay effect, a separate mixed-design ANOVA was performed to analyze the effect of group (HI and controls) by trials (5, 20-min and 1-hr delay) by order (fixed and variable), the former being a between-subjects factor and the latter two within-subjects factors. The results show that only the main effects, but not the interaction between them, reached significance. The significant group main effect, $F(1, 34) = 23.29$, $p < .001$ signifies that, overall, the control group read the lists faster (mean × 61.71 sec) than the HI group (mean = 97.36 sec). The significant order main effect, $F(1, 34) = 8.38$, $p < .007$, signifies that, overall, reading time was less for the fixed order list (mean = 75.92 sec) than for the variable order (mean = 83.15 sec). With regard to trial, $F(2, 68) = 6.96$, $p < .002$, the means for trial 5, 20-min and 1-hr delay were found to be 76.95, 79.27, and 82.38, respectively.

For further clarification of the results, follow-up pairwise comparisons between the baseline measure—trial 1 and the delayed measure—were conducted separately for each group. Table 2 presents the results of the different comparisons for both groups. In the comparison between the first trial (which served as the baseline measure) and the 20-min delay trial, it was found that for both groups on both reading orders (fixed and variable), the 20-min delay trial was still significantly faster than trial one. However, in the comparison between trial 1 and the 1-hr delay trial, the latter was faster than the first trial for both groups only on reading the fixed order list.

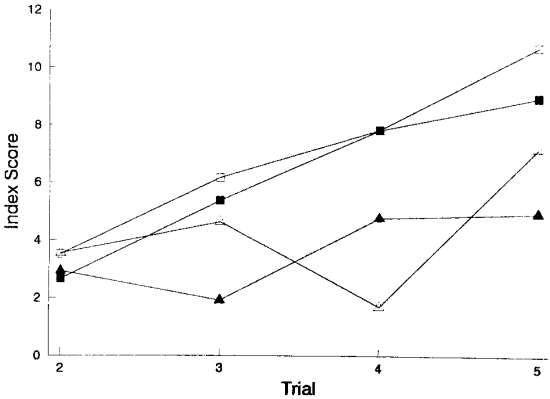


FIG. 3. Index scores for the control and HI groups as a function of learning trials. Solid square, fixed control; solid triangle; open square, fixed head-injured; open triangle, variable head-injured.

*Reading speed analysis: Index scores*

Moscovitch et al. (1986) have proposed an index that enables comparison between the groups, despite the difference in baseline reading speed. The index is [(initial reading time − new reading time)/(initial reading time + new reading time)] * 100. In our paradigm, since we have repeatedly measured reading speed, we produced repeated ''new reading times.'' Index scores were calculated, where the initial reading time on trial one serves as a baseline, for all the trials in the acquisition process (trials 2 to 5), for all the trial in retention process (trial 5, 20-min and 1-hr delay trials), and for each reading order list, yielding a total of eight index scores for the acquisition stage and six index scores for the retention stage. Note that trial 5 is used in both analyses.

As above, two separate analyses of variance were conducted in order to analyze the data, first for the acquisition portion (i.e., trials 2 to 5) and then for the retention portion (i.e., trial 5, 20-min delay and 1-hr delay).

*Acquisition.* The index scores for the control and HI groups for the acquisition stage are presented in Fig. 3. These scores were submitted to a mixed design ANOVA to analyze the effect of group (HI and controls) by trial (2 to 5) by order (fixed and variable), the former being a between-subjects factor and the latter two within-subjects factors. Main effect for group did not reach significance, but the main effects for trial and order were found to be significant. With regard to trial, $F(3, 102) = 12.96$, $p < .001$, means for trials 2 through 5 were 3.16, 4.53, 5.54, and 7.83, respectively. With regard to order, $F(1, 34) = 4.00$, $p < .05$, means for the fixed order and the variable order were 6.57 and 3.96, respectively. Both groups showed the same pattern of results, since none of the interactions with group reached significance. The

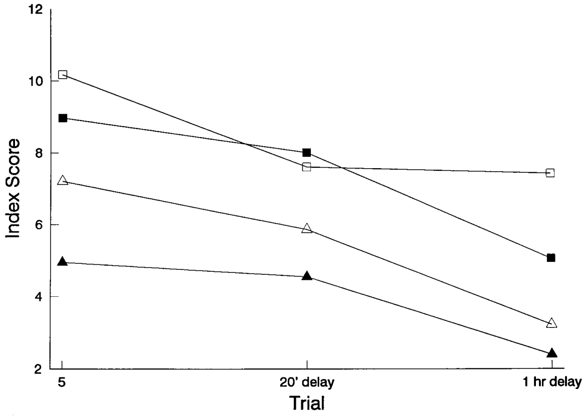


FIG. 4. Index scores for the control and HI groups as a function of delayed trials. Solid square, fixed control; solid triangle, variable control; open square, fixed head-injured; open triangle, variable head-injured.

only significant interaction was the order by trial interaction, $F(3, 102) = 4.11$, $p < .01$. As can be seen in Fig. 3, a steeper change over trials was observed in the fixed order than in the variable order.

*Retention.* Index scores for the control and HI groups in the retention stage are presented in Fig. 4. These scores were submitted to a mixed-design ANOVA to analyze the effect of group (HI and controls) by trial (5, 20-min delay and 1-hr delay) by order (fixed and variable), the former being a between-subjects factor and the latter two within-subjects factors. The results suggest that the groups did not differ significantly on this index score. The main effect for trials reached significance, $F(2, 68) = 8.38$, $p < .001$. Means for trial 5, 20-min and 1-hr delay were 7.82, 6.50, and 4.51, respectively. The main effect for order also reached significance, $F(1, 34) = 4.95$, $p < .03$. The index score for the fixed order list was higher (mean = 11.80 sec) overall than that of the variable order (mean = 7.03 sec). Just as in the results of the raw scores analysis of reading speed retention, none of the interactions reached significance. However, one difference still remains; in this proportional index score the main effect for group is no longer significant, due to a correction for the initial difference between the groups in their reading time.

## DISCUSSION

As expected, the normal control group recalled more words overall than the HI group, and acquisition of information (i.e., learning rate) was better for the control group. These findings confirm the assumption underlying our selection of the HI group that patients following diffuse head injury suffer from memory impairment, an assumption based on many previous reports in the literature (for review see Levin, 1989). Furthermore, the control group benefitted more from reading the list in fixed order than in variable order. Thus, reading order and repetition had a differential effect on the two groups (significant interactions) when recall was measured. The overall advantage of the control group over the HI group remained after the two delay intervals (i.e., 20-min and 1-hr delay). Surprisingly, however, the forgetting rate of the control group was steeper than that of the HI group. A possible explanation for this is that there is a trade-off between reading time at the aquisition stage and retention of the information over time. In order to test for this possibility, a Pearson's product–moment correlation was calculated between the total reading time at the acquisition stage and the rate of forgetting from trial 5 to the 1-hr delay. The correlation was negative but did not reach significance, $r(34) = -.266$, $p > .05$. The tendency of the results supports the possibility that the longer it takes to read at the acquisition stage, the smaller the forgetting rate. An alternative interpretation might be that the explicit memory trace for order information decays or is interfered with more rapidly than that for associations. Presumably such a trend would not be seen in the patients because they do not show any evidence of an explicit memory trace for order. Further study is required to see whether this group difference in the forgetting rate is reliable. If so, the above possible interpretation should be confirmed more conclusively.

In contrast with the findings concerning the explicit memory measures, when a different aspect of the same task was measured (i.e., priming - reading speed) the findings were very different. The overall reading speed of the control group was faster than that of the HI group. When the list was presented in a fixed order both groups benefitted equally. With regard to acquisition, repetition had an effect on both groups, but the HI group benefited more. One possible explanation for these unexpected results is (as seen in Fig. 2) that the control group is nearer the ceiling (faster reading time) and therefore does not show as much improvement over repetitions as the patient group. This interpretation is supported by results of this experiment; when both groups were statistically equated, using the index score analysis, the apparent differential improvement between groups disappeared. An alternative explanation can be found in Musen's et al. (1990) interpretation of similar findings. In Musen's et al. (1990) study, amnesic patients improved their reading speed of a story over three trials even more than did the control group. They interpreted the results to mean that control subjects may at times reduce their pace in order to assure comprehension and retention of the stories, whereas amnesics may forget that recall of the stories will be tested. In order to test for this possibility of the trade-off between reading speed and recall of the word list, Pearson's product–moment correlations between the average number of words recalled over all trials, and average reading time over all trials were performed for each group separately and for the entire sample. The correlation for the entire group was negative and reached significance $r(34) = -.359$, $p < .05$. The separate correlations for each group showed the same tendency but did not reach significance, $r(16) = -.110$, $p > .05$, for the control group. Almost identical results were found for the HI group $r(16) = -.112$, $p > .05$. Very similar results were obtained when the measures were based on just the acquisition trials (1 to 5) or on just the delay trials (20-min and 1-hr delay). The negative correlation indicates that a decrease in reading time is related to an increase in number of words recalled. Thus, in the present study there is no indication for a trade-off between reading speed and recall for both groups; on the contrary, the subjects that learned and recalled more words were also the faster readers.

The correlation results of reading time with learning, on the one hand, and retention, on the other, are quite puzzling. Faster reading was associated with both, better learning and poorer retention. A possible explanation for these seemingly conflicting findings is that the instructions, requiring both to read as fast as one could, as well as to recall as many words as possible, have a differential effect on the learning and retention. The additional requirement to read fast was found to affect the subjects' retention of the information over time, but not the immediate-repeated learning process. Thus, subjects with the better learning abilities were those that read faster, as expressed in the negative correlation between reading time and number of words recalled. The consequence of these subjects' fast reading was that they also forgot the information faster, as expressed in the negative correlation between reading time and the forgetting rate. The differential effect of reading speed on acquisition and retention processes requires further investigation.

In any event, it is safe to conclude that HI demonstrate a priming effect *at least* as much as control subjects. This finding offers a very different picture than the results in the explicit memory task. With regard to retention, the overall reading speed of the control group remained faster than that of the HI group. Groups otherwise showed the same pattern of results. For both groups, even after the 1-hr delay, reading time on the fixed order list was significantly less than the initial reading time. However, both groups read the variable list after the 20-min delay faster than their initial reading speed. One hour later, though, their reading time did not differ significantly from baseline performance. Musen et al. (1990) reported that facilitation persisted for 10 min for control, as well as amnesic subjects, on a passage read three successive times and then reread later, but disappeared after 2 hr. Therefore, in the present experiment, we chose delay times of 20 min and 1 hr, which fall in between the above measured times.

Our findings contribute in two ways to the determination of the extent of priming effect retention. First, we discovered the effect of consistency of presentation on retention of the priming effect over time. Second, it helped to refine the time boundaries within which the priming effect persists. Under both reading conditions, the facilitation effect persisted for at least 20 min. In the fixed order reading condition, this effect persisted for at least one hour.

Moscovitch et al. (1986) raised a concern with regard to possible contamination when the same items are used for recall and reading speed. Our results counter this possibility, since group performance on the recall task did not at all resemble reading speed performance. More specifically, the steeper learning rate of the control group over the HI group was not paralleled by a similar pattern in reading speed. Thus, we have no indication that one task affected the other.

Another concern raised by both Moscovitch et al. (1986) and by Mayes et al. (1991) relates to the fact that the two groups' baseline reading speed is different; this leads to a difficulty in drawing clearcut conclusions from the groups' performance in later stages. This problem was addressed here in two ways. First, the fact that in our paradigm seven repeated trials were conducted, enabled us to compare the two groups in the process. Although the control group benefitted more from the repeated trials on the recall task than the HI group, the HI group benefitted more than the control group on the priming task. The second way in which this problem was addressed was by analyzing the index proportional scores of both groups, as suggested by Moscovitch et al. (1986). The results reconfirmed our previous findings that the groups did not differ on the priming task.

Head-injured patients have been shown to have impaired memory for temporal order when measured explicitly, but not when measured implicitly (Vakil et al., 1991). The results obtained in this study are in accordance with this finding, since the HI group benefitted from the consistent order in the priming task just as much as the control group. However, it is important to note that the implicit effect of consistent order could have been reflected in the recall task as well. In accordance with Pellegrino and Batting (1974), the control group benefitted from the consistent order in the recall task. The HI group, however, did not show such a significant advantage on recall of the fixed order list over the variable order list. This distinction between different implicit/indirect measures of memory requires further investigation.

In conclusion, memory-impaired patients following head injury demonstrated the same pattern of dissociation reported in amnesics with various aetiologies, between memory tasks measured explicitly and implicitly. These findings support the notion that memory impairment following head injury resembles the memory profile found in classical amnesia. Furthermore, in this study, two aspects of memory, acquisition and retention, were measured explicitly (i.e., recall) and implicitly (i.e., priming - reading speed). Although the HI group was impaired on most measures of the explicit task, they demonstrated the same pattern of results as did control subjects on the implicit task. If anything, they showed a greater decrease in reading time than control subjects.

Presenting lists in fixed and variable order enabled us to answer an unresolved question in the Mayes et al. (1991) study. The memory impaired group learned and retained the fixed order list better only when memory was tested implicitly. This finding suggests that memory impaired patients are capable of acquiring and retaining novel information, which is in accordance with the Mayes et al. definition above. Furthermore, the results support the notion presented by Moscovitch et al. (1986) that, in this kind of memory, intra-item as well as inter-item processes take place. Intra-item processes are said to occur, since the priming effect was observed even when the list was presented in variable order. Inter-item processes are said to occur, since presentation of lists in fixed order produced a significantly stronger priming effect than in the variable list.

An alternative approach to explain these findings is in terms of the distinction between procedural or skill learning, and priming. Both types of memory tasks are considered implicit (Schacter, Chiu, & Ochsner, 1993) or nondeclarative tasks (Squire, 1992), which are preserved in amnesics. It has recently been claimed that in different tasks, both processes are involved. For this reason, an attempt has been made to sort out these two processes (Russo & Parkin, 1993; Schwartz & Hashtroudi, 1991). In their investigation of age differences in implicit memory, Russo and Parkin (1993) presented different sets of fragmented pictures to their subjects. The saving observed from one set of pictures to another was considered as skill or procedural learning. The additional saving observed when the same set of pictures was presented was interpreted as the facilitating effect of priming, since they were exactly the same pictures. Similarly, in the present study, the improvement in the variable order list can be attributed to a more general skill-procedural learning, since the words were presented in a different verbal context each time. The improvement on the fixed order list can be attributed to the facilitatory effect of priming, since the same words were presented in exactly the same verbal context. Since, unlike Russo and Parkins' experimental design, the same items were presented here in variable order, an additional condition was required in which a different list of words was tested following training on a particular word list. The savings in reading time of the second list as compared to the initial reading time of the first list could be more conclusively attributed to as the skill-procedural learning mechanism. Further research is required using different implicit memory paradigms in order to reach the above conclusions with regard to implicit memory in general.

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