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Impaired Learning in Patients With Closed-Head Injuries: An Analysis of Components of the Acquisition Process

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Several studies have already shown a deficit in learning ability following closed-head injury (CHI). Moreover, different learning curves have been claimed to characterize different head-injured subgroups (Luria, 1973). The present study separated the learning process into two different components: the number of new words added in each learning trial, and the number of words omitted from trial to trial. The Rey Auditory Verbal Learning Test was administered to 30 normal subjects and 30 CHI patients. Analysis of the number of words recalled in each of the five learning trials showed that, relative to the CHI group, the control group recalled a greater number of words and exhibited a steeper learning curve. Further analysis revealed that the control group's steeper learning curve was a product of both a significantly greater increment of words in each trial and a significantly smaller number of words omitted from trial to trial. The clinical and theoretical implications of the distinction between addition and omission of information in the learning process are discussed.

Many distinctions have been suggested to clarify what memory processes are composed of (e.g., episodic vs. semantic, procedural vs. declarative). Certain other distinctions stemming from theoretical conceptualizations are reflected in approaches to memory assessment. Erickson and Scott (1977) offered a very important and basic distinction in memory assessment, that between acquisition and retention. The former is a learning process, whereas the latter term refers to the retention over time of learned information. Lezak (1983) suggested that memory assessors distinguish between memory span and learning increment. Memory span is a measure of the capacity to learn information in a single trial. Learning increment reflects learning rate, that is, the ability to add information from trial to trial. This distinction may be regarded as reflecting two different aspects of the acquisition process.

Some studies have found that learning ability is useful in differentiating between normal subjects and those who have sustained head injury (Query & Berger, 1980; Query & Megran, 1983). Luria (1973) used learning rate for finer differentiation between subgroups with cerebral lesions in different brain locations. For instance, relative to subjects with a posterior lesion, patients with frontal lobe damage were characterized by a flatter learning curve. Thus, learning ability, as measured by the amount of information acquired, is usually assumed to be composed of initially retained information, which increases at different rates for different populations.

On the basis of his clinical observations of pathological learning processes, Luria (1966) discriminated between two aspects of the learning curve: words added at each trial, and words omitted during repeated recall trials. A similar distinction was offered by Tulving (1964), who used the terms *intratrial* and *intertrial* retention. Tulving used a free-recall paradigm in a study of normal subjects to show that the traditional learning curve can be additively composed of intratrial and intertrial retention. Figure 1 presents a schematic view of the relationships between these different distinctions.

The purpose of the present study was to compare the learning ability of normal subjects and subjects with closed-head injury (CHI) by separating two components in the learning curve, additions and omissions. These measures, and their separate results, were expected to provide a representation of the learning strategy utilized by each group that could not be achieved

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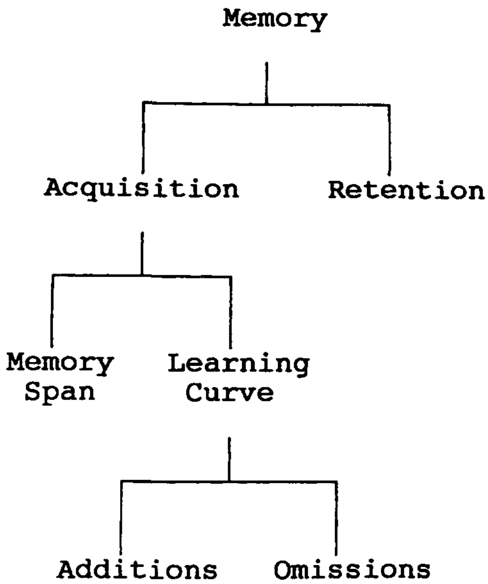

Figure 1. Schematic representation of different suggested distinctions between memory processes.

by comparing the learning rate or by relying only on comparison of the total amount of information learned. The simpler methods noted earlier yield less informative results because minimal increments can be offset by minimal omissions, and maximal increments can be offset by maximal omissions, resulting in virtually identical learning curves.

Method

Subjects

Two groups of subjects participated in the present study: a control group (non-brain-damaged) and a CHI group. The control group consisted of 30 healthy volunteers who ranged in age from 19 to 49 years (mean age = 24.12 years) and who had from 12 to 17 years of formal education. None had a history of alcohol abuse or any history of psychiatric intervention or hospitalization. None had serious medical conditions or were taking medications when tested.

The CHI group included 30 patients who suffered from documented CHI. Table 1 presents demographic information, clinical characteristics, and intelligence test scores for the CHI group. The CHI patients were on average 4.17 years postinjury, with medical records reflecting loss of consciousness ranging from a few seconds to 5 months. Their ages ranged from 19 to 57 years (mean age = 30.27 years), and they had completed 8 to 16 years of formal education. All but 3 subjects had either a Verbal or a Performance IQ greater than 80 on the Wechsler Adult Intelligence Scale (Wechsler, 1945). Subjects 3, 24, and 27 did not meet that criterion, but on the basis of clinical judgment their abilities were considered superior to the IQ score attained. The IQ scores for two other subjects (29 and 30) were unavailable. CHI patients had been referred for extensive neuropsychological evaluation to the National Institute for Rehabilitation of the Brain Injured in Tel Aviv, Israel. All patients were ambulatory, and as a condition for admission to the rehabilitation program, none were employed at time of testing. Upon admission to the rehabilitation program, each CHI patient was administered a battery of neuropsychological tests, which included the Wechsler Adult Intelligence Scale and several widely used memory tests. None of the patients showed any indication of a significant language problem.

Instrument and Procedure

A Hebrew version of the Rey Auditory Verbal Learning Test (AVLT) was used (Vakil & Blachstein, in press). Administration was standard, as described in Lezak (1983). The test consisted of 15 common nouns, which were read in a fixed order to the subjects for five consecutive trials, with each trial followed by free recall. The standard recognition and delay trials that follow the five learning trials were administered but were not considered for analysis.

Results

Three different measurements were calculated at each trial: (a) words recalled, (b) words added (the cumulative number of words recalled at each trial that had not been recalled at previous trials, and (c) words omitted (i.e., the cumulative number of words not recalled that had been recalled during previous trials—for example, if a word were omitted in Trials 2, 3, 4, and 5 but had been given in Trial 1, it would be counted four times). Figures 2, 3, and 4 present these three measures in the five consecutive learning trials for the control and CHI groups.

The three scores were subjected to separate statistical analysis. Multivariate analysis of variance (MANOVA) was used to analyze interactions between group (control vs. CHI) and repetition (five trials for word recall; only four trials for words added and words omitted because these could not, of course, be measured during the first trial). Age and education were added as covariates to the MANOVA analyses because they differed between the two groups. It was found that these two factors did not significantly change the pattern of results.

The analysis of words recalled revealed a significant group main effect, $F(1, 58) = 102.13$, $p < .01$. The

Table 1
Demographic and Clinical Characteristics and Intelligence Scores of the Patients With Closed-Head Injuries

Subject	Sex	Age at exam	Years of education	Age at injury	Damage–test interval (in years)	Hemiplegia[a]	Aphasia[a]	Loss of consciousness (in days)	WAIS		
									FIQ	VIQ	PIQ
1	Male	32	8	31	1	—	—	4	96	99	93
2	Male	44	8	42	2	—	—	—	77	82	74
3	Female	20	11	19	1	Ataxia	—	20	72	76	69
4	Male	23	12	21	2	—	—	1	92	96	87
5	Male	27	12	21	6	—	—	3	84	87	81
6	Female	20	12	19	1	—	Motoric	60	90	95	86
7	Male	25	11	20	5	Left	—	3	97	99	95
8	Male	29	13	25	4	—	—	—	99	99	99
9	Male	31	12	26	5	Right	Expressive	3	93	99	86
10	Female	51	16	49	2	—	—	1	108	120	91
11	Male	28	10	22	6	—	Anomia	11	88	90	86
12	Male	29	10	24	4	—	—	60	77	85	69
13	Male	19	11	17	2	—	—	1	107	106	103
14	Female	40	12	25	15	Left	—	150	89	88	92
15	Male	20	12	19	1	—	—	15	99	99	99
16	Male	24	12	12	12	Ataxia	—	30	103	105	98
17	Male	40	8	35	5	—	—	1	97	95	100
18	Male	31	11	26	5	Apraxia	—	3	91	88	88
19	Male	39	12	38	1	—	—	21	94	95	93
20	Male	23	10	17	6	—	—	150	106	109	100
21	Male	45	15	43	2	—	—	11	92	101	82
22	Male	57	10	55	2	—	—	14	94	99	88
23	Male	23	12	22	1	—	—	10	94	109	74
24	Male	39	14	37	2	—	—	—	69	69	71
25	Male	25	13	22	3	Right	—	3	114	122	102
26	Female	26	12	16	10	Right	—	14	96	113	73
27	Male	28	12	22	6	—	—	14	76	77	77
28	Female	22	12	19	3	Left	—	7	86	99	72
29	Male	24	10	19	5	—	—	—	—	—	—
30	Female	24	12	19	5	—	—	—	—	—	—

Note. Dashes indicate that categories were not applicable or that data were not available. WAIS = Wechsler Adult Intelligence Scale.
[a] Hemiplegia and aphasia refer to reports within the acute stage; none of the subjects showed hemiplegia or aphasia at the time of testing.

repetition main effect was also significant, $F(4, 232) = 182.62, p < .001$, as was the interaction between group and repetitions, $F(4, 232) = 5.71, p < .001$. Both the total number of words recalled and the steeper learning curve (see Figure 2) reflected the control group's advantage over the CHI group.

The analysis of words added revealed a significant group main effect, $F(1, 58) = 57.28, p < .001$, a significant repetition main effect, $F(3, 174) = 156.34$, $p < .001$, and a significant interaction between these two factors, $F(3, 174) = 5.24, p < .002$. As may be seen in Figure 3, the control group used more new words overall, but the interaction is due to the fact that the gap between the groups narrowed from trial to trial.

The analysis of words omitted also revealed significant main effects and a significant interaction: for group, $F(1, 58) = 38.03, p < .001$; for repetitions, $F(3, 174) = 6.22, p < .001$; and for the Group × Repetition interaction, $F(3, 174) = 7.41, p < .001$. As may be seen in Figure 4, overall, the CHI group omitted more words than the control group. The interaction is due to the fact that the CHI group increased the number of omissions from trial to trial, whereas the control group omitted a constant number of words across trials.

For the CHI group, correlations of the clinical and demographic parameters and the different Wechsler Adult Intelligence Scale scores with the total number of omissions, total number of additions, and total number of words learned were very weak and did not reach significance. Also not significant were correlations of these three measures with age and education for the control group.

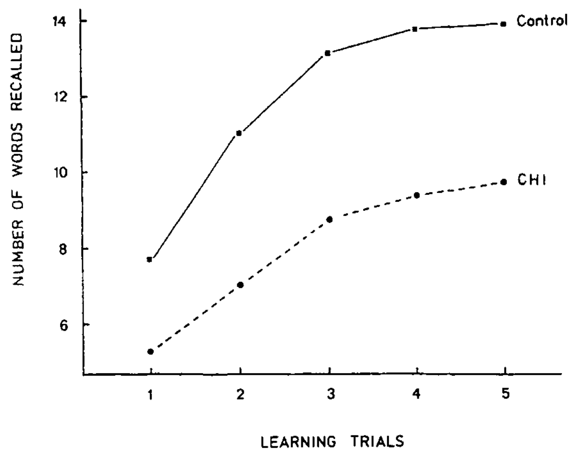

Figure 2. Number of words recalled by control and CHI groups in the learning trials.

Discussion

In previous studies, impaired verbal learning by CHI patients has been found with such different measures as forgetting rate on a free-recall task (Gupta & Ghai, 1991); a stimulus cued-recall task (Mutter, Howard, Howard, & Wiggs, 1990); and the clustering of words on a free-recall task (Levin & Goldstein, 1986). Two studies that involved more particular analysis of CHI patients' learning ability with word lists also found deficits in maintaining elements already acquired. Paniak, Shore, and Rourke (1989) reported a deficit in maintaining words in the Selective Reminding Test, and Levin and Goldstein (1986) reported a deficit in maintaining category exemplars across trials, as measured with a categorized words list.

Studies that have focused on the acquisition process and have closely analyzed the learning curve in the same manner as in the present study used tests such as Buschke's Selective Reminding Test (SRT; Levin & Eisenberg, 1979; Levin, 1989; Paniak et al., 1989) and the California Verbal Learning Test (CVLT; Crosson, Novack, Trenerry, & Craig, 1988). One of the interpretations offered for this impaired learning curve is that CHI patients have a passive approach to learning, so that they benefit when information is highly structured but do not spontaneously use strategies to improve their recall (Levin & Goldstein, 1986).

The primary goal of the present study was to analyze underlying components of the learning curve to better explain how the learning mechanism is impaired following head injury. The results clearly demonstrate that the different learning curves found for the control group and the CHI group are the product of two factors: the number of words added and the number of words omitted in each trial. Interestingly, the number of words omitted differentiated between groups just as well as the number of words added.

The correlations between the number of words omitted and added and the clinical parameters and the different intelligence scores suggest that the processes underlying these parameters are independent. However, because patients with traumatic head injury often have frontal lobe damage (Levin, Benton, & Grossman, 1982), the CHI patients' difficulty in retaining words could also be explained in terms of strategy and awareness. As a result of the frontal lobe damage, CHI patients are insufficiently aware of their limitations.

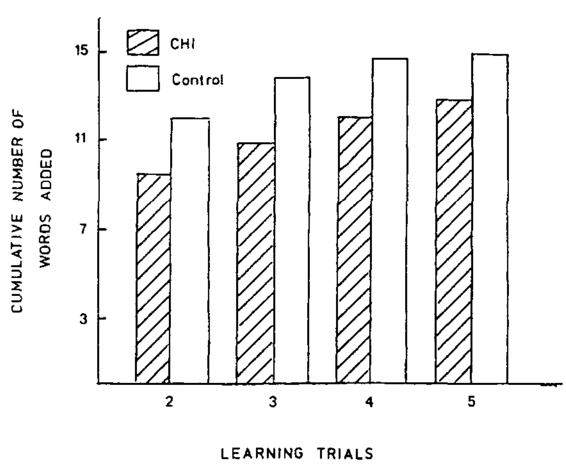

Figure 3. Cumulative number of words added by control and CHI groups in the learning trials.

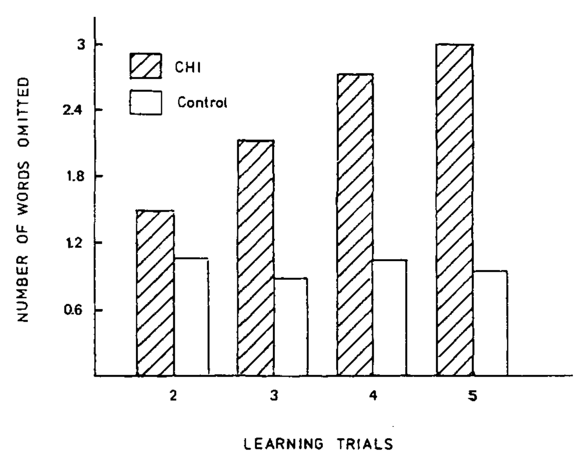

Figure 4. Cumulative number of words omitted by control and CHI groups in the learning trials.

This causes them to try to focus on words that they did not recall in the previous trial. However, by doing so, they in effect make a trade-off between old and new words.

The turnover of words in the learning process can also be interpreted in the framework of information processing. Whereas some researchers have focused on the impairment already found at the storage stage (e.g., Milner, 1969), others have located the impairment at the retrieval stage (Warrington & Weiskrantz, 1970). Two of the studies reporting learning deficits in severe CHI patients (Levin & Eisenberg, 1979, with the SRT and Crosson et al., 1988, with the CVLT) have indicated that both a storage and a retrieval deficit may be involved.

In spite of the similarity between the Rey AVLT and the CVLT, these two tests differ in a few critical elements. The most important is that the list presented in the CVLT is composed of words from four categories, facilitating long-term storage, whereas the Rey AVLT list, which we used, consists of unrelated words.

Also, the SRT is administered differently from the Rey AVLT. First, in the SRT, the words recalled once by the subject are not reread in the next trial, or, in the restricted version, not reread at all. Second, what Buschke referred to as long-term storage we called additions in the present study, and the measure that he called consistent recall is the inverse of the measure we termed omissions. However, in the SRT, a word is considered remembered if it is recalled consistently throughout all the trials. In the present study, additions and omissions from trial to trial were compared, enabling production of a learning curve based on measurement of the turnover of words from trial to trial.

In conclusion, the attempt to separately measure the two components of the learning curve is important from a theoretical point of view because it provides access to a qualitative analysis of particular acquisition patterns and a better understanding of the learning process for normal and CHI groups. Moreover, the decomposition of the learning curve into smaller components can identify different underlying acquisition processes that seem to show the same learning curve. Identifying different patterns within acquisition composites has diagnostic and clinical value. From a diagnostic point of view, different groups with memory deficits can attain the same learning course but different acquisition composite profiles. From a clinical point of view, clarification of this issue can make it possible to more accurately pinpoint the weak link in the learning process found in CHI patients and, accordingly, to offer the appropriate strategy for improving that process.

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The following ethical standards are extracted from the "Ethical Principles of Psychologists and Code of Conduct," which appeared in the December 1992 issue of the *American Psychologist* (Vol. 47, No. 12, pp. 1597–1611). Standards 6.21–6.26 deal with the reporting and publishing of scientific information.

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