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Performance of Nondisabled Adults and Adults with Learning Disabilities on a Computerized Multiphasic Cognitive Memory Battery

Lynnette Wilhardt and Curt A. Sandman

There is scant research on cognitive impairment in adults with learning disabilities (LD), even though at least some children with LD remain affected throughout adulthood. The present study was designed to examine several memory processes in adults with LD, including (a) recall with and without cueing, (b) item recognition, (c) proactive inhibition, and (d) semantically organized material. Twenty-one adults with learning disabilities (17 males and 4 females) between 18 and 33 years of age were compared with age matched controls (N = 88). There were two noteworthy findings: First, the adults with LD consistently overestimated their ability to remember lists of words; second, adults with LD were especially impaired in the test requiring termination of an exhaustive and thorough search for relevant material. The data suggest that level of expectation and organizational (structural) strategies are areas worthy of further investigation.

There is scant research on cognitive impairment in adults with learning disabilities (LD), even though the available literature suggests that at least a portion of children with LD remain affected throughout adulthood (Andrulis & Alio, 1976; Birely & Manley, 1980). A child with at least normal intelligence, who has no significant emotional problems, normal eyesight and hearing, and who cannot master basic school subjects is considered learning disabled (Johnson, 1981). Procrastination, concentration difficulties, and writing blocks are just a few of the many symptoms that are common for a child as well as an adult with LD (Cohen, 1983). Children with LD are also less aware of the phonological structure of spoken words (Fox & Routh, 1975; Golinkoff, 1978; Liberman, Shankweiler, Fischer, & Carter, 1974; Rosner & Simon, 1971) and have poorer performance in short-term memory for a string of letters (Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1979), a string of words (Mann, Liberman, & Shankweiler, 1980), and even words of a sentence (Mann et al., 1980; Wiig & Semel, 1976). Relatedly, adults with LD have deficits in short-term memory described as "a deficient capacity to actively encode incoming information according to useful classificatory schema" (Rudel, 1980, p. 547). Adults with LD also show deficits in long-term memory, memory search, and use of mnemonic strategies (Pressley, Heisel, McCormick, & Nakamura, 1982; Torgesen & Kail 1980; Worden, 1983). Adults and children with LD apply poor organizational strategies for learning new information (Dallago & Moely, 1980) and have inefficient performance with slow presentation formats (Torgesen & Kail, 1980) on primacy items (Bauer, 1977b, 1979; Tarver, Hallahan, Kauffman, & Ball, 1976). However, when adults with LD are provided learning and memory strategies (e.g., Mastropieri, Scruggs, & Levin, in press), their performance is facilitated even though they still take significantly longer than nondisabled adults to respond.

The present study was designed to examine several memory processes in adults with LD, including (a) recall with and without cueing, (b) item recognition, (c) proactive inhibition, and (d) semantic organization of material. The recall tests assessed encoding and/or retrieval deficits. This probe-recall task is widely used for specific issues of short-term memory as well as a general technique for the study of memory (Jarret & Scheibe, 1962; Johnson, 1978; Murdock, 1963). In general, the purpose of the item recognition test is to assess short-term memory in situations in which learning and retention are essentially intact. The third test, Proactive Inhibition, was developed originally by Peterson and Peterson (1959) and Brown (1958); a slightly modified version was developed by Keppel and Underwood (1962). This test measured the organization of memory by evaluating whether more recently learned information was confused with less recently learned information. By manipulating the semantic similarity of the memory items, the probability of old information interfering with newly learned items is controlled. Highly similar information has a higher interference capability than unrelated items. The final test was a test of secondary or semantic memory. Semantic memory is organized in our language and as such is permanent, long-term, or secondary. Knowledge of the meaning of words or of a sentence is embedded in this structure (Smith, 1978).

METHOD

Subjects

Twenty-one adults with LD (17 males and 4 females) were tested at the Rehabilitation Center for Brain Dysfunction (RCBD) in Irvine, California. A summary of the subject marker variables, as described by Keogh, Major-Kingsley, Omori-Gordon, and Reid (1982), is presented in Table 1. Nineteen of the subjects were Caucasian, two were Hispanic, and one was Persian. Eighty-eight age and education matched controls were obtained mostly from the undergraduate pop-

Table 1
Summary of Subject Marker Variables for Adults with LD (N = 21)

Mean Age	WAIS[a] Mean Verbal IQ	WAIS[a] Mean Performance IQ	WAIS[a] Mean Full-Scale IQ
24.8	80.7	76.8	80.5

Education	WRAT[a] Math Grade Level	WRAT[a] Spelling Grade Level	WRAT[a] Reading Grade Level
12.0	4.5	5.5	7.5

[a]WAIS = Wechsler Adult Intelligence Scale (Wechsler, 1955); WRAT = Wide Range Achievement Test (Jastak & Jastak, 1978).

ulation at the University of California, Irvine.

Apparatus

An Atari 800XL microcomputer equipped with an Atari 1050 disc drive and a Zenith Data Systems monitor model ZVM-122 was used to administer the tests. The subjects responded on an Atari touch tablet (Model CX 77). The software was kindly provided by Neurocomp, Newport Beach, California.

Procedure

All subjects were tested individually in a distraction free environment at the Rehabilitation Center for Brain Dysfunction. The entire testing procedure was computerized to ensure standardized administration. The subject was seated in front of the computer monitor. The experimenter read the following instructions: "You will be taking four memory tests. The entire session will last about one hour. At the beginning of each test, I will read the directions with you and make sure you understand them before we start the test." The item recognition and semantic memory tests were scored automatically. The tests of recall and proactive inhibition were scored by the clinician.

Recall Test. Before beginning the recall phase, the subjects were told they would see 10 words, one at a time, and then be asked to recall them. Following the instructions, they were asked to estimate the number of items they would recall (metamemory estimate). The recall test was administered in five progressive subtests; free recall, cued encoding, cued recall, paired associates, and recognition. The subject was shown the instruction, "Memorize the following words." The words then appeared on the screen one at a time at a rate of 1,200 msec per word. When all 10 words had been presented, the subject was instructed, "Recall the words." For the second subtest, cued encoding, subjects were shown two related words. They were instructed to look at both of them but encouraged to remember only the second word. Ten pairs of words appeared one at a time at a rate of 1,200 msec per pair. When all 10 pairs had been presented the subject was instructed, "Recall the words." For the cued recall subtest the subject was shown a list of single words. After all 10 words had been presented, a cue word, related to one of the memorized sets, was given to initiate each response. The fourth test was paired associates. Subjects were shown a pair of common English words (Murdock, 1963) that were functionally related in some way, for example, tomato-seed (Jarret & Scheibe, 1962). They were instructed to remember the second word of each pair. The 10 pairs appeared at a rate of 1,200 msec per pair. After all pairs had been presented, subjects were shown the first word of each pair and asked to recall the second word. The last subtest, recognition, was similar to paired associates. However, during recall, subjects were instructed to choose the correct associate from a list of four possibilities presented simultaneously on the monitor. The increasing structure and priming through the battery increased the probability of recalling the information. Thus, if recall improves dramatically with cueing, a retrieval deficit may be suggested.

Item Recognition. The underlying supposition of the item recognition test (Sternberg, 1969) is that selection of a response requires the use of information that is in memory, and that the latency of the response will reveal something about the process by which the information is retrieved (Sternberg, 1969). This test measures at least two additive functions. One is scanning (serial-comparison) time, which is determined by memory capacity, and the second is composed of stimulus encoding plus response selection or execution. These two functions were proposed to be extracted, respectively, from the slope and intercept calculation of the reaction time across varied set sizes.

The subjects were shown one, two, or four numbers for 800, 1,000, or 1,200 msec, respectively. After the presentation of the numbers (memory set), a probe was presented. The probe consisted of a number that was either in the memory set or not. The subject pressed the YES key (matched to their dominant hand) if the probe was a member of the set and a NO key if it was not. In addition, the probe contained irrelevant material, three letters surrounding the number with position determined randomly. This required the subject to attend to the display.

Example: "REMEMBER"
"7089" (memory set),
(800 to 1,200 msec)
"READY" (1,000 msec)
"NR7S" (probe stimuli)

The subject pressed the "YES" key because 7 is part of the memory set. The subject's response terminated the trial. A 3,000-msec ceiling on reaction time eliminated delays that may have been task irrelevant.

Response latency was defined as the

time from the onset of the probe to the occurrence of the response; this typically increases as a function of memory load or set size (Sternberg, 1969). A linear relation between mean reaction time and the size of the set was expected. That is, subjects responded more slowly to probes when two items were in memory compared to one, and most slowly when four items were in memory. It was proposed that for successful completion of this test, the subject scanned the array of numbers held in memory (Sternberg, 1969). In a serial, exhaustive search process, the subject compared the test stimulus successively to all members of the original positive set (which the subject had memorized) before making a positive or negative response. Even when a match has occurred, scanning continues through the entire series. The search was thought to be exhaustive because (a) each addition of an item to the set of test stimuli increased the reaction time by roughly 38 msec in highly practiced subjects; (b) both positive and negative responses have the same slope; and (c) the serial position effects across the lists are flat. If the search were not exhaustive, the slopes for positive and negative matches would deviate and the serial position curves would increase (Sternberg, 1973).

Proactive Inhibition. In this test, triads of semantically related material were presented, each containing three items to be remembered (Wickens, 1970). These semantically similar items were interrupted by a release (Wickens, Born, & Allen, 1963) trial. This trial contained three items to be remembered that were unrelated, semantically, to the items in the immediately preceding three trials. The subjects were instructed to memorize the three items that appeared on the screen for 2,000 msec. In order to eliminate rehearsal between the memory items and recall, the subjects played an engaging 10-second video game on the monitor. The game required the subject to move a "chaser" after a randomly moving target. When the game stopped, the subjects were instructed to recall the items. The responses were again recorded by the examiner. Two kinds of errors were recorded: (1) total errors which consisted of a nonresponse or a confabulation; and (2) proactive inhibition errors, which consisted of errors made if the response included items from a previous trial.

Semantic Memory. In this test, common phrases with correct or incorrect single word endings were presented. Subjects were asked to judge the appropriateness of the ending and press a true or false button (true matched to their dominant hand) as fast as they could. One third of the time the second presentation immediately followed the first; one third of the time it was delayed by one item, and one-third of the time it was delayed by two items. The categories and probes were assigned randomly with an equal number of items in each temporal interval. They were presented in the same order and remained constant for each subject. In addition, 15 catch trials (trials with nonsensical endings) were included to prevent response bias. The computer presented the inquiry or statement, blanked the screen, then presented the single word (probe) ending.

For example:
(statement): A type of fabric (2,000 msec presentation)
(probe): Wool

Subjects responded by pushing the "True" button because wool is a type of fabric.

The 60 scored phrases (30 different categories) and 15 catch trials resulted in a test of 75 items. By presenting the statements twice (with different endings or probes), the effect of priming was evaluated. The potency of the priming effect was assessed by comparing the differential influence of the three temporal intervals on reaction time.

RESULTS

Metacognitive Estimate Data

The utility of the estimate of performance is by comparison with actual performance. Thus, the ratio of estimated accuracy to the number of items correct in free recall provides an expectation index. Even though control subjects predicted higher estimates than the individuals with LD (see Figure 1), $F(1, 105) = 4.39, p < .05$, the subjects with LD had significantly higher metacognitive ratios, $F(1, 104) = 5.35, p < .05$, indicating that they consistently overestimated their performance. The estimate for the individuals with LD was 29% higher than actual performance, compared with only a 1% overestimation in the control subjects.

Recall Data

Figure 1 illustrates the mean number of words recalled in each of the five subtests of the recall task. Subjects with LD were significantly impaired on each of the five subtests; free recall test, $F(1, 105) = 4.39, p < .001$; cued encoding subtest, $F(1, 105) = 7.53, p < .05$; cued recall subtest, $F(1, 105) = 23.11$, $p < .001$; paired associates subtest, $F(1, 105) = 8.87$, $p < .005$; and the recognition subtest, $F(1, 105) = 4.77$, $p < .05$. However, as is apparent from Figure 1, the differences between the groups diminished as the retrieval cues increased (i.e., the recognition test). A retrieval index was calculated by determining the slope of free recall, paired associate, and the recognition test.[1] The slope difference in this index, $F(1, 104) = 14.79, p < .001$, indicated a significant increase in recall as the structure of the task increased. The adults with LD increased their recall by 1.5 words per subtest whereas the control subjects increased their recall by only .74 words.

[1]Only free recall, paired associate, and recognition were included in the retrieval index because, based upon a data base of about 500 volunteer subjects, we found that neither cued encoding nor cued recall improved memory. We expected to observe incremental improvement in memory with each test from free recall to recognition. We did not find this and assume it relates to our presentation format. Thus, our index of retrieval is empirically derived.

Item Recognition Data

The slope measure for the YES responses (i.e., reaction times with the memory set size) was not significantly different between groups, $F(1, 104) = 1.84$, $p > .05$; adults with LD = 120.2 msec/item; control subjects = 99.0 msec/item). However, for the NO responses (i.e., the probe was not contained in the memory set), the slope was significantly different between groups, $F(1, 104) = 15.61$, $p < .001$. The slope for adults with LD (212.2 msec/item) is nearly twice as steep as that for control subjects (103.7 msec/item), and in comparison with YES trials, it indicated a disproportionate increase in reaction time, with increasing memory load in this condition. Differences between groups on the intercept also were calculated to determine the effects of stimulus encoding and response selection. For the YES responses, $F(1, 104) = 11.41$, $p < .005$, and NO responses, $F(1, 104) = 28.81$, $p < .001$, the control subjects had significantly faster reaction times than the adults with LD. These data are illustrated in Figure 2.

Proactive Inhibition Data

The performance of both groups for all types of errors is shown in Figure 3. Adults with LD made more total errors, $F(1, 105) = 5.00$, $p < .05$, and proactive inhibition errors, $F(1, 105) = 9.34$, $p < .05$, than the control subjects.

Semantic Data

Ratios of first/second presentation trials of each category were calculated to determine the effects of priming. An analysis of variance showed no significant differences in reaction time when the phrases appeared with maximum, $F(1, 104) = .04$, $p > .05$; moderate (one sentence between), $F(1, 104) = .2$, $p > .05$; and minimal (two sentences between), $F(1, 104) = 2.18$, $p > .05$, priming. Since the priming effect dissipates as time between the first and second presentation increases, a negative slope is expected. As presented in Figure 4, this was evident. However, the "priming slope" was not signifi-

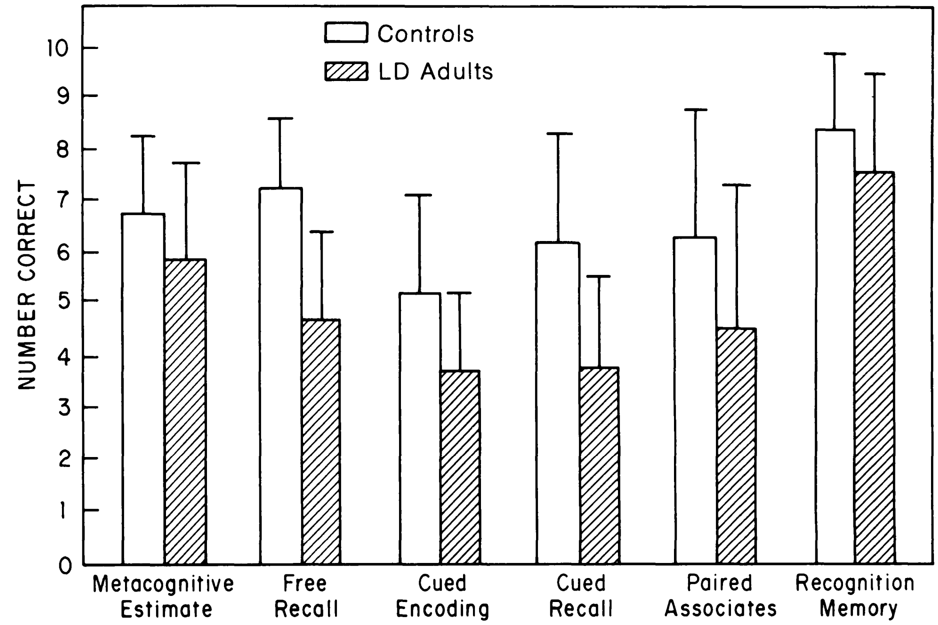

Figure 1. Mean number of words recalled for each of the five subtests of the recall task.

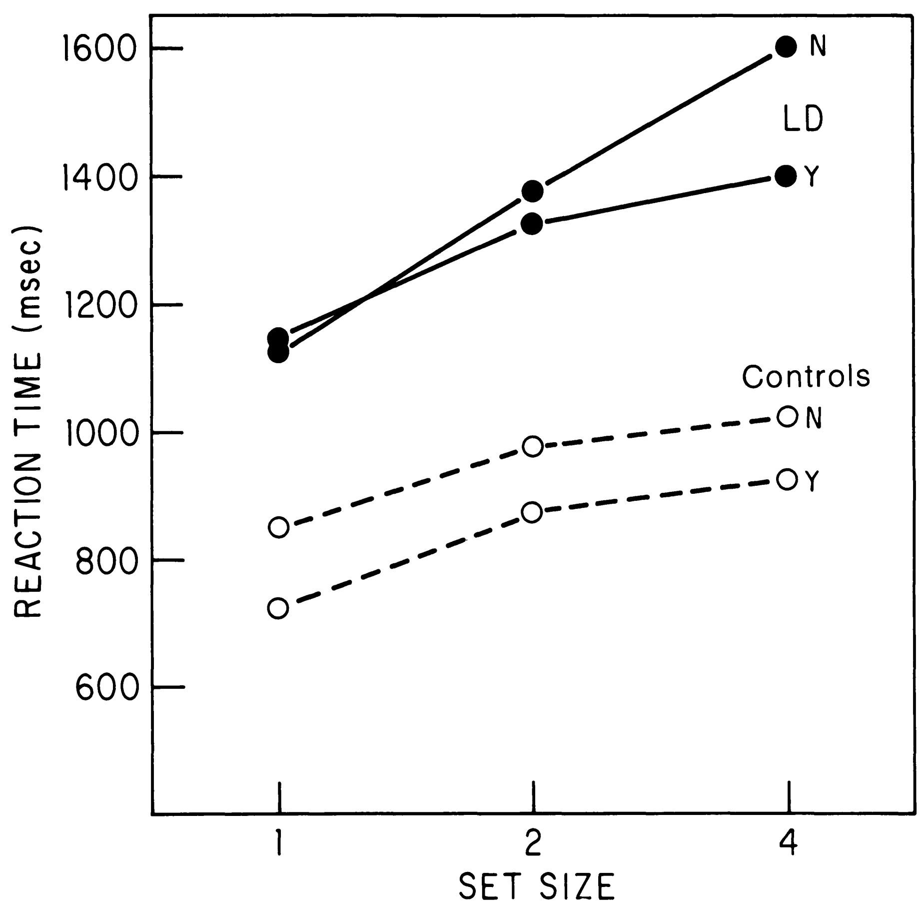

Figure 2. Differences in reaction times between groups for the YES and NO responses in the item recognition test.

cantly different between the individuals with LD and control subjects, $F(1, 104) = 0.00, p > .05$.

Discriminant Function Analysis

A stepwise discriminant analysis with a jackknife-validation procedure was performed to reduce the bias in the group classifications. In this analysis, a linear combination of variables is created that maximally separates the two groups. The variables selected for entry into the equation in order of their contribution were as follows: (1) free recall, (2) the semantic intercept, (3) the semantic slope, (4) the YES slope for the item recognition test, and (5) proactive inhibition (P.I.) errors. As a result of the jackknife-validation, 86.1% of the cases were classified correctly. Among the control subjects, 90.5% were correctly identified and 64.7% adults with LD were accurately placed. Table 2 illustrates these data.

DISCUSSION

The present study produced two noteworthy findings. First, the adults with LD consistently overestimated their ability to remember lists of words. These results complement previous research (Campione & Brown, 1977; Swanson & Mullen, 1983), in which children with LD described themselves as having good memories no matter what the size of the list. Since children with LD tend to fail to use effective mnemonic strategies spontaneously (Torgesen & Houck, 1980), it is plausible that their poor recall is related to unrealistic estimation of ability and their subsequent disregard of mnemonic strategies. Previous research has shown that although children with LD do not employ spontaneous mnemonic strategies, they can be taught to use such strategies to improve their performance (Bauer, 1977a, 1977b). In the present study, the performance of adults with LD improved as the task became more structured (i.e., with more cues and mnemonic devices). Compared to the control subjects, adults with LD benefited significantly from increased structure in the recall task.

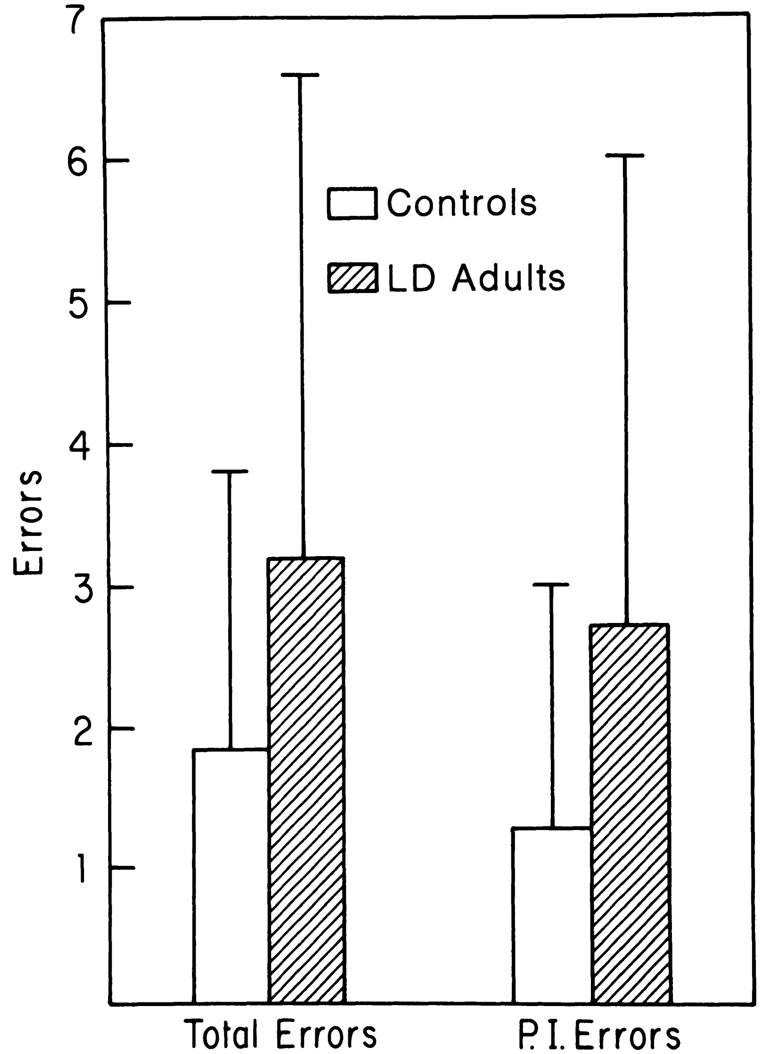

Figure 3. Number of errors for both groups in the proactive inhibition test.

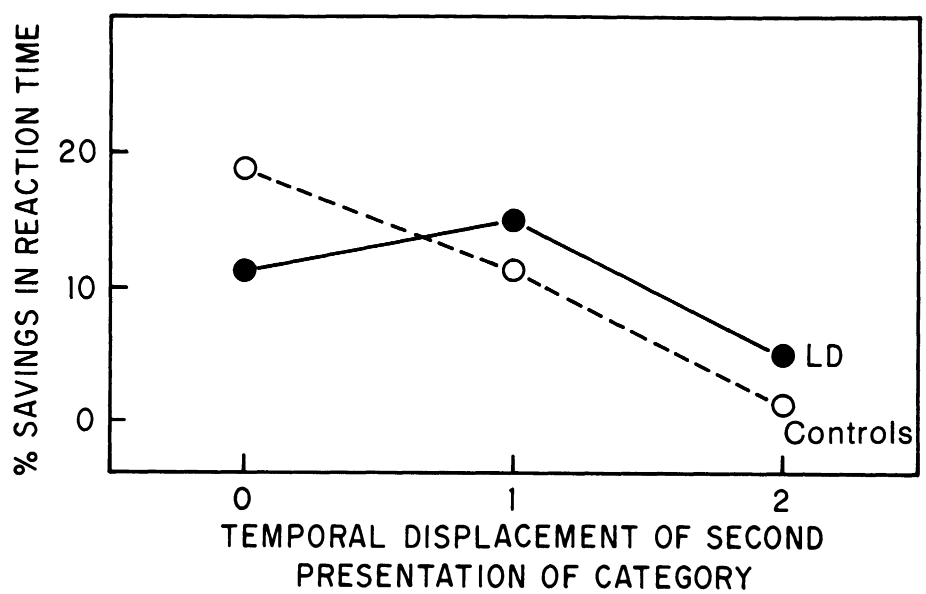

Figure 4. Priming effect for both groups in the semantic task. The savings score was calculated by the formula: RT1/RT2 × 100-100.

The second noteworthy finding was that adults with LD were especially impaired in the test requiring termination of an exhaustive and thorough search for relevant material. When confronted with a negative display, the adults with LD showed an inability to terminate an exhaustive search. Their disproportionate increase in reaction time with increasing set size for the NO responses, but not the YES responses, may be the result of indecision when there was no match between the memory set and the probe. The control subjects scanned each memory set more efficiently and terminated the search equally fast regardless of whether a match was made. The adults with LD appeared to scan less efficiently, especially when a probe was not in the memory set. They failed to be bound by the contextual determinants of the test and continued searching through their memory set when a match was not made.

Table 2
Discriminant Function Summary Table

Order of Variables Entering Predictive Equation

Variable	**U-Statistic**	**F-Statistic**	**Degrees of Freedom**	
Free Recall	0.7500	32.995	1.00	99.00
Semantic Intercept	0.6697	24.163	2.00	98.00
Semantic Slope	0.6266	19.265	3.00	97.00
Item Recall	0.6136	15.114	4.00	96.00
YES Intercept				
Proactive Inhibition Errors	0.6006	12.636	5.00	95.00

Jackknifed Classification Matrix

		No. of Cases	
	% Correctly Classified	**Control Subjects**	**Adults with LD**
Control Subjects	90.5	76	8
Adults with LD	64.7	6	11
Total	86.1	82	19

Results of the P.I. test indicated that individuals with LD were susceptible both to semantic interference (Wickens et al., 1963) and to the prevention of rehearsal. Rehearsal inhibition may be due to an attention deficit, which is characteristic of children with LD (Dykman, Ackerman, Clements, & Peters, 1971) and which continues into adolescence (Ackerman, Dykman, & Peters, 1977; Dykman et al., 1971) and early adulthood (Cordoni, O'Donnel, Ramaniah, Kurtz, & Rosenshein, 1981). The results of the P.I. test are also consistent with the findings of Torgesen (1980) and Worden (1983), who reported that patients with LD performed poorly on memory tasks due to ineffective rehearsal or excessively elaborate mnemonic strategies.

Remarkably, in view of the other tests, no differences in secondary or semantic memory were discovered between individuals with LD and controls. The influence of priming on memories within semantic networks was equivalent in the two groups. This suggests that processes related to storage and access (retrieval) of information in secondary memory were similar. Torgesen (1977) characterized the adult with LD as an inactive learner, lacking a purposeful, goal directed approach to cognitive and academic tasks. Since the semantic task in the present study did not require active modification or initiation of a mnemonic strategy, but rather the retrieval of information already stored successfully, subjects with LD performed as well as the control subjects.

CONCLUSIONS

The pattern of findings suggests that the adult with LD performed poorly on tests requiring recall of immediately learned information especially if the test required organizational strategies or if there was competing or interfering information. However, if provided with structure, adults with LD performed almost as well as control subjects. Two interesting indices of cognitive style characterized the adults with LD: (1) They consistently overestimated their performance and (2) they evidenced uncertainty when memory sets and probes were mismatched. Even though their reaction time increment with increasing memory load was identical to that of control subjects when the memory set and probe matched, the adult with LD required twice as long to make a decision in the mismatched condition. Finally, even though the adults with LD had slower reaction times and expressed the learning deficits described, they were indistinguishable from control subjects in their ability to benefit from priming in a test of semantic memory. These data suggest that level of expectation and the effectiveness of organizational (structural) strategies are areas worthy of intervention in adults with LD.

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