Verbal Learning in Boys With P-Type Dyslexia, L-Type Dyslexia, and Boys Without Learning Disabilities: Differences in Learning Curves and in Serial Position Curves*

Jan W. van Strien
Vrije Universiteit Amsterdam, The Netherlands

ABSTRACT

Twenty-five boys with P-dyslexia, 23 with L-dyslexia, and 26 boys without reading disabilities were administered the Digit Span (Forward and Backward) and the Dutch version of the Rey Auditory-Verbal Learning Test. Compared to normal boys, dyslexic boys exhibited reduced scores on Digits Backward and recalled fewer words during the five learning trials. Nonlinear modeling of the data for the five learning trials revealed that dyslexic boys showed smaller learning parameters than did normal boys and that L-dyslexic boys exhibited more loss of information during learning than did P-dyslexic boys. In dyslexic boys, the word-list primacy effect was strongly reduced. In normal boys, but not in dyslexic boys, Digits Backward correlated moderately with the primacy measure. The results suggest that reduced word-list learning in dyslexics is a consequence of a temporal ordering deficit rather than a rehearsal deficit.

Children with dyslexia tend to show deficits across a variety of verbal memory measures. Many studies, including our own, have demonstrated impaired performances on memory span and auditory verbal learning tasks (e.g., Levin, 1990; McDougall, Hulme, Ellis, & Monk, 1994; Van Strien, Bakker, Bouma, & Koops, 1990). The deficit on span measures seems to be specific to tasks requiring phonological processes (Share, 1994), although Van Strien et al. (1990) reported poor performances of dyslexic boys on a visuospatial span measure (Corsi block-tapping). Hulme and Mackenzie (1992) interpreted phonological short-term memory problems reflecting a rehearsal deficit in the articulatory loop.

Diminished free recall of supraspan word lists can be explained as a consequence of either short- or long-term memory deficits, depending on the shape of the serial position curve. Normal subjects tend to recall the early items (primacy effect) and late items (recency effect) in a word list better than the midlist words. The primacy effect is thought to be associated with long-term memory (LTM), while the recency effect is thought to be associated with short-term memory (STM). In many patients with defective learning abilities, the primacy effect is reduced, which could indicate a LTM problem. According to Capitani, Della Salla, Logie, and Spinnler (1992), the interpretation of the primacy effect as associated with LTM and the recency effect as associated with STM is controversial. Like in other studies, these authors found a poor correlation between a span measure of short-term memory and the word-list recency measure. Moreover, they found a moderate correlation between span and the word-list primacy mea-
sure. Capitani et al. interpreted their results in terms of a model of verbal short-term memory comprising two components, one responsible for span and one responsible for recency (as an inherent feature of any memory system with gradual loss of information over time).

In addition to the serial position curve, the learning curve can also be examined. With reference to supraspan word-list learning, several authors have distinguished between memory span and learning capacity (Blachstein, Vakil, & Hooffen, 1993; Lezak, 1995). Memory span is the capacity to learn information in a single trial, while learning capacity reflects the ability to add information from trial to trial. Because there are limits to the number of words that can be learned from a supraspan word list, the learning curve is not linear but asymptotic, with less new words added in the later trials. This curve can be expressed in a nonlinear model with two different components: the proportion of information added in each trial and the proportion of already learned information forgotten in each trial. The two components can be estimated by means of the least-squares criterion (see Results). The serial position and learning curves can provide additional information about the nature of the memory deficits in dyslexics. Therefore, the purpose of the present study was to compare dyslexic boys and normal boys on the various word-list learning parameters.

A distinction was made between two subtypes of dyslexia: P- and L-type (Bakker, 1990). According to Bakker’s (1990) neuropsychological model for the normal and deviant learning-to-read process, the relative participation of left- and right-hemisphere functions in the process of reading alters with development. In the initial stage of the learning-to-read process, there is a predominance of right-hemispheric involvement: the novice reader will use visuoperceptual analysis to discriminate and identify the perceptually complex graphemic information. In the course of normal development, the grapheme identification becomes an automatism. The child will then switch to semantic and syntactic strategies, predominantly generated by the left hemisphere. This shift in hemispheric involvement has been demonstrated in electrophysiological studies (Bakker & Licht, 1986; De Graaff, 1995; Licht, Bakker, Kok, & Bouma, 1988). Reading disabilities develop when these respective hemispheric balances are disturbed.

Children with P-type dyslexia are slow but relatively accurate readers, with a fragmented style of reading. Children with L-type dyslexia are relatively fast but inaccurate readers. Children with P-dyslexia rely primarily on right-hemispheric visuoperceptual processing, and are unable to switch to left hemispheric, semantic strategies in the later stages of the learning-to-read process (perceptual reading type). Children with L-dyslexia employ left hemispheric, linguistic strategies prematurely from the very beginning of the learning-to-read process (linguistic reading type). Examination of cognitive functioning has provided good external validity for the P- and L-type classification (Bakker, 1994; Bakker, Licht, & Van Strien, 1991). Van Strien et al. (1990) found lowered memory performances in both P- and L-types when compared to normal readers, but no differences in memory functioning between the two dyslexia subtypes. The present study explored whether the additional memory measures yielded differences in learning strategies utilized by P- and L-types.

METHOD

Participants
The sample consisted of 48 dyslexic boys and 26 boys without reading disabilities. Only righthanded boys participated. The dyslexic boys had IQ scores ranging from 85 to 118 with a mean IQ of 99.6 (IQ scores were obtained from school records). In terms of a standardized Dutch text-reading test (Van den Berg & Te Lintelo, 1977), they had reading scores of at least 1.5 years below the expectancy level based on years of education. Dyslexic boys were classified as P-type (n = 25, mean IQ = 99.4) or L-type (n = 23, mean IQ = 99.8) dyslexics. The P/L classification was based on the reading style of the dyslexics when performing a sentence-reading task with levels of difficulty of 5 to 7 months of reading instruction above each participant’s present level. Accurate but slow readers were classified as P-type dyslexics. Fast but inaccurate readers were classified as L-type dyslexics.
(see for details, Van Strien et al., 1990, 1993). The participants in the three groups were matched for age ($M = 10.8$ years; range 8-13 years).

**Materials and Procedure**

All participants were administered the Digit Span subtest of the Revised Wechsler Intelligence Scale for Children (WISC-R) and a Dutch verbal learning test as part of a larger battery of cognitive tasks (Van Strien et al., 1990, 1993). The WISC-R Digit Span test comprises two parts: Digits Forward and Digits Backward. Lezak (1995) has argued that these two parts involve different mental activities. In her view, Digits Forward is related to the efficiency of attention rather than to memory, whereas Digits Backward is related to working memory and temporal ordering. Combining the scores of both tests means loss of information. For this reason, we will analyze the raw scores for Digits Forward and Digits Backward separately, as well as the WISC-R scaled scores.

To assess verbal learning, the Dutch adaptation (15-words test, see Deelman, 1990) of the Rey Auditory-Verbal Learning Test (Lezak, 1995) was used. The word list contains 15 meaningful monosyllabic words (referring to concrete objects). For five consecutive learning trials, the examiner verbally presents the list. The subject is instructed to immediately recall as many words as possible following each trial. For each trial, the number of words correctly recalled is scored. Unlike the original test, there is no presentation of a second 15-word list. A sixth recall trial is given after a 20-min delay, during which the subject performs a nonverbal task. Finally, a recognition trial is given consisting of the 15 words of the word list and 15 new distracter words.

**RESULTS**

The various scores on the verbal learning task were subjected to analyses of variance (ANOVAs). In all ANOVAs, orthogonal contrast were computed to test, in addition to the main group effect, whether dyslexic boys (P and L pooled) differed from normal boys, and whether P-dyslexics differed from L-dyslexics.

**Learning Curves**

For each group, the mean number of words correctly recalled on each of the five learning trials is displayed in Figure 1.

A 3 (Group) × 5 (Trial) ANOVA revealed a significant group effect, $F(2,71) = 12.22, p < .001$ (P-dyslexics: $M = 35.52$ words; L-dyslexics, $M = 36.35$ words; normal boys: $M = 46.58$ words). The orthogonal contrasts revealed that, compared to normal boys, dyslexic boys (P/L pooled) recalled significantly less words during the five learning trials, $F(1,72) = 24.25, p < .001$, but that the dyslexia subtypes did not differ from each other in overall performances, $F(1,72) = .10, \text{NS}$. There was a significant effect for trial, $F(4,284) = 143.83, p < .001$, with more words recalled as the number of trials increased. In addition, the interaction of group and trial was significant, $F(8,284) = 2.14, p < .05$. This interaction was significant for the P versus L contrast, $F(4,284) = 2.90, p < .05$, but not for the P/L versus normal readers contrast $F(4,284) = 1.41, \text{NS}$. From Fig. 1, it can be seen that in the first trial L-dyslexics tend to perform better than P-dyslexics, whereas in the fifth trial the opposite is true.

The differential learning curves were further analyzed by modeling the data to a nonlinear learning curve with two components: a ‘learning’ component and a ‘decay’ component. These two components have an opposite effect upon the rate of learning. The model is an adaptation of the model developed by Dekker, Mulder, and Dekker (1996) for the 16-item Dutch version of the California Verbal Learning Test (VLGT, Mulder, Dekker, & Dekker, 1996) and can be formulated as follows:

$$\Delta Y = a \times (15 - Y) - b \times Y$$

where $\Delta Y$ is the difference in performance between two successive trials, $Y$ is the number of already mastered words, $a$ is the proportion of not yet mastered words that is learned during a given trial (‘learning parameter’), and $b$ is the proportion of already mastered words that is forgotten during that trial (‘decay parameter’).

The parameters $a$ and $b$ were estimated for each subject with the help of nonlinear regression (least-squares solution). The means of these parameters and the resulting curves for the three subject groups are displayed in Figure 2. The parameters were subjected to ANOVAs.
learning parameter ($a$), there was a significant effect for the P/L versus normal readers comparison, $F(1,71) = 6.12, p < .02$. From Figure 2, it can be seen that normal readers exhibited higher learning parameters than did P- and L-dyslexics. The difference between P- and L-dyslexics was not significant. For the decay parameter ($b$), there was a significant effect for the P versus L comparison, $F(1,71) = 5.02, p < .03$, but not for the P/L versus normal readers comparison. L-dyslexics showed significantly greater decay parameters than did P-dyslexics, who showed decay parameters comparable to those of normal readers.

**Serial Position Curves**

The proportion that each word of the word list was recalled during the first immediate recall trial is displayed for each position and each group in Figure 3. From this figure, it can be seen that the dyslexic boys exhibited much weaker primacy effects than did normal boys. To obtain serial position summary scores for the first trial, total numbers of recall from the primacy (first five words), middle (five words), and recency (last five words) regions were calculated. The data were analyzed by means of an ANOVA with Serial Position (primacy, middle, recency) as a factor within subjects. In addition to significant main effects for Group, $F(2,71) = 6.14, p < .005$, and Serial Position, $F(2, 142) = 22.46, p < .001$, a significant Group × Serial Position interaction was found, $F(4, 142) = 5.76, p < .001$.

The interaction is depicted in Figure 4. The Group × Serial Position interaction appeared to be significant for the P/L versus normal readers comparison, $F(2,142) = 11.33, p < .001$, but not for the P versus L comparison, $F(2,142) = .22, NS$. From Figure 4, it can be seen that all groups
displayed a recency effect, whereas only normal readers exhibited a clear primacy effect. Separate group comparisons for each serial position measure revealed that, indeed, the primacy measure was significantly larger in normal boys than in dyslexic boys (P/L pooled), $F(1,71) = 32.05, p < .001$. For midlist and recency measures, no group differences were found.

**Delayed Recall**

To examine the retention during the 20-min period between the last learning trial and the delayed recall, the serial position scores on the fifth and delayed recall trials were subjected to an ANOVA with Serial Position and Time of Recall (immediate vs. delayed) as factors within subjects. The mean scores for the fifth immediate recall trial and the delayed recall trial are displayed in Figure 5. The ANOVA yielded significant main effects for Group (P/L vs. normal readers, $F(1,71) = 14.49, p < .001$), Serial Position, $F(2,142) = 17.74, p < .001$, and Time of Recall, $F(1,71) = 73.75, p < .001$. In addition, the Serial Position × Time of Recall interaction was significant, $F(2,142) = 9.98, p < .001$. From Figure 5, it can be seen that, across groups, the largest amount of forgetting was found for the recency region: The recency effect was totally absent in the delayed recall trial. Simple comparisons (immediate vs. delayed recall) for each of the three position measures revealed that the forgetting was significant for each position (primacy: $F(1,71) = 6.04, p < .02$, middle: $F(1,71) = 14.03, p < .001$, recency: $F(1,71) = 49.21, p < .001$). No significant interactions of Group with Serial Position or Time of Recall were found.

**Recognition**

Compared to normal boys, dyslexic boys (P/L pooled) showed a significantly reduced number
Fig. 3. Serial position curves for the three subject groups on the first trial. (Circles = P-dyslexics; triangles = L-dyslexics; squares = normal readers.)

of valid positives (P-dyslexics: $M = 13.56$, L-dyslexics: $M = 13.00$, normal boys: $M = 14.73$), $F(1,71) = 19.79$, $p < .001$. The groups did not differ significantly in number of false positives (P-dyslexics: $M = .68$, L-dyslexics: $M = 1.13$, normal readers: $M = .39$), $F(1,71) = 1.64$, NS.

**Digit Span**

For Digits Forward, no differences between groups were found (P-dyslexics: $M = 4.92$, L-dyslexics: $M = 4.52$, normal readers: $M = 4.81$). For Digits Backward, the difference between dyslexic boys (P/L pooled) and normal boys was significant (P-dyslexics: $M = 3.52$, L-dyslexics: $M = 3.52$, normal readers: $M = 4.89$), $F(1,71) = 17.58$, $p < .001$.

Across all participants, the score for Digits Backward correlated significantly with the primacy measure for the first immediate recall trial of the verbal learning task ($r = .35$, $p = .002$, two-tailed significance), but not with the recency measure ($r = .11$, NS.). Within the dyslexia groups, the correlation between Digits Backward and the primacy measure was less substantial (P-dyslexics: $r = -.12$, NS.; L-dyslexics: $r = .27$, NS.) than within the group of normal readers ($r = .39$, $p < .05$).

**DISCUSSION**

The three groups exhibited differential learning curves. Compared to normal boys, dyslexic boys recalled less words during the five learning trials. Within the dyslexia groups, P-type dyslexic boys started slightly worse but ended better than L-type dyslexic boys. Modeling the data of the five learning trials to nonlinear learning curves with a ‘learning’ and a ‘decay’ component revealed that dyslexic boys had lower learning
parameters than did normal boys and that L-dyslexic boys exhibited larger decay parameters than P-dyslexic boys, the latter group having scores comparable to those of normal boys. Hence, the difference in learning curves between P- and L-dyslexic boys appears to be mainly a consequence of more loss of information during the learning trials in the L-dyslexics. This loss of information should be conceived as a property of the learning capacity rather than of long term retention.

The three groups also showed differences in the serial position curves. On the first learning trial, the dyslexic boys showed a strongly reduced primacy effect, together with a normal recency effect. A similar pattern is seen in patients with defective learning ability (Lezak, 1995). According to Lezak, the presentation of words in excess of the patient’s immediate memory span interferes with the retention of the words first heard. Possibly, the same type of interference is responsible for the reduced primacy effect in dyslexics.

Dyslexics and normal readers exhibited comparable retention patterns during the 20-min period between the fifth learning trial and the delayed recall. In all groups, most forgetting occurred for the recency items of the word list (see Fig. 5). In a study with adults, Carlesimo, Sabbadini, Fadda, and Caltagirone (1995) found, for delayed recall, a comparable loss of recency items, in both healthy controls and memory disordered patients. It is known for decades that the recency effect is highly sensitive to distraction prior to recall (e.g., Parkin, 1997).

On the recognition trial, dyslexic boys recognized less valid positives than did normal boys. This most probably is a consequence of the lower number of words mastered during immediate recall (the correlation between the number
of recalled words during the fifth immediate recall trial and the number of valid positives of the recognition trial was substantial, \( r = .55, p < .001 \). It indicates that the lower performances of dyslexic boys on the verbal learning task are the result of a deficit in the encoding of new information, rather than of a deficit in the retrieval of this information.

Dyslexic and normal boys showed comparable scores on the Digits Forward test. This outcome makes a rehearsal deficit as the main cause of verbal memory problems in dyslexics less likely. Dyslexic boys evidenced reduced scores on the Digits Backward test. As Lezak (1995) has noted, Digits Backward involves an effortful activity that calls upon working memory and that is related to temporal ordering. Interestingly, Bakker (1972) already suggested that dyslexics exhibited a deficit in the temporal ordering of verbal stimuli.

Across participants, the scores for Digits Backward correlated moderately with the primacy but not with the recency measure. The association between Digits Backward and the primacy measure may be explained by the extent to which memory span is resistant to interference. A reduced primacy effect and a lowered score on Digits Backward may be the consequence of greater interference with memory span due to either an excess of word stimuli during verbal learning or mental reversal operations during Digits Backward.

In summary, dyslexic boys evidenced reduced working memory and verbal learning capacities. The delayed recall and recognition scores indicate that the lower verbal-learning performances

---

**Fig. 5.** Summary scores for the primacy, middle, and recency regions of the fifth immediate (black bars) and delayed (gray bars) recall trial (P = primacy region, M = middle region, R = recency region).
of dyslexic boys are not a consequence of disturbed retention or retrieval. The reduced primacy effect and the lower performances on Digits Backward suggest that, most probably, reduced word-list learning in dyslexics is a consequence of a temporal ordering deficit. In addition, the nonlinear modeling of the learning curve revealed more loss of information during learning in L-dyslexics when compared to P-dyslexics and normal readers.

REFERENCES


