Archives of Clinical Neuropsychology, Vol. 7, pp. 111–120, 1992
0887-6177/92 $5.00 + .00

Total Amount Learned Versus Learning Rate of Verbal and Nonverbal Information, in Differentiating Left- From Right-Brain Injured Patients

Eli Vakil

Bar-Ilan University, Ramat-Gan, Israel, and Recanati Rehabilitation Center, Tel-Aviv, Israel

Dan Hoofien and Haya Blachstein

Recanati Rehabilitation Center, Tel Aviv, Israel

Twenty Left-Brain Damaged (LBD), 20 Right-Brain Damaged (RBD), and 20 control subjects were compared on three different learning tasks: (a) verbal, the Paired Associate Learning subtest of the Wechsler Memory Scale; (b) figural, the Gollin Incomplete Figures task, which can be easily verbalized, and (c) spatial, the Stylus Maze. When learning ability was measured, by assessing the total amount learned *(sum of items learned in all trials), the results showed that, on all three tasks, the control group's performance significantly surpassed that of the patient groups. The RBD group performed better than the LBD group on the verbal learning task, while LBD subjects performed better than their RBD counterparts on the spatial learning task. No significant difference between the two patient groups was detected on the figural task, suggesting that a task using visually and verbally codable stimuli is not useful in differentiating between LBD and RBD groups. When the* learning rate *was measured, similar results were obtained in the verbal and figural task. However, in the spatial task, the learning rates of the three groups did not significantly differ, probably because the specific task used required procedural learning, which is normally preserved in amnesics.*

Partial results of the present research were presented at the International Neuropsychological Society Conference, Vancouver, British Columbia, Canada, 1989.

Requests for reprints should be addressed to Dr. Eli Vakil, Psychology Department, Bar Ilan University, Ramat-Gan, 52900, ISRAEL.

Memory has been treated in the literature from different perspectives. Some studies have investigated memory in terms of modality (verbal versus figural: Paivio, 1969), whereas others have done so in terms of information processing (acquisition, encoding, and retrieval: Huppert & Piercy, 1978).

A connection was found between the lateral location of brain injury and modality- specific memory deficit; verbal memory is affected by damage to the left cerebral hemisphere (Milner, 1968), while memory for figural information is affected by damage to the right cerebral hemisphere (Nebes, 1974). Erickson and Scott (1977) differentiated between two components of memory, *acquisition*, and *retention* of information. The former is defined as a learning process; the latter refers to retention-over-time of learned information. Studies examining memory have not usually differentiated between these two components. Few studies focus specifically on the acquisition process. Huppert and Piercy (1978) found that selective impairment in the acquisition stage is characteristic of the memory deficit of Korsakoff patients. Moreover, analysis of the shape of the learning curve was used to characterize different locations of cerebral injury (Luria, 1973). Very few studies have also investigated the acquisition process for patients with lateralized damage. Milner (1965), using a spatial learning task (Stylus Maze), found a pronounced deficit in the performance of patients following a right temporal lobectomy. A specific verbal learning impairment, following left brain damage, was found by several investigators (Black, 1973; Bornstein, 1982; Holland, 1974). These studies have placed major emphasis on the products of acquisition of information (e.g., number of trials needed to reach criterion; sum of, or mean number of errors after repeated training; etc.), and, unlike Luria (1973), usually did not refer to the course of the acquisition process. Furthermore, these studies did not include more than one stimulus modality (verbal or figural) in a single research design.

A study by Goldstein, Canavan, and Polkey (1988) investigated the interactive influence of modality and laterality variables on acquisition of information, examining the effect of repeated trials on acquisition. This study indicated that learning increased with the number of trials on the verbal test only, with an advantage for right temporal lobectomized patients over left temporal lobectomized patients. On the figural task there was no learning effect for any group and no significant lateral damage effect. The study's authors ascribe the asymmetric results obtained for verbal and figural stimuli, either to application of two response modes, namely, the recall required for verbal stimuli and the recognition required for figural stimuli, or, more generally, to differences in task difficulty. In addition, they attributed the lack of differential effect of the laterality of brain damage on the figural task to a possible verbalization of the abstract designs used.

The present study focuses on analysis of the acquisition process after lateralized damage for three different learning tasks using verbal stimuli, figural stimuli (verbally codable), and spatial stimuli (not verbally codable). A three-trial learning procedure was used for each of the three tasks.

METHOD

Subjects

Three groups of subjects participated in the present study: Non-brain-damaged (Control), left-brain damaged (LBD), and right-brain damaged (RBD). The control group consisted of 20 volunteers, with a mean age = 40 (range = 21–60), mean years of formal education = 14 (range = 8–20). The 20 LBD and 20 RBD cases, were selected from among brain-injured patients referred for neuropsychological evaluation to the National Institute for Rehabilitation of the Brain Injured in Tel Aviv. They suffered from lesions localized unilaterally due to either Cerebro-Vascular-Accidents (CVA), or to tumor excision. Tables 1 and 2 provide a fuller description. The mean age of the LBD patients was 38 (range = 19–59). The mean educational level was 11.7 years of schooling (range = 9–17 years). All of the subjects in the LBD group were able to communicate well, and none of them exhibited major linguistic deficits which might have interfered with task comprehension or performance. The mean age of the RBD

TABLE 1
Characteristics of Left Cerebral Hemisphere Lesioned Subjects

Subject	Type Damage	Hemipr/ Hemipl	Aphasia	Age at Onset	Age at Exam	Sex	Educ (years)
A.R.	TM	+	–	44	46	M	9
L.R.	EMBOLISM	–	–	37	40	F	10
P.I.	TM	–	–	30	33	M	11
C.Z.	CVA	+	ALEXIA	25	30	M	9
L.S.	CVA	–	–	20	25	F	12
B.B.	CVA	–	+	51	53	M	12
M.D.	CVA	+	+	50	52	M	12
B.S.	TM	+	+	18	19	F	11
P.D.	TM	+	–	52	53	M	15
V.D.	TM	–	–	36	41	F	10
S.I.	TM	–	–	28	30	M	11
T.O.	TM	–	–	25	26	F	12
S.E.	CVA	+	+	56	57	M	12
B.Z.	CVA	+	–	58	59	M	17
A.S.	CVA	+	–	44	53	M	12
R.V.	TM	–	+	18	19	M	12
Z.A	CVA	–	+	35	37	F	12
E.C.	CVA	+	+	35	36	M	11
A.E.	CVA	+	+	19	21	F	12
V.S.	CVA	+	+	29	30	M	12

Hemipr - hemiparesis; Hemipl - hemiplegia; Educ - education.

TABLE 2
Characteristics of Right Cerebral Hemisphere Lesioned Subjects

Subject	Type Damage	Hemipr/ Hemipl	Aphasia	Age at Onset	Age at Exam	Sex	Educ (years)
P.G	CVA	+	–	40	43	M	8
R.M.	TM	–	–	20	23	M	12
N.A.	TM	–	–	24	28	F	12
A.H.	TM	+	–	37	40	M	10
E.S.	TM	–	–	18	19	M	12
I.C.	CVA	+	–	40	47	M	12
L.M.	CVA	+	–	47	48	F	12
R.P.	TM	–	–	19	24	M	12
L.K.	CVA	+	–	47	49	M	15
S.M.	TM	–	–	51	53	M	13
R.Z.	CVA	+	–	44	45	F	15
P.C.	CVA	+	–	47	49	M	10
S.G.	CVA	–	–	33	36	M	12
D.Z.	CVA	+	–	42	43	M	10
M.C.	CVA	–	–	63	67	M	20
M.M.	CVA	+	–	40	45	M	20
M.MO.	CVA	–	–	27	30	M	15
A.G.	TM	–	–	33	35	M	12
S.D.	CVA	+	–	49	50	M	8
E.Z.	TM	–	–	19	20	M	12

Hemipr - hemiparesis; Hemipl - hemiplegia; Educ - education.

patients was 39.7 (range = 19–67). The mean educational level was 12.6 years of schooling (range = 8–20 years). At the time of the test none of the RBD subjects exhibited visual or perceptual impairments such as hemineglect.

Instruments

1. The Paired Associate Learning subtest of the Wechsler Memory Scale (Wechsler, 1945). This test was used to assess verbal learning.

2. The Gollin Incomplete Figure Test (Gollin, 1960). This test was implemented to measure figural (verbally codable) learning (Parkin, 1982). In all 11 figures representing common objects were used. As suggested by Warrington and Taylor (1973), three forms of each figure were presented: incomplete, where only a few segments of the figure are drawn; nearly complete, with more details added to the incomplete figure; and complete (see Figure 1).

3. The Stylus Maze (Milner, 1965). This instrument was used to measure spatial learning. It is a square metal board to which a 10 by 10 array of metal dots, serving as "stepping stones", are affixed, with a metal stylus (pencil) for pointing to the stones (see Figure 2). The subject's task was to find the correct path by moving the stylus from dot to dot, guided by electrical clicks generat-

FIGURE 1. Examples from Gollin figures.

ed when he or she pointed to dots which did not lie on the correct path. Diagonal moves were prohibited, and subjects were required to return to the preceding step after each error.

Procedure

Each of the three tests was administered in three consecutive repetitions. The Paired Associate subtest was administered in its standard form. Each of the Gollin Figures was presented, beginning with the least complete and concluding with the most complete picture. This sequence was repeated consecutively for each figure, and the entire procedure was repeated three times. Subjects were asked to complete the Stylus Maze task three times.

RESULTS

For each trial, performance on the Paired Associate subtest was scored as recommended by the manual (i.e., the sum of the correctly remembered easy pairs divided by two, plus the sum of the correctly remembered difficult pairs). Scores on the Gollin task consisted of the number of the least complete figures correctly identified at each repetition. The Stylus Maze scores were

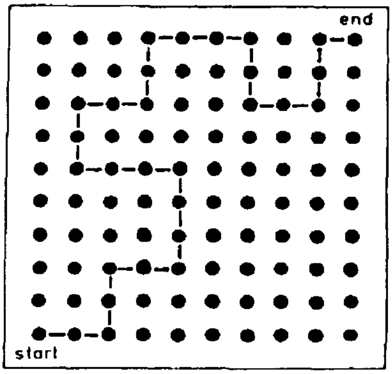

FIGURE 2. The plan of Stylus maze. The correct path is indicated by the black line.

determined by the number of errors made in each trial, before the subject reached the path's terminal point.

Performance on these three tasks by the LBD, RBD, and the control groups is presented in Figure 3.

Scores of the three groups (LBD, RBD, and control), with three repetitions (first, second, and third) for each task, were subjected to MANOVA with repeated measures on the second factor. The analyses for the three tasks showed a significant main effect for group. For Paired Associate, $F(56, 2) = 29.77$ and $p < .01$; for Gollin, $F(57, 2) = 5.66$ and $p < .01$; for Stylus Maze, $F(54, 2) = 5.07$ and $p < .01$. Main effect for repetition was also found significant for the three tasks: for Paired Associate, $F(114, 2) = 115.09$ and $p < .01$; for Gollin, $F(114, 2) = 319.04$ and $p < .01$ for Stylus Maze, $F(108, 2) = 16.64$ and $p < .01$. The Group × Repetition Interaction was found significant only for the Paired Associate subtest, $F(112, 4) = 9.58$; $p < .01$, and for the Gollin task, $F(114, 4) = 10.81$; $p < .01$.

A follow up analysis of the three tests, using Duncan procedure to determine the source of the significant group main effects, revealed that, on all three tasks, control group performance consistently and significantly surpassed that of both the LBD and RBD groups. Comparison between the patient groups showed an advantage for RBD over LBD subjects in the Paired Associate learning task. However, in the Stylus Maze task, the LBD group performed significantly better than the RBD group. On the Gollin task, performance of the two patient groups did not differ significantly. The significant Group × Repetition interaction on the Paired Associate task, as seen in Figure 3, is attributable to the control group's steeper learning curve than the two

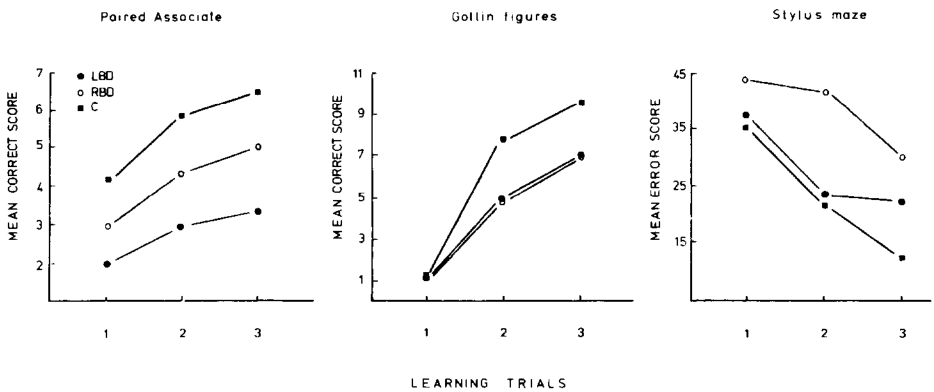

FIGURE 3. Acquisition curves for the different learning tasks for control group, right-, and left-brain damaged groups. C = control group; RBD = right-brain damaged group; LBD = left-brain damaged group.

patient groups, and the RBD group's having a steeper learning curve than the LBD group. The significant Group × Repetition interaction on the Gollin task, evident in Figure 3, is due to the fact that, unlike the two patient groups, the control group improved greatly from the first to the second trial. The learning curves of the two patient groups did not differ significantly.

DISCUSSION

Learning ability can be measured in two different ways — the total amount learned (sum of items learned in all trials), and the learning rate. In the present study, the first is reflected statistically in the group main effect; the second is described by the Group × Repetition interaction. The findings indicate that these two measures are independent, and may therefore produce different results.

Using the first measure, total amount learned, the three tasks used in this study illustrate specific memory impairment following lateralized brain damage. As expected, LBD subjects were more impaired on the verbal learning task (Paired Associate), while RBD subjects were more impaired on the spatial learning task (Stylus Maze). The verbally-codable-figures learning task (Gollin) did not differentiate between the two patient groups. A possible explanation is that the stimuli may be coded either visually or verbally. Thus, RBD patients may have used a verbal code, and LBD patients a visual code, in order to remember. These results reinforce the suggestion of Goldstein, Canavan, and Polkey (1988) that there may be verbal mediation in the memorization of familiar designs stimuli.

Using the second measure, learning rate, we find similar but not identical results. The interaction of Group × Repetition was found significant in two out of the three tasks (i. e., Paired Associate and Gollin). As Figure 3 demonstrates, the learning rates of the three groups in the verbal task (i. e., Paired Associate) differ. The learning rate of the control group was significantly superior to that of the patient groups. Among the patients, the RBD group showed a better learning rate than the LBD group. In the figural task (i. e., Gollin), the significant interaction, shown in figure 3, reflects the steeper learning rate of the control group, as compared to that of the two patient groups, and the fact that the two patient groups did not differ significantly from one another.

The results described above show similar findings irrespective of the use of the total amount learned or the learning rate criterion; that is, both measures yielded evidence of the control group's superior performance, relative to that of the patient groups. However, in the spatial task (Stylus Maze), in spite of the significant group main effect (control better than LBD and RBD, and LBD better than RBD), the insignificant group × repetition interaction indicates that the learning curve of the three groups did not differ significantly.

We interpret this difference in results to mean that the groups differ in their storage capability, as reflected in the significant overall group main effect. That the groups' learning rates did not differ in the Stylus Maze task may be explained in the light of the task's nature. It does not require conscious retrieval of the stylus's path, but rather repeated traversal of the path. Thus, in terms of task demands, it is very similar to such tasks as mirror-tracing, which has been found preserved in amnesic patients like H.M. (Corkin, 1965), and which is considered a procedural learning task (Cohen & Squire, 1980).

These findings accord with those of Brooks (1976), which showed that the learning curve of normal subjects on the Paired Associate subtest is steeper than that of closed head injured patients. A study by Vakil and Rattok (1990) also supports this finding. When exposed to repetition of stories from the Logical Memory Subtest of the Wechsler Memory Scale, their control group yielded a steeper learning curve than the closed head injured group. In addition, Luria's (1973) description of the different learning curves of patients with and without frontal lobe damage may suggest that the frontal lobe involvement also has a critical effect on the learning process.

To summarize, when total amount learned was measured, verbal and spatial learning tasks differentiated between groups. On both tasks the control group performed better than the brain injured groups; on the verbal task the RBD subjects performed better than the LBD, and on the spatial task, the situation was reversed. When the learning task was composed of verbally codable figures, it did not differentiate between the two patient groups, although it did demonstrate a clear advantage for the control group. When learning rate was used as a measure of learning, verbal tasks differentiated among all the groups, and figural tasks differentiated between control and patient groups but not between patient groups. The spatial task did not differentiate at all between the learning rates of the groups. Our interpretation is that the spatial task requires procedural learning which is not sensitive to group differences.

It would seem, therefore, that differential diagnosis of lateralized damage can be improved with the combined use of spatial and verbal tests.

On the basis of the present study, it may be concluded that total amount learned is a more sensitive index of learning ability than learning rate, since, in all tasks, it differentiated between control and patient groups, and showed a double dissociation between the LBD and the RBD groups, in verbal and spatial learning. Further study is required to discover if double dissociation can be found by comparing the learning rate of LBD, RBD, and control groups, when the task assigned to subjects does not appear to require procedural learning.

REFERENCES

Black, F. W. (1973). Memory and Paired-Associate learning of patients with unilateral brain lesions. *Psychological Reports*, **33**, 919–922.

Bornstein, R. A. (1982). Effects of unilateral lesions of the Wechsler Memory Scale. *Journal of Clinical Psychology*, **38**, 389–392.

Brooks, D. N. (1976). Wechsler Memory Scale performance and its relationship to brain damage after severe closed head injury. *Journal of Neurology, Neurosurgery, and Psychiatry*, **39**, 593–601.

Cohen, N. J., & Squire, L. R. (1980). Preserved learning and retention of pattern analyzing skill in amnesia: Dissociation of knowing how and knowing that. *Science*, **210**, 207–209.

Corkin, S. (1965). Tactually-guided maze-learning in man: Effects of unilateral cortical excisions and bilateral hippocampal lesion. *Neuropsychologia*, **3**, 339–351.

Erickson, R. C., & Scott, M. L. (1977). Clinical memory testing: A review. *Psychological Bulletin*, **84**, 1130–1149.

Goldstein, L. H., Canavan, A. G. M., & Polkey, C. E. (1988). Verbal and abstract designs Paired Associate learning after unilateral temporal lobectomy. *Cortex*, **24**, 41–52.

Gollin, E. S. (1960). Developmental studies of visual recognition of incomplete figures. *Perceptual and Motor Skills*, **11**, 289–298.

Holland, T. R. (1974). Wechsler Memory Scale Paired Associate learning in discrimination of brain-damaged and nonbrain-damaged psychiatric patients. *Perceptual and Motor Skills*, **39**, 227–230.

Huppert, F. A., & Piercy, M. (1978). Dissociation between learning and remembering in organic amnesia. *Nature*, **275**, 317–318.

Luria, A. R. (1973). *The working brain: An introduction to neuropsychology*. Harwordsworth, Great Britain: Penguin Books.

Milner, B. (1965). Visually-guided maze learning in man: effects of bilateral hippocampal, bilateral frontal, and unilateral cerebral lesions. *Neuropsychologia*, **3**, 317–338.

Milner, B. (1968). Disorders of memory after brain lesions in man. Preface: Material specific and general memory loss. *Neuropsychologia*, **6**, 175–179.

Nebes, R. D. (1974). Hemispheric specialization in commissurotomized man. *Psychological Bulletin*, **81**, 1–14.

Paivio, A. (1969). Mental imagery in associative learning and memory. *Psychological Review*, **76**, 241–263.

Parkin, A. J. (1982). Residual learning capability in organic amnesia. *Cortex*, **18**, 417–440.

Vakil, E., & Rattok, J. (1990, in press). The effect of repetition and delayed recall on memory following brain injury. *International Journal of Clinical Neuropsychology.*

Warrington, E. K., & Taylor, A. M. (1973). The contribution of the right parietal lobe to object recognition. *Cortex*, **9**, 152–164.

Wechsler, D. (1945). A standardized memory scale for clinical use. *Journal of Psychology*, **9**, 87-95.