Verbal Memory Impairments in Dyslexia

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Although verbal memory deficits are frequently reported in reading disabled children, the specific mechanisms underlying these impairments have yet to be clearly defined. The present study used the California Verbal Learning Test-Children’s Version (CVLT-C) to assess verbal learning in 57 dyslexic children and 114 controls matched for gender, age, and WISC-R Vocabulary score. Three areas of verbal memory were investigated: Recall and recognition, use of learning strategies, and interference effects. The dyslexic group learned the list items more slowly, recalled fewer words on the last learning trial and the delayed trials, and performed less well on the recognition condition. Dyslexics and controls displayed similar vulnerability to interference, but group differences were evident in serial position effects. Taken together, our data suggest that dyslexics have less efficient rehearsal and encoding mechanisms, resulting in deficient encoding of new information, but normal retention and retrieval. © 1999 National Academy of Neuropsychology. Published by Elsevier Science Ltd

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Evidence documenting subtle language processing difficulties in disabled readers has been accumulating since the 1960s (Kinsbourne & Warrington, 1963). A range of language difficulties has been posited, including syntax (Vogel, 1974), phonology (Liberman, Shankweiler, Fischer, & Carter, 1974), and rapid naming (Denckla & Rudel, 1976). In his comprehensive review of alternative explanations for reading disabilities, Vellutino (1977) concluded that the most compelling research evidence pointed to deficiencies in verbal processing as the probable etiology.

Consistent with their underlying difficulties with language processing, children and adults with developmental reading disability generally perform less well than controls on

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The specific mechanisms underlying these verbal memory impairments have yet to be clearly defined. One area of debate concerns whether the primary difficulty is one of acquisition or retrieval. Although children with dyslexia often perform poorly when required to recall previously presented verbal information, this performance may reflect a deficit in the initial encoding and storage of the information or, alternately, a deficit in retrieving information that has been stored. Using a selective reminding paradigm, Fletcher (1985) found that subjects with reading and spelling deficits failed to differ from controls on a storage measure, but did perform significantly less well on a retrieval index, suggesting that the locus of memory impairment in reading disabilities is at the level of retrieval. On the other hand, Nelson and Warrington (1980) reported that dyslexic children have poorer performance than controls on a recognition memory test for words. Because recognition paradigms are thought to maximally aid retrieval, deficits in recognition memory are typically interpreted as indicating more of an encoding problem (Klatzky, 1980). In summarizing the results of several experiments, Nelson and Warrington (1980) concluded that dyslexic children had deficits in long-term verbal memory storage and were less proficient in the acquisition of new information, but were normal in the rate that they accessed information.

Other investigators have examined the possibility that the memory impairment in learning disabilities is related to less efficient encoding strategies. Active rehearsal is generally thought to aid acquisition and retention, and age-related growth in rehearsal is associated with superior performance on memory measures (Kail, 1990). To assess rehearsal in children with learning disabilities, Bauer (1977) examined serial position effects, positing that primacy items, by virtue of being presented early, would receive the most rehearsal and be most likely encoded into long-term memory. On the other hand, recency items are more likely to be retrieved from a short-term memory storage system. Bauer reported that the learning disabled group recalled fewer words than controls from the primacy region, but the same number of words as controls from the recency region. Cermak (1983) also found that although normal readers tended to rehearse several words simultaneously, subjects with dyslexia were more likely to rehearse only the word currently being presented. These findings invite the hypothesis that reading disabled children are deficient in their use of rehearsal strategies.

There have been few studies investigating whether or not children with reading disabilities exhibit increased vulnerability to interference on verbal memory tasks. Cermak (1983) found that learning disabled children recalled as many words as controls when the interval between item presentation and recall was filled with nonverbal tasks. When the distracting material was semantically related to the to-be-learned material, however, the learning disabled children recalled fewer words than controls, suggesting increased vulnerability to semantically related retroactive interference. Nelson and Warrington (1980) reported that their subjects with dyslexia demonstrated normal build-up and release from proactive interference. Although these findings suggest that children with impaired reading may be more vulnerable to particular types of interference, little is understood about interference effects in dyslexia.
In sum, considerable uncertainty remains about the mechanisms underlying verbal memory impairment in disabled readers. The goal of the present study was to utilize a comprehensive list learning paradigm (the California Verbal Learning Test-Children's Version (CVLT-C; Delis, Kramer, Kaplan & Ober, 1994) to simultaneously address several questions about learning and memory in dyslexia. The CVLT-C is a multiple trial list learning task that quantifies immediate recall, brief and long delayed recall, recognition, rates of learning and forgetting, organization, serial position effects, interference, and error types. This study poses three general questions that are outlined below:

1. **Are children with dyslexia deficient in their acquisition, retention, or retrieval of new verbal information?** If disabled readers have impaired acquisition, we hypothesized that they would show lower levels of both recall and recognition than controls during the learning trials. If disabled readers have impaired retention, we would expect a faster rate of forgetting over the delay periods. Finally, if disabled readers have impaired retrieval, we would predict impaired recall but relatively normal recognition. This is because recognition testing maximally aids retrieval processes.

2. **Do children with dyslexia display evidence for less efficient encoding?** Analysis of serial position effects offers clues about how subjects approach a list learning task. Because recency-region words are thought to be retrieved from short-term memory, a disproportionate number of words recalled from the recency region reflects a more passive and less effective learning style (Delis, Freeland, Kramer, & Kaplan, 1988). Items from the middle region of the list are the most difficult to learn because they are held in short-term memory for the least amount of time and are therefore rehearsed less often. A high proportion of words recalled from the middle region, therefore, reflects efficient rehearsal and encoding mechanisms (Klatzky, 1980). Therefore, if disabled readers are deficient in their use of learning strategies, we would expect them to exhibit proportionately lower recall from the middle-region of the CVLT-C list.

3. **Are children with dyslexia more vulnerable to interference?** The CVLT-C affords the opportunity to examine interference effects because a second list is interposed between the initial presentations of the target list and the delayed recall and recognition trials of the target list. Importantly, several of the words on the interference list share semantic categorical properties with target list words, thus increasing the potential degree of interference (Cermak, 1983).

   Two types of interference have been posited. Proactive interference is the decremental effect of prior learning on the retention of subsequently learned information (Postman, 1971). Two markers of proactive interference on the CVLT-C were used in the present study. If children with dyslexia are more vulnerable to proactive interference, we hypothesized that relative to controls: 1) dyslexic subjects would exhibit a greater decrement in recall for interference list items that are semantically related to target list items than for items that are semantically unrelated (Kramer & Delis, 1991); and 2) dyslexic subjects would display higher rates of target list items intruding into their recall of the interference list.

   Retroactive interference is the decremental effect of subsequent learning on the retention of previously learned information (Postman, 1971). Three markers of retroactive interference on the CVLT-C were selected for the present study. If disabled readers are more vulnerable to retroactive interference, we predicted that: 1) dyslexics and nondisabled readers would exhibit similar decrements in delayed recall for target list items that were semantically unrelated to interference
list items, although dyslexics would exhibit a steeper decrement in their delayed recall for target list items that were semantically related to interference list items; 2) dyslexics would have higher rates of interference list items intruding during the delayed recall trials of the target list; and 3) dyslexics would have higher rates of interference list items being incorrectly endorsed on the recognition trial.

METHODS

Subjects

The dyslexic sample consisted of 44 boys and 13 girls with a mean age of 9.41 years (SD = 0.95) from the Broward County School System. Each dyslexic student satisfied the DSM-III-R criteria for developmental dyslexia, had at least a one standard deviation discrepancy between IQ and reading achievement, and a WISC-R Full Scale IQ greater than 85. School records were reviewed to determine if any of the study participants had an active diagnosis of Attention Deficit-Hyperactivity Disorder (ADHD). Only one child had a past history of taking medication to treat ADHD symptoms, and this child was no longer taking the medication. The dyslexic sample had a mean WISC-R Verbal IQ of 98.9 (SD = 12.3), Performance IQ of 97.6 (SD = 12.8), and Full Scale IQ of 97.6 (SD = 11.2). Their mean WISC-R Vocabulary subtest scaled score was 9.78 (SD = 2.51), whereas their mean WRAT-R Reading subtest score was only 73.57 (SD = 10.0; range = 46–98). The mean discrepancy between IQ and reading achievement was 29.34 (SD = 8.5).

For each dyslexic subject, two comparison subjects matched for gender, age, and WISC-R Vocabulary scaled score were selected at random from the CVLT-C standardization sample (Delis et al., 1994). This resulted in a control group comprised of 88 boys and 26 girls. They had a mean age of 9.48 years (SD = 0.96) and a mean Vocabulary scaled score of 9.91 (SD = 3.36). Children in the control group had been carefully screened for any history of neurological, psychiatric, and learning problems. All were in mainstream classes. There were no differences between the dyslexic and control sample on gender, age or WISC-R Vocabulary scaled score. The control sample was 73% White, 14% African-American, 10% Hispanic and 3% other, while the dyslexic sample was 81% White, 16% African-American, and 3% Hispanic.

Procedure

All subjects were administered the CVLT-C according to standardized procedures (Delis et al., 1994). The CVLT-C begins with five learning trials of a 15-word, semantically categorizable target list, with words read aloud by the examiner at the rate of one word per second. After each list presentation, the examinee is instructed to freely recall as many words as possible, in any order. An interference list is then presented for one learning trial, followed by ‘brief-delay’ free recall trial and a second recall trial in which subjects are cued with the semantic category name (e.g., fruits). After a 20-minute interval during which non-verbal tasks are administered, ‘long-delay’ free and cued recall and recognition of the target list are assessed. The recognition trial is a yes-no paradigm in which the 15 target words and 45 distractor words are presented sequentially; the subject is asked to respond with “yes” to each target word and “no” to each non-target. The non-targets are a mix of interference list words that are semantically related to target words, interference list words that are semantically unrelated, novel words that are semantically related to target words, novel words that are phonemically similar to target words, and novel words that are unrelated to target words.
The Vocabulary subtest from the WISC-R was administered according to standardized procedures.

**RESULTS**

Group means and standard deviations for several of the key CVLT-C variables are listed in Table 1.

**Acquisition, Retention, and Retrieval**

Total number of words recalled and rate of acquisition during the five CVLT-C learning trials were analyzed with a repeated-measures analysis of variance (ANOVA), with Trial as the within-subject variable and Diagnosis (dyslexic vs. control) as the grouping variable. The main effect for diagnosis approached but did not reach statistical significance, $F(1,169) = 3.77, p = .054$. The Diagnosis by Trial interaction was significant, however, $F(4,676) = 2.55, p < .05$. Univariate analyses of the individual learning trials indicated that the two groups had identical levels of recall on Trial 1 (5.8 words), but the control group recalled significantly more words on Trial 2 and Trial 5 (see Figure 1).

Retention of information over the brief and 20-minute delay periods was also assessed with repeated-measures ANOVA. Recall (Trial 5 vs. brief-delay free recall) was the within-subject variable and Diagnosis was the between groups variable. The main effects for Diagnosis, $F(1,169) = 5.23, p < .05$ and Trial, $F(1,169) = 101.9, p < .001$, were significant but the Diagnosis by Trial interaction was not ($p > .9$). These results indicate that although normal readers recalled more words than impaired readers, the two groups were equally able to retain what they had originally learned. A similar pattern of results was evident when the two delayed recall trials (brief vs. 20-minute delay) were contrasted. The main effects for Diagnosis, $F(1,169) = 6.27, p < .05$ and Trial, $F(1,169) = 4.46, p < .05$ were significant but the Diagnosis by Trial interaction was not ($p > .9$) (see Figure 1).

The recognition portion of the CVLT-C yields scores for hits (target words correctly endorsed), false-positive errors (distractors incorrectly endorsed), and a Discriminability Index that reflects the total number of correct responses during the recognition trial. The Discriminability Index was the primary recognition measure because it is sensitive

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**TABLE 1**

Mean Scores for Dyslexic and Control Subjects on Selected CVLT-C Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dyslexics</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1 Recall</td>
<td>5.81 (1.8)</td>
<td>5.81 (1.8)</td>
</tr>
<tr>
<td>Trial 5 Recall</td>
<td>9.67 (2.3)</td>
<td>10.61 (2.3)</td>
</tr>
<tr>
<td>Brief-Delay Recall</td>
<td>7.96 (2.7)</td>
<td>8.92 (2.8)</td>
</tr>
<tr>
<td>Long-Delay Recall</td>
<td>8.25 (2.6)</td>
<td>9.24 (2.8)</td>
</tr>
<tr>
<td>Recognition Hits</td>
<td>12.89 (2.0)</td>
<td>13.68 (1.5)</td>
</tr>
<tr>
<td>Recognition FPs</td>
<td>2.72 (2.9)</td>
<td>1.82 (2.9)</td>
</tr>
<tr>
<td>Semantically Related FPs</td>
<td>1.51 (1.6)</td>
<td>0.81 (1.3)</td>
</tr>
<tr>
<td>Semantically Unrelated FPs</td>
<td>1.21 (1.6)</td>
<td>1.01 (1.7)</td>
</tr>
<tr>
<td>Primacy Region (%)</td>
<td>30.32 (7.7)</td>
<td>29.80 (5.8)</td>
</tr>
<tr>
<td>Middle Region (%)</td>
<td>38.52 (9.0)</td>
<td>41.78 (7.9)</td>
</tr>
<tr>
<td>Recency Region (%)</td>
<td>31.16 (10.7)</td>
<td>28.42 (8.4)</td>
</tr>
</tbody>
</table>

Standard deviations are in parentheses (FPs = False Positives).
to both hits and false positives. The control group performed significantly better than the dyslexic group on the Discriminability Index, \( t(169) = 3.08, p < .005 \). Follow-up analyses indicated that control subjects recognized more target words than dyslexics, \( t(169) = 2.84, p < .01 \). The mean number of false positives was higher for the dyslexic group than the controls but this difference failed to reach statistical significance, \( t(169) = 1.94, p = .054 \).

**Learning Strategies**

The CVLT-C calculates the proportion of a child’s total recall that came from the primacy (first four words), middle (middle seven words), and recency (last four words) regions of the list. A high proportion of words recalled from the recency region was presumed to represent an over reliance on short-term memory mechanisms and less active rehearsal. A high proportion of middle region words recalled was presumed to represent more efficient rehearsal and encoding. Data were analyzed with a repeated measures ANOVA, with Diagnosis as the between groups variable and Region (primacy vs. middle vs. recency) as the within-subject variable. The Diagnosis by Regions interaction was significant, \( F(2,338) = 3.59, p < .05 \). Post-hoc analyses indicated that controls recalled a higher proportion of words from the middle region than did dyslexics, \( F(1,169) = 5.94, p < .05 \) (see Figure 2). There were no significant group differences for the proportion of words recalled from the primacy or recency regions.

**Interference Effects**

Two markers of proactive interference were examined. First, the number of semantically related and semantically unrelated items on Trial 1 of the target list was contrasted with the number of related and unrelated items on the single trial of the interference list. A weighted average of related and unrelated items was computed for Trial 1 because the
relative proportion of related and unrelated items recalled across all five learning trials affects the potential for interference during recall of the interference list (Kramer & Delis, 1991). The data were analyzed with a repeated-measures ANOVA, with List (target vs. interference) and Category (related vs. unrelated) as the within-subject variables. The List by Category interaction was significant, $F(1,169) = 26.94, p < .001$. Post-hoc analyses indicated a significant decline in recall for semantically related words on the interference list but not for semantically unrelated words; these findings indicate the expected build-up of proactive interference for semantically related words. The Diagnosis by List by Category interaction was not significant, however, indicating the absence of group differences in the amount of interference exhibited.

The second marker of proactive interference was the frequency of target list items intruding during the interference list learning trial. The dyslexic and control subjects were equivalent on this measure.

Comparable analyses were conducted for retroactive interference. First, the number of semantically related and semantically unrelated items on Trial 5 of the target list was contrasted with the number of related and unrelated items on the brief delay recall of the target list. A weighted average of related and unrelated words was computed for Trial 5 to adjust for the relative proportion of related and unrelated words recalled across all five learning trials. The data were analyzed with a repeated-measures ANOVA, with Trial (Trial 5 vs. brief delay) and Category (related vs. unrelated) as the within-subject variables. The Trial by Category interaction was significant, $F(1,169) = 7.55, p < .01$, indicating a slightly larger decrement in recall for semantically related words over the brief delay interval. The Diagnosis by Trial by Category interaction was not significant, however. The second marker of retroactive interference, the number of interference list items intruding during the delayed recall trials, also was not significantly different between the two groups. Finally, the possibility that dyslexics would be more prone to endorsing interference list items when they appeared on the delayed recogni-
tion trial was assessed. The number of false-positive errors that were interference list words and the number of false-positive errors that were novel words were tabulated. The repeated-measures ANOVA yielded a non-significant main effect for Diagnosis and a non-significant Diagnosis by False Positive Type interaction.

Visual inspection of the false-positive errors made on the recognition trial raised the possibility that impaired readers were more easily confused than controls by distractors that were semantically related to target list words. Two types of distractors were semantically related to the target list: Semantically related words from the interference list and novel words that were prototypical members of the categories on the target list. There were three types of distractors that were semantically unrelated to the target list: Semantically unrelated words from the interference list, novel words that were semantically unrelated but phonemically similar to target words, and novel words that were semantically and phonemically unrelated to target words. To assess the possibility that dyslexics were more confused than controls by semantically related distractors, we carried out a repeated-measures ANOVA, with Category (semantically related vs. semantically unrelated) as the within-subjects variable. The Diagnosis by Category interaction was significant, $F(1,169) = 6.22, p < .05$. Post-hoc analyses indicated that the dyslexic and control subjects made equal numbers of false positive errors for semantically unrelated distractors, whereas the dyslexics made almost twice as many semantically related false-positive errors as the controls, $F(1,169) = 9.76, p < .005$.

**DISCUSSION**

The present study indicates that when compared to normal readers matched for gender, age, and WISC-R Vocabulary, children with impaired reading are deficient in their ability to learn new verbal material. This finding is consistent with several earlier studies that argue for a verbal memory impairment in dyslexia (Douglas & Benezra, 1990; Felton et al., 1987; Helfgott, Rudel & Kairam, 1986; McGee, Williams, Moffitt & Anderson, 1989; O’Neill & Douglas, 1991). Importantly, the CVLT-C performance of our dyslexic and control subjects points to specific mechanisms that underlie this verbal memory deficit.

The dyslexic group had lower levels of recall and a slower rate of learning across the five learning trials than the controls. Dyslexics also were impaired relative to controls on the recognition condition. Because recognition paradigms aid retrieval, dyslexics’ impairment on the recognition condition suggests that their poor recall is not likely to be related to a retrieval deficit. Further, although the delayed recall performance of the dyslexic group remained below that of controls, there were no differences between the groups in their rate of forgetting, indicating that once learned, dyslexics are able to retain information to a normal degree. Taken together, the present data indicate that the primary locus of verbal memory difficulty in reading disability is in the acquisition of new information, and not in retaining or retrieving it.

The serial position data also yielded important group differences, with controls recalling a significantly greater proportion of their words from the middle region of the list. Previous studies have linked serial position effects with rehearsal mechanisms (Bauer, 1977; Klatzky, 1980). Words from the middle region of the list must compete with preceding and succeeding items, and are least likely to be rehearsed and encoded. The superiority of the control group in middle region recall implies more efficient rehearsal and encoding mechanisms. These findings would also be consistent with Swanson (1983), who reported evidence for deficient elaborative rehearsal and semantic encoding in LD children.
Analyses of interference measures indicated that disabled readers exhibited normal vulnerability to proactive and retroactive interference. No group differences were found for changes in recall of semantically related and semantically unrelated items between the target list and the interference list. Similarly, the number of cross-list intrusions and number of false positive errors for interference list items were equivalent across groups. Dyslexic children were more prone to endorse recognition distractors that were semantically related to target list items, however, regardless of whether they were novel or from the interference list. This suggests that dyslexics may be more vulnerable to interference arising from shared-category properties, consistent with the possibility that dyslexics did not encode the target list items to a degree sufficient to allow for discrimination between target words and semantically similar words.

The present study used an age matched control group rather than a reading level matched control group. Although incorporation of both types of control groups in dyslexia research is ideal, the design and goals of the current study argued more strongly for the age matched control group. First, the current study was not designed to identify possible underlying mechanisms for reading disability, a task for which a reading level matched control group is essential. Second, reading level was not significantly correlated with long-delayed recall ($r = .17; p > .2$), whereas age and recall were correlated ($r = .26; p < .05$), furthering supporting the appropriateness of the age matched control group.

Although a review of school records yielded a reference to ADHD in only one of our dyslexic subjects, it is possible that some of our subjects may have had ADHD. ADHD and reading disabilities are generally felt to represent distinct disorders (Gilger, Pennington, & DeFries, 1992; Shaywitz, Fletcher, & Shaywitz, 1995), with ADHD linked to behavioral disturbance and executive dysfunction and reading disability seen as a disorder of language (Pennington, Groisser, & Welsh, 1993; Purvis & Tannock, 1997). These disorders often co-occur in the same child, however, and both disorders have been associated with impairments on memory tests (Katz et al., 1998; Seidman et al., 1998; O’Neill & Douglas, 1996; Webster, Hall, Brown, & Bolen, 1996). It remains to be seen whether the observed pattern of verbal memory dysfunction in dyslexia can be differentiated from the performance seen in children with ADHD. Both groups of children, for example, may display deficits in their rehearsal strategies (O’Neill & Douglas, 1996; Swanson, 1983). On an earlier research version of the CVLT-C, however, Loge, Staton, and Beatty (1990) found that children with ADHD were mildly impaired on the learning and delayed recall trials, but performed as well as controls on the recognition trial. This pattern is in contrast to the pattern of low recall and low recognition exhibited by our reading disabled group, and implicates retrieval problems in the ADHD sample. Other recent findings also suggest differences in the verbal memory failures between reading disabled and ADHD subjects, with verbal processing deficits associated with dyslexia and impaired organization and regulatory processes associated with ADHD (Douglas & Benezra, 1990; McGee et al., 1989). More studies directly comparing the nature of memory failures in ADHD and dyslexia are needed.

Although the present study demonstrates a relationship between a diagnosis of dyslexia and verbal memory problems, the nature of the relationship remains unclear. Given the lack of correlation between delayed recall and reading level, it is highly unlikely that the verbal memory difficulties cause dyslexia. Rather, a more plausible inference is that both reading disability and poor verbal memory stem from underlying verbal processing deficiencies. Research into the verbal processing deficiencies in reading disability has focused on two related areas, auditory working memory and phonological processing (Torgesen, 1996; Baddeley & Gathercole, 1992; Siegel, 1994; Ackerman & Dykman, 1993). Working
memory has been posited to play a role in rehearsal and encoding. Several studies have pointed out that rate of rehearsal is directly related to how well information is maintained in working memory’s articulatory loop. Words that require more time to rehearse (e.g., words that are difficult to articulate; polysyllabic words) decay more rapidly (Baddeley, Thomson, & Buchanan, 1975). Poor readers may be abnormal in their ability to utilize the articulatory loop (Hulme & Mackenzie, 1992; Jorm, 1983). This would result in incoming information being rehearsed more slowly and less often, decaying more quickly, and being encoded into long-term memory less often or less thoroughly. This hypothesis would be entirely consistent with our CVLT-C data, where dyslexics’ proportionately lower middle-region recall and greater degree of confusion between target items and semantically similar foils suggest an encoding impairment. Finally, this model places the primary locus of difficulty with the initial processing and encoding of new verbal information. Thus, the model would predict that dyslexics would display normal levels of retention over time, that was one of the findings of the present study.

The present study demonstrates that not all components of verbal memory are compromised in dyslexia, and that the pattern of impairment may be distinct from other pediatric disorders (e.g., ADHD). Importantly, these findings were obtained using a standardized, well-normed clinical instrument. Thus, in addition to their theoretical implications, the present data indicate that clinicians can utilize clinical tools to more clearly delineate where and how their patients’ verbal learning is breaking down and where remedial efforts can be focused.

REFERENCES


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