

Verbal Memory and Semantic Organization of Children with Learning Disabilities

Fotini Polychroni
Alexandra Economou
Anna Printezi
Ifigeneia Koutlidi
University of Athens

The present study examined the verbal learning performance and the semantic organization used by Greek reading-disabled readers as compared to a control group using a list-learning task. The sample consisted of 45 elementary school children with reading difficulties and 45 comparison children matched for age and gender. Tests of reading ability, verbal memory and learning and IQ were administered to the participants. Results indicated that the reading difficulties group had lower levels of verbal acquisition, but did not differ in learning rate. There was no significant effect of group on the clustering index, but the poor readers increased their clustering index a trial after the control group. No significant differences were found concerning serial position, suggesting that both groups recalled similar numbers of words from the different regions of the list. The results indicate that the verbal learning difficulties of children with reading deficits do not stem from deficient organizational strategies but rather from phonological working memory limitations, which can affect the acquisition of verbal information. The findings are discussed with respect to previous research that examines the verbal learning impairment of reading-disabled children and implications are drawn for the provision of effective assessment and learning support and instruction of children with reading difficulties.

Keywords: Reading Difficulties, Verbal Memory, Learning Strategies, List Learning

Reading is an important and complex cognitive skill, playing a central role in the learning process. Unexpected and unremitting impairment in the acquisition of literacy is linked to decreased academic performance and possibly long- term social and emotional adjustment difficulties. There is strong evidence that reading difficulties in dyslexia are primarily attributed to language-based deficits, such as phonological encoding difficulties (Shaywitz, 1998; Snowling, Nation, Moxham, Gallagher, & Frith, 1997; Vellutino & Fletcher, 2007), which are considered to be the core deficit of the disorder. A consequence of difficulties in phonological skills is that poor readers tend to perform lower in measures of verbal learning and verbal memory (Kramer, Knee, & Delis, 2000; Tijms, 2004). The phonological deficit has been found to be both a precursor of reading and a consequence of it (Goswami, 2000). Despite the evidence documenting the role of phonological processing in reading difficulties, the specific mechanisms of the verbal learning deficits and the role of organization in verbal memory in children with reading difficulties have received considerably less attention from researchers. The purpose of the present study is to investigate the verbal learning performance and the use of organizational strategies by children with reading difficulties and to compare them with those of a control group.

Phonological awareness, verbal memory, and verbal processing speed (the time taken to process familiar verbal information, such as letters and digits) are all aspects of phonological processing. A convincing body of evidence shows that these aspects are among the best predictors of a child's ability to learn to read (Bradley & Bryant, 1983; Goswami, 2000; Snowling, 2000; Vellutino, Fletcher, Snowling, & Scanlon, 2004) and appear to be deficient in children with dyslexia (Bryant & Bradley, 1996; Porpodas, 1999; Wagner, Torgesen, & Rashotte, 1994). This deficit appears to be universal, evident both in transparent and opaque languages (Caravolas, 2005; Goswami, 2000). Verbal (phonological short-term) memory is the ability to retain an ordered sequence of verbal material for a short period of time; it is used, for example, to recall a list of words or numbers or to remember a list of instructions. When deficient, difficulties occur in tasks such as paired associate learning, list learning and story recall (de Jong, 1998; Howes, Bigler, Lawson & Burlingame, 1999; Lymperopoulou & Polychroni, 2008; McDougall, Hulme, Ellis, & Monk, 1994). These memory impairments frequently occur in reading difficulties and are believed to reflect manifestations of an underlying phonological deficit, often assumed to be a deficit in the quality of phonological representations (Elbro, 1996; Liebermann & Shankweiler, 1991; Mayringer & Wimmer, 2000; Messbauer & de Jong, 2003; Rack, Hulme, Snowling, & Whightman, 1994). The contribution of verbal short-term memory to reading performance (decoding and comprehension) is well documented in the literature, with poor readers showing low performance in verbal short-term memory tasks (Baddeley & Hitch, 1994; De Jong, 1998; Howes, Bigler, Burlingame, & Lawson, 2003; Porpodas, 1999; Swanson, Cooney, & McNamara, 2004). On the other hand, poor readers' performance in non-verbal tasks, such as visual tasks is comparable to that of their peers, thus showing that the deficits in dyslexia are mainly within the verbal learning and memory domain (Tijms, 2004; Vellutino et al., 2004). As to the causation, there remains uncertainty regarding whether phonological deficits and verbal memory weakness in dyslexia have the same origin, are the consequence of one another, or have relatively independent origins.

Two theories have been proposed to account for the ineffective verbal memory in dyslexia. Children with reading impairments have either an encoding deficit, resulting from lack of familiarity with phonetic stimuli (Mann, Liberman, & Shankweiler, 1980) or, alternatively, a memory strategy deficit in rehearsal or semantic category clustering (Swanson, 1986).

A number of studies have examined the verbal memory ability of children with reading disabilities using a list-learning paradigm (Kibby, 2009a; Kibby, 2009b; Kibby & Cohen, 2008; Knee, Mittenberg, Burns, DeSands, & Keenan, 1991; Kramer et al., 2000; Tijms, 2004). Evidence from these studies concurs that learning-disabled readers, compared with age control peers, had a lower recall performance after the first presentation of a list of items and a slower rate of learning across the learning trials. In contrast, they showed similar vulnerability to interference as typical peers and were able to retain the words after brief and long delays. These findings were attributed to inefficient rehearsal and verbal encoding strategies, which are difficulties within the acquisition phase and are not related to consolidation or retrieval deficits. The verbal memory acquisition deficit and at least part of the phonological processing deficit in dyslexia may stem from a common underlying impairment, which reflects an inaccurate encoding of the phonological characteristics of verbal information (Tijms, 2004).

The Role of Organization in Verbal Learning

The organization of information in verbal learning is an essential component of recall performance. Two broad categories of organization are commonly identified, depending on the level of processing (Tulving, 1968). Primary organization is based on the way the words are presented: in this type of processing, serial position effects (primacy, recency) and short-term memory restrictions occur. Secondary organization refers to the individual's previous experience with the presented words. In this type of organization, the individual utilizes semantic associations between the list items, e.g., grouping words together by category. The use of semantic organization depends on the use of deep levels of processing (Craig & Lockhart, 1972) and is considered a more effective learning strategy than serial recall. In other words, it is suggested that primary organization is the result of short-term processing where no learning occurs. Secondary organization, on the other hand, is a higher-order skill that may lead to learning (Delis, Kramer, Kaplan, & Ober, 1994).

According to Siegler's "adaptive strategy choice model" (Siegler, 1987), children have a repertoire of strategies at their disposal. As children grow older, the application of effective strategies increases, and the use of ineffective strategies decreases. Spontaneous use of a semantic clustering strategy in recall is a developmental function that depends on the task employed. Children at the end of the 2nd grade use clustering strategies when a 20-item visual sort-recall task from 5 semantic categories is presented (Kron-Sperl, Schneider, & Hasselhorn, 2008). On the other hand, memory performance using a verbal list-learning task of 15 items belonging to three categories showed no spontaneous semantic clustering before adolescence (Delis et al., 1994). Irrespective of task, it is assumed that there is developmental progression in competent strategy use from the preschool to primary school years and individual differences in memory capacity, previous knowledge and metamemory all play an important role in memory strategy use (Schlagmüller & Schneider, 2002).

Thus far, there is very little evidence as to the learning strategies utilized by children with reading difficulties. Some studies suggest that while children with dyslexia score lower than average readers on phonological short term memory tasks, they are quite comparable in the use of categorisation strategies (Kibby, 2009a; Kibby & Cohen, 2008; Knee et al., 1991; Lee & Obrzut, 1994). Therefore, it is the phonological short-term memory that is deficient in children with reading difficulties, with semantic organization remaining relatively intact, consistent with the phonological core deficit model of dyslexia (Liberman & Shankweiler, 1991). On the other hand, there is evidence showing that students with dyslexia perform worse than controls on semantic encoding (Swanson, 1983a) and use deficient elaborative rehearsal strategies (Kaplan, Dewey, Crawford, & Fisher, 1998). Furthermore, learning disabled readers score lower than average readers in memory, even after undergoing training in mnemonic strategies (rehearsal and semantic clustering) (O'Shaughnesy & Swanson, 1998). According to the assumptions of serial position effects, primacy items, because they are presented early, receive the most rehearsal and reflect deeper levels of processing. Learning disabled readers recalled fewer words from the primacy region but the same number of words as controls from the recency region, suggesting that they use deficient rehearsal strategies (Kramer et al., 2000).

Despite the central role of verbal memory in reading, the specific mechanisms underlying the verbal learning of children with reading impairments have yet to be clearly defined. Relevant questions for research and practice are (1) whether poor readers learn slower than their typical peers, (2) whether recall performance is improved when cues are provided, and (3) whether and to what degree organization strategies are utilised. The aim of the present study is to investigate the verbal memory of children with reading difficulties and their ability to use semantic clustering, using a list-learning paradigm.

In the present study we have adopted the integrated model of reading difficulties classification proposed by Fletcher, Lyon, Fuchs, & Barnes (2007). Unlike the traditional approach to the assessment of learning disabilities, this approach does not differentiate between IQ-discrepant and non-discrepant poor readers because the IQ-achievement discrepancy does not reliably distinguish between disabled and non-disabled readers (Stuebing et al., 2002; Vellutino et al., 2004). In this alternative approach to assessment, poor readers are viewed as showing poor performance on reading achievement tests and a poorer response to high-quality instruction. Moreover, because it is increasingly recognised that dyslexia is best thought of as a continuum, from mild to severe, rather than as a distinct category (Rose, 2009), the terms *reading difficulties* and *reading disabilities* are used interchangeably in the present paper.

In the present study, the following questions and hypotheses were formulated.

1. *Do children with reading difficulties have lower acquisition performance of verbal information using a list learning task?* We hypothesised that disabled readers will have difficulties in the acquisition of verbal information, reflected in lower scores in the immediate free recall learning trials, as compared to typical peers.
2. *Are children with reading difficulties less proficient in their use of semantic organization across the five learning trials?* We hypothesised that poor readers will have deficits in the use of semantic organization, after adjusting for number of items recalled in their learning trials, as compared to typical peers.
3. *Do children with reading difficulties display evidence for less efficient encoding as measured by serial position effects?* Our hypothesis is that the reading difficulties group will demonstrate less effective strategies, reflected in the recall of more words from the recency region of the list compared to their peers.

Method

Participants

Forty-five children (28 boys and 17 girls) with a mean age of 9.63 years (*SD* = .95) who were experiencing difficulties in reading and either were in the process of referral or had a prior diagnosis of dyslexia in certified assessment centers in the area of Athens participated in the study (Table 1). The children spoke Greek as a first language and attended Grades 3, 4 and 5 of Primary School. They were selected from a larger pool of students with reading difficulties. Any child who met the following criteria was considered a poor reader: (1) Reading Accuracy (score < 20^{th} percentile); (2) estimate of IQ (WISC-III combined Vocabulary and Block Design standard scores each being >8) (see next section for description of assessment tools) and (3) no additional difficulties such as hearing impairment, attention deficit-hyperactivity disorder or other disabilities. Choice of reading cutoff scores varies across studies. Some researchers have used the 10^{th} percentile for severely impaired readers (Protopapas, Sideridis, Mouzaki, & Simos, 2007), while others have used the rather lenient 25^{th} percentile for low-achieving readers (Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996). The reading score cutoff of the 20^{th} percentile we used in the present study represents an intermediate choice that places the readers within the moderate impaired range (Vellutino, Tunmer, Jaccard, & Chen, 2007).

Forty five children met the criteria for inclusion in the reading difficulties group (RD) from a sample of 67 children, 62.2% (*n*=28) boys and 37.8% (*n*=17) girls. Thirteen children attended the 3^{rd} grade, 16 the 4^{th} grade, and 16 the 5^{th} grade.

The control group (CG) comprised 45 children, matched with the RD group for age (*M*=9.79 years, *SD*=.90) and gender. They were selected from the *Learning and Categorization Test* standardisation sample that consisted of 382 six-to-twelve-year-old children drawn from urban, semi-urban and rural areas of Greece using a stratified quota sampling method (Economou, Besevegis, Mylonas & Polychroni, 2008). Children whose first language was not Greek or had a diagnosis of dyslexia or any other type of disability were excluded from the CG. In addition, we excluded children who were rated as significantly below their peers in terms of cognitive ability by their teacher, using a Likert scale from -2 = very low to +2 = very high.

Permission for participation in the study for the students with reading difficulties was obtained by the school and/or by the assessment centre and parents, in cases where children were referred for evaluation. The Pedagogical Institute of Greece granted access to the schools from which the CG was obtained. The assessment for the RD group was completed in the autumn of 2008 whilst the control group was assessed as part of the standardisation study during the spring of 2007.

Table 1. *Characteristics of the Reading Difficulties Group (n=45)*

		RD	
	M (SD)	min	max
Age (years)	9.63(.95)	8.06	11.05
WISC-III Vocabulary	10.17(2.12)	8	15
WISC-III Block Design	11.07(2.09)	8	17
Estimated IQ	10.83(1.62)	8	15
Reading Accuracy (non words)	7.91 (3.12)	0	16
Reading Accuracy (words)	33.58 (8.68)	7	44

Materials

Reading Ability. Because of lack of commonly agreed assessment instruments for the detection of reading difficulties in assessment centers in Greece, a standardized reading test was administered to all the RD children to confirm the severity and specificity of the children's difficulties (TEST-A, Padeliadu & Antoniou, 2008).[1] The final sample was selected on the basis of performance on the reading accuracy subtests (Subtest 1, 2 and 3) that required the children (1) to read a list of words and a list of non words in order of ascending difficulty and (2) to correctly identify real words from a wider choice of words and non words. A composite reading accuracy score was calculated according to the test guidelines. Children with reading difficulties who scored below the 20th percentile of standard scores of this composite score were included in the RD group.

Verbal memory and learning. Verbal memory and learning was assessed using the verbal learning subtest from the Learning and Categorization Test for Kindergarten and Primary School Children (Economou et al., 2008). The Learning Scale of the Learning and Categorization Test is a list-learning task that assesses the number of words recalled and their semantic organization (clustering). Use of clustering provides data for use of learning strategy. The older children's version (9 to 12 years) consists of a 12-item word list (4 words from each of 3 semantic categories, 4 fruits, 4 school items, and 4 clothing items) read aloud by the examiner at the rate of one word per second, in five successive learning trials. After each list presentation, the child is instructed to freely recall as many words as possible, in any order. After the five trials, an interference list of 12 new items is presented. Children are first requested to freely recall the words from the original list and then are given a subsequent trial in which semantic cues to the words are presented in order to facilitate recall. After a 20-30 minute interval, during which non-verbal tasks are administered, "long-delay" free and cued recall and recognition of the target list are assessed.

In this study, only recall from trials 1-5 was used and the following measures were employed in the analyses: the number of words recalled correctly per trial, the clustering index per trial (CI, see following section), and the percentage of words recalled from the primacy, middle and recency regions of the list.

Estimate of IQ. The combined standard scores of the Vocabulary and Block Design subtests of the Greek version of the WISC-III (Georgas, Paraskevopoulos, Bezevegis, & Giannitsas, 1997) were used to provide an estimate of Full-Scale IQ. The two subtests assess the expressive vocabulary and non-verbal abilities of the children respectively, which are highly correlated with the Full-Scale IQ (Mouzaki & Sideridis, 2007; Sattler, 1992). A mean standard score lower than 8 was used as a cut-off .

Procedure

All 67 children of the initial sample (RD group) completed the reading, general cognitive and verbal learning measures in one session lasting approximately one hour. Assessment took place individually in a quiet room, either in the children's school or in the assessment center where the children were referred to. Before each task, each child was provided with oral instructions explaining the procedure.

The RD group was administered all three tests, whereas the control group was administered the Learning and Categorization Test only.

All assessments were carried out by trained graduate students and followed standard administration procedures. In the case of the RD group referred to assessment centers, the testing took place in the center as part of their comprehensive assessment procedure.

The order of test administration was fixed and was the following: The reading test was administered first, followed by the verbal learning test. During the 20-30 minute interval of the verbal learning test, according to the administration procedure, the Block Design subtest of the WISC-III was administered in order to avoid the potential influence of verbal material on verbal recall. After the interval, the remaining subtests of the verbal learning test were administered, followed by the Vocabulary subtest of the WISC-III.

Calculation of the clustering index

The number of semantic clusters—i.e., the occurrence of two consecutive words from the same category—the expected number of semantic clusters, and the clustering index were calculated after Stricker, Brown, Wixted, Baldo, & Delis (2002). Because the more words a child recalls, the more likely it becomes that words of the same category will appear together simply by chance, even when no organizational strategy is used, the number of observed clusters would increase as recall increases. To control for observed clusters that may occur by chance, we used a list-based clustering index which adjusts the amount of observed clustering by a value that would be expected if the subject recalled words without organising them, following the formula of Stricker et al. (2002). This clustering index is in line with the assumptions that organization is an antecedent to recall, and increases in the use of organizational strategies will result in better recall performance.

The formula of the Semantic Clustering Index (CI) used in the present study is the following:

$$CI= OBS - EXP,$$

Where, OBS= Observed semantic cluster (for the specific trial), EXP = expected semantic cluster and CI= no. of clusters that the child employed beyond that expected by chance. The index could take a positive or a negative value. The formula for calculating EXP is provided below:

EXP: Expected semantic cluster calculated as follows (for a 12 word list):

$$EXP = \frac{[(r-1)(m-1)]}{T-1} = \frac{[(r-1)(3-1)]}{12-1} = (r-1) \times 2/11$$

EXP: expected semantic cluster (for the specific Trial), *r*: number of correct words recalled (for the specific Trial), *m*: number of semantic categories on the original list, *T*: total number of words on the original list.

Results

The means and standard deviations for words recalled and the clustering index for the RD and the CG, on the five consecutive list learning trials are presented in Table 2. The RD group scored lower than the CG on all five learning trials. The mean total recall performance according to the normative data of the test (T-scores) was 8 for the RD group, with 26.7% of the RD group performed in the impaired range on the test, scoring lower than 7 and 11 for the CG.

In order to examine whether results can be reliably attributed to learning through consecutive trials, a mixed model repeated-measures analysis of covariance (ANCOVA) was conducted using a 5 x 2 design, with Trial (T1,T2, T3, T4, T5) as the within-subjects variable, Group (RD vs. CG) as the between-subjects variable, and age (in years) as a covariate. The dependent variable was the number of words recalled per trial.

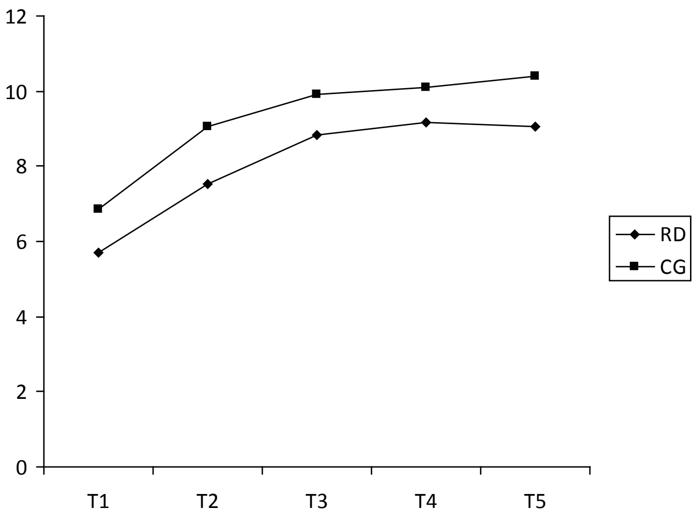
The findings showed a statistically significant main effect of Group, ($F_{(1,87)} = 21.319$, $p < .000$, $n^2=.20$) indicating that the control group maintained an advantage over the RD group, consistently recalling more words than the RD group after taking into account the children's age. There was no interaction between Group and Age ($F_{(3.83,\ 333.58)=}$ .39, ns). A significant main effect of Trial was also found [$F_{(3.83,\ 333.58)=}$ 2.44, $p < .05$, $n^2= .03$][2]. Within subjects, contrasts showed significant differences in the number of words recalled between Trial 1 and all subsequent trials (T1 < T2, T3, T4, T5) and between Trial 2 and all subsequent trials (T2 < T3, T4, T5) for both groups. The mean recall for the two groups at Trial 1 was $M_{RD}= 5.69$, SD= 1.52 and $M_{CG}= 6.87$, SD= 1.70, and both groups recalled significantly more words at Trial 2 relative to Trial 1. No significant gain was made, however, after Trial 2 for either group. Although some of the children of the CG may have reached ceiling performance at Trials 4 and 5, it is unlikely that the RD reached ceiling performance at these trials (see Table 2 and Figure 1). The Group by Trial interaction was not

Table 2. ***Means and Standard Deviations for Free Recall Trials and Clustering Index for the Two Groups of the Study***

	T1		T2		T3		T4		T5	
	RD	CG	RD	CG	RD	CG	RD	CG	RD	CG
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Free Recall (raw scores)	5.69 (1.52)	6.87 (1.70)	7.53 (1.74)	9.04 (1.91)	8.84 (1.74)	9.93 (1.51)	9.18 (1.61)	10.11 (1.60)	9.04 (1.64)	10.38 (1.30)
Clustering Index	.66 (.94)	.73 (.96)	1.19 (1.39)	1.91 (1.45)	2.20 (.62)	1.78 (1.35)	2.42 (1.71)	1.83 (1.74)	2.38 (1.80	2.12 (1.52)

significant [$F_{(3.83,\ 333.58)=}$ .687, $p > .05$, $n^2 = .01$], nor was the Trial by Age interaction [$F_{(3.83,\ 333.58)=}$ .390, $p > .05$, $n^2 = .01$]. Figure 1 shows the mean number of words recalled by the RD group and the CG across the five free recall trials.

***Figure 1.* Mean number of words recalled by the RD and CG across the five free recall trials.**

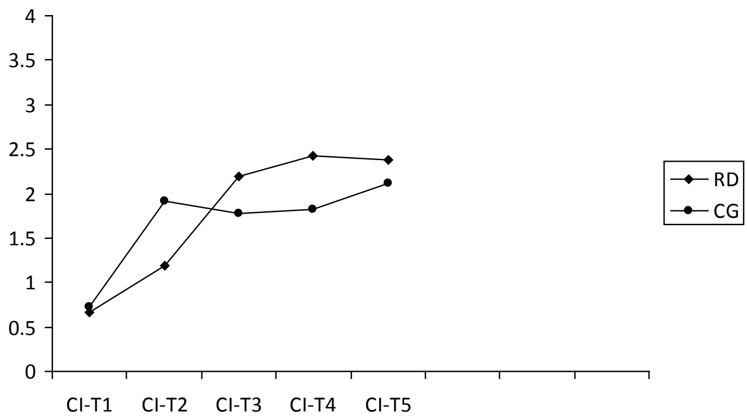


Key: T1 =Trial 1, T2 =Trial 2, T3 =Trial 3, T4= Trial 4, T5=Trial 5

Means and standard deviations for the clustering index used by the two groups for the five learning trials were presented in Table 2. It seems that both groups used a clustering strategy after Trial 1 (CI>1).

In order to further examine whether results can be reliably attributed to more effective use of clustering strategy in consecutive trials, a 5 x 2 repeated measures ANCOVA was performed with Clustering Index as the within-subjects variable (CI T1 to CI T5), Group (RD vs. CG) as the between-subjects variable and age as a covariate. The effects of Group [F (1,87) = .431, $p > .50$] and Trial [F (3.83, 333.65)= 1.08, $p > .30$][3] were not significant. A significant Group by Trial interaction was revealed, however (F (3.83, 333.65) = 3.42, $p < .01$) and repeated contrasts were performed to determine the nature of the interaction. The contrast between CI 2 and CI 3 was significant [F (1,87)= 9.63, $p < .01$) for the RD group only, suggesting that the children with reading difficulties increased the use of clustering in T3 but not after. On the other hand, the CG group made a gain in T2, with no further improvement. No other comparison was significant. Bonferroni post-hoc pairwise comparisons showed significant differences in clustering between Trial 1 and subsequent trials (T1 < T2, T3, T4, T5), and between Trial 2 and Trial 5 (T2 < T5) for the RD group, implying that the RD group made greater gains than the CG group in these trials. Figure 2 presents the Mean Clustering Indices resulting from the five trials for the two groups of the study.

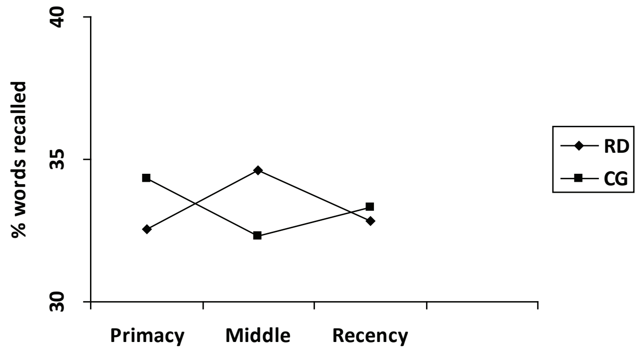
Figure 2. **Clustering Indices of the RD and CG across the five free recall trials.**



Key: T1 =Trial 1, T2 =Trial 2, T3 =Trial 3, T4= Trial 4, T5=Trial 5

The two groups' learning strategies were also examined by calculating the percentage of a child's total recall that came from the primacy (first four words), middle (middle four words), and recency (last four words) positions of the free recall word list. Data were analyzed with a repeated measures ANOVA, with Group (RD vs. CG) as the between-subjects variable and Position (primacy vs. middle vs. recency) as the within-subjects variable. The percentage of words recalled were 32.53 (SD=6.76) and 34.34 (SD=4.30) from the primacy region for the RD and the CG respectively, 34.62 (SD=5.93) and 32.31 (SD=4.73) from the middle region for the RD and the CG respectively, and 32.85 (SD=6.70) and 33.34 (SD=4.94) from the recency region for the RD and the CG respectively (see Figure 3). The effect of Group was not significant [$F(1, 88) = .284$, $p > .10$], nor was the Group x Position interaction [$F(2, 176) = 2.77$, $p > .10$].

Figure 3. **Percentage of words recalled by the RD and CG from the primacy, middle, and recency regions of the list.**



Discussion

The aims of this study were to compare the acquisition performance of verbal information and the use of semantic organization in children with reading difficulties and a typical readers group. For this purpose 45 children with reading difficulties and an age- and gender-matched comparison group were assessed using a list-learning task.

The primary finding of the present study was that the children with reading difficulties had lower levels of verbal acquisition, represented by the lower scores in the free recall trials relative to the control group, thus confirming our initial hypothesis. Poor readers recalled fewer words at Trial 1 and despite their improvement they were able to recall fewer words than their typical peers at Trial 5. However, the absence of an interaction between trial and group indicates that the learning rates between the two groups do not differ significantly; that is, both groups capitalised on repetitions and demonstrated improvement in learning efficiency. This finding replicates previous studies using list-learning tasks with dyslexic students (Kibby, 2009a; Knee et al., 1991), although Kramer et al. (2000) reported slower rates of learning for students with dyslexia. Overall, the lower score on Trial 1 of the RD group relative to the CG, indicating lower verbal encoding, might explain the lower recall performance at subsequent trials. The above differences between the two groups likely reflect differences in verbal short-term memory, which have long been documented for dyslexia (Porpodas, 1999; Swanson & Saez, 2003; Vellutino et al., 2004).

This study also demonstrated that there was no significant gain in recall performance for either group after Trial 2; in other words, the two groups reached a plateau at Trial 3. Considering that there was no ceiling effect for the RD group, this finding might be due to short-term memory limitations. Using a 15-item list of non-clusterable words, Poreh (2005) found that the slope of the learning curve was constant across trials, was independent of age and other demographic factors and was determined mainly by short-term memory span (performance at Trial 1). Because the present study included a small number of children from the 3rd to the 5th grade, future studies with larger samples could explore the learning curves of the children by grade.

Another important finding is that there was no significant effect of group on the clustering index overall, inconsistent with our research hypothesis. However, while both groups used a clustering strategy after Trial 1, the poor readers increased their clustering index a trial after the control group. In other words, the poor readers needed an extra repetition of the words in order to reach the level of semantic organization of the typical readers.

A lower performance at Trial 1 and overall in the RD group, together with lack of differences in the semantic categorisation used by the two groups, indicates that the differences in recall between the two groups (for each trial) cannot be attributed to differences in clustering strategy but possibly to differences in processing ability (short-term or working memory). As noted before, this finding is in line with the impaired phonological processing hypothesis for learning disabled children. To our knowledge, this is the first systematic investigation of semantic categorisation of children with reading difficulties with the use of a list-based clustering index and indicates that differences in verbal learning are not attributed to differences in organizational ability.

Contrary to recall-based indices of clustering, list-based indices do not assume that only the words and categories recalled are relevant to measurement of organization and that organizational processes do not occur until after words are retrieved from memory, in agreement with incremental theories of category learning which reflect the incremental mastery of a list in a graded increase of the list-based measure (Stricker et al., 2002). Use of a list-based clustering index, therefore, permits the evaluation of the joint occurrence of clustering and list mastery. The later gain of the RD group in the use of semantic clustering, combined with its lower recall performance overall, point to the contribution of additional factors to the learning and memory differences between the two groups. Lower working memory capacity has been shown to influence the learning slope (Poreh, 2005) and the strategy use (Kron-Sperl et al., 2008; Shlagmüller & Schneider, 2002) of typical children and should be explored further in poor readers.

The learning strategies of the two groups were also examined by assessing the serial position effect. A higher percentage of words recalled from the recency region relative to the other two regions is presumed to represent an over-reliance on short-term memory mechanisms and less active rehearsal. A higher percentage of primacy and middle region words recalled is presumed to represent more efficient rehearsal and encoding capacity (Bauer, 1977; Bauer & Emhert, 1984; Swanson, 1983b). Indeed, words recalled from the middle region, together with List A Trial 1 recall of the California Verbal Learning Test-Children's Version (CVLT-C) loaded on a "Verbal Attention-Working Memory" factor in a pediatric epilepsy sample (Griffiths et al., 2006), as well as a traumatic brain injury sample (Mottram & Donders, 2005), indicating that this measure reflects the ability to hold and repeat phonological information. No significant differences were found concerning serial position, suggesting that both groups recalled similar numbers of words from the different regions of the list. This finding does not support our initial hypothesis and disagrees with the findings of previous studies, which showed that children with learning disabilities recall significantly fewer words than non-disabled readers from the primacy and middle regions, implying less efficient encoding and rehearsal mechanisms, whilst there is no difference in their recall of recently presented items (Kramer et al., 2000; Strien, 1999). Further analyses by trial would indicate whether RD children exhibit a deficient ability to hold and repeat phonological information, which would manifest in the initial trials of the task, especially Trial 1, without the benefit of the repetition of the list of words.

Certain limitations of this study should be noted. The children with reading difficulties who were recruited from assessment and intervention centres had been receiving individual and/or group learning support from specialists, which may have affected their learning style. Another limitation was that the control group was not matched to the RD group for IQ and did not receive a reading assessment because it came from a standardization sample. Given the moderate correlations between verbal IQ and verbal learning ability, if the comparison group had substantially higher non-memory verbal abilities than the RD group, differences on list-learning performance would have been somewhat inflated. Such a possibility cannot be ruled out, though it is considered less likely given that the mean Vocabulary score of the RD group was well within the average range, and it is not likely that the typical readers, derived from the normative sample, would be significantly above the average range. Related to this is the use of 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 preferable, the current study was not intended to identify the underlying mechanisms for reading disability but rather to investigate the acquisition performance and use of organizational strategies in reading-disabled children. Future research on learning strategies could extend the present findings by including younger age children since effective use of strategies develops as age increases (Swanson & Saez, 2003).

The findings of the present study have several implications for assessment and instruction of children with reading difficulties. The process of acquiring information runs through every aspect of a student's life. Students of all ages are required to encode, process, and retrieve a great deal of verbal information throughout their school life. Consequently, assessing verbal learning has ecological validity. Learning-disabled students commonly experience difficulties with learning verbal material, requiring more repetitions than non leaning-disabled students. The Greek educational system places great emphasis on preparing for examinations, and this is especially evident after students leave primary school.

Difficulties in verbal short-term memory may result in difficulty recalling classroom instructions and responding to questions, and failure in more complex activities involving storage and processing of information and keeping track of progress in difficult tasks (Gathercole & Alloway, 2004; Gathercole & Alloway, 2008). All these difficulties can lead to the impression that the child has not been paying attention. At later stages of schooling, problems with note taking, essay planning and self-organization can be seriously troublesome for a child with greater than usual difficulties in verbal memory. Targeted strategies may be applied to classroom practice to help reduce short-term memory loads (Gathercole & Alloway, 2008). For example, short and syntactically simple task instructions, use of mnemonics and repetitions may reduce the processing requirements of the task and help the children integrate the information better. In general, it is suggested that classroom teaching should provide patterns through which information can be registered and organized more easily. Early intervention is paramount, without which working memory deficits may continue to compromise a child's likelihood of academic success.

In conclusion, the findings of the present study indicate that reading-disabled children are able to use organizational strategies to acquire verbal material but are deficient in short-term and working memory capacity for phonological information. Future studies could specifically explore the contribution of working memory to strategy use by typical and poor readers.

References

Baddeley, A.D., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology, 8,* 485-493.

Bauer, R. H. (1977). Memory processes in children with learning disabilities: Evidence for deficient rehearsal. *Journal of Experimental Child Psychology*, *24*, 415–430.

Bauer, R. H., & Emhert, J. (1984). Information processing in reading disabled and non disabled children. *Journal of Experimental Child Psychology, 37,* 271-281.

Bradley, L., & Bryant, P. E. (1983). Categorising sounds and learning to read: A causal connection. *Nature, 301,* 419–521.

Bryant, P., & Bradley, L. (1996). *Children's reading problems.* Oxford & Cambridge: Blackwell.

Caravolas, M. (2005). The nature and causes of dyslexia in different languages. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 336–356). Oxford, UK: Blackwell.

Craig, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11,* 671-684.

De Jong, P. F. (1998). Working memory deficits of reading disabled children. *Journal of Experimental Child Psychology, 70*, 75–96.

Delis, D.C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1994). *California Verbal Learning Test—Children's Version Manual.* San Antonio, TX: Psychological Corporation.

Economou, A, Besevegis, E, Mylonas, K., & Polychroni, F. (2008). *Τεστ μάθησης και κατηγοριοποίησης* Learning and Categorization Test. Athens: Department for Education.

Elbro, C. (1996). Early linguistic abilities and reading development: A review and a hypothesis. *Reading and Writing: An Interdisciplinary Journal, 8*, 453–486.

Fletcher, J. M., Lyon, G. R., Fuchs, L. S., & Barnes, M. A. (2007). *Learning disabilities: From identification to intervention.* New York: Guildford Press.

Francis, D. J., Shaywitz, S. E., Stuebing, K. K., Shaywitz, B. A., & Fletcher, J. M. (1996). Developmental lag versus deficit models of reading disability: A longitudinal individual growth curves analysis. *Journal of Educational Psychology*, *88*, 3–17.

Georgas, D., Paraskevopoulos, I., Besevegis, E., & Giannitsas, N. (1997). *Ελληνικό WISC-III: Wecshler κλίμακες νοημοσύνης για παιδιά* Greek WISC-III: Wechsler intelligence scales for children [in Greek]. Athens: Ellinika Grammata.

Gathercole, S. E., & Alloway, T. P. (2004). *Working memory and classroom learning, Dyslexia Review 15***,** 4–9.

Gathercole, S. E., & Alloway, T. P. (2008). *Working memory and learning: A practical guide.* London: Sage Publications.

Goswami, U. (2000). Phonological representations, reading development and dyslexia: Towards a cross-linguistic theoretical framework. *Dyslexia, 6*, 133-151.

Griffiths, S. Y., Sherman, E. M. S., Slick, D. J., Lautzenhiser, A., Westerveld, M., & Zaroff, C. M. (2006). The factor structure of the CVLT-C in pediatric epilepsy. *Child Neuropsychology*, *12*, 191-203.

Howes, N. L., Bigler, E., Burlingame, G., & Lawson, J. (2003). Memory performance of children with dyslexia: A comparative analysis of theoretical perspectives. *Journal of Learning Disabilities, 36,* 230-246.

Howes, N. L., Bigler, E. D., Lawson, J. S., & Burlingame, G. M. (1999). *Reading disability subtypes and the test of memory and learning. Archives of Clinical Neuropsychology, 14*, 317–339.

Kaplan, B. J., Dewey, D., Crawford, S. G., & Fisher, G. C. (1998). Deficits in long-term memory are not characteristic of ADHD. *Journal of Clinical and Experimental Neuropsychology, 20,* 518–528.

Kibby, M. (2009a). Memory functioning in developmental dyslexia: An analysis using two clinical memory measures. *Archives of Clinical Neuropsychology 24*, 245-254.

Kibby, M. (2009b). There are multiple contributors to the verbal short-term memory deficit in children with developmental reading disabilities. *Child Neuropsychology*, *15,* 485–506.

Kibby, M.Y. & Cohen, M. J. (2008). Memory functioning in children with reading disabilities and/or attention deficit/hyperactivity disorder: A clinical investigation of their working memory and long-term memory functioning. *Child Neuropsychology*, *14,* 525-546.

Knee, K., Mittenberg, W., Burns, W., DeSands, M. & Keenan, M. (1991). *Memory of Specific Learning Disabled Readers Using the California Verbal Learning Test for Children.* Presented at the Annual Convention of the American Psychological Association, San Francisco, USA, August 16-20.

Kramer, J., Knee, K., & Delis, D. (2000). Verbal memory impairments in dyslexia. *Archives of Clinical Neuropsychology*, *15*, 83–93.

Kron-Sperl, V., Schneider, W., & Hasselhorn, M. (2008). The development and effectiveness of memory strategies in kindergarten and elementary school: Findings from the Wurzburg and Gottingen longitudinal memory studies. *Cognitive Development, 23,* 79-104.

Lee, C. P., & Obrzut, J.E. (1994). Taxonomic clustering and frequency associations as features of semantic memory development in children with learning disabilities. *Journal of Learning Disabilities, 27,* 454-464.

Liberman, I. Y., & Shankweiler, D. (1991). Phonology and beginning reading: A tutorial. In L. Rieben & C. Perfetti (Eds.), *Learning to read: Basic research and its implications* (pp. 3-18). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Lymperopoulou, V., & Polychroni, F. (2008, May). *Metamemory assessment, self-esteem and academic performance in high-school students.* Paper presented at the 3rd Biennial meeting EARLI SIG-16 Metacognition, Ioannina, Greece .

Mann, V. A., Liberman, I. Y., & Shankweiler, D. (1980).Children's memory for sentences and words strings in relation to reading ability. *Journal of Experimental Child Psychology, 37*, 187-206.

Mayringer, H., & Wimmer, H. (2000). Pseudoname learning by German-speaking children with dyslexia: Evidence for a phonological learning deficit. *Journal of Experimental Child Psychology, 75*, 116–133.

McDougall, S., Hulme, C., Ellis, A., & Monk, A. (1994). Learning to read: The role of short-term memory and phonological skills. *Journal of Experimental Child Psychology, 58*, 112-133.

Messbauer, V. & De Jong, P. (2003). Word, nonword, and visual paired associate learning in Dutch dyslexic children. *Journal of Experimental Child Psychology 84*, 77-96.

Mottram, L., & Donders, J. (2005). Construct validity of the California Verbal Learning Test-Children's Version (CVLT-C) after pediatric traumatic brain injury. *Psychological Assessment*, *17*, 212-217.

Mouzaki, A., & Sideridis, G. (2007). Poor readers' profile among Greek students of elementary school. *Hellenic Journal of Psychology, 4,* 205-232.

O'Shaughnessy, T., & Swanson, H. L. (1998). Do immediate memory deficits in students with learning disabilities in reading reflect a developmental lag or deficit? A selective meta-analysis of the literature, *Learning Disability Quarterly, 21*, 123-148.

Padeliadu, S., & Antoniou, F. (2008). Reading Test, Test-A. Athens: Department for Education.

Poreh, A. (2005). Analysis of mean learning of normal participants on the Rey Auditory-Verbal Learning Test. *Psychological Assessment*, *17*, 191-199.

Porpodas, C. D. (1999). Patterns of phonological and memory processing in beginning readers and spellers of Greek. *Journal of Learning Disabilities, 32*, 406-417.

Protopapas, A., Sideridis, G. D., Mouzaki, A., & Simos, P. G. (2007). Development of lexical mediation in the relation between reading comprehension and word reading skills in Greek. *Scientific Studies of Reading,11*, 165-197.

Rack, J., Hulme, C., Snowling, M., & Whightman, J. (1994). The role of phonology in young children learning to read words: The direct- mapping hypothesis. *Journal of Experimental Child Psychology, 57*, 42-71.

Rose, J. (2009). *Identifying and teaching children and young people with dyslexia and literacy difficulties. An independent report from Sir Jim Rose to the Secretary of State for Children, Schools and Families.* UK: Department for Schools, Children and their Families.

Sattler, J. M. (1992). *Assessment of children (3rd edition).* San Diego, CA: J.M. Sattler Publisher.

Schlagmüller, M. & Schneider, W. (2002). The development of organizational strategies in children: Evidence from a microgenetic longitudinal study. *Journal of Experimental Child Psychology*, *81*, 298-319.

Shaywitz, S. (1998). Current concepts: dyslexia. *The New England Journal of Medicine, 338*, 307-12.

Siegler, R. S. (1987). The perils of averaging data over strategies: An example from children's addition. *Journal of Experimental Child Psychology: General, 116,* 250-264.

Snowling, M. J. (2000). *Dyslexia* (2nd ed.). Oxford, UK: Blackwell.

Snowling, M. J., Nation, K., Moxham, P., Gallagher, A., & Frith, U. (1997). Phonological processing deficits in dyslexic students: a preliminary account. *Journal of Research in Reading, 20,* 31-34.

Stricker, J. L., Brown, J. J., Wixted, J., Baldo, J., & Delis, D. (2002). New semantic and serial clustering indices for the California Verbal Learning Test–Second Edition: Background, rationale, and formulae. *Journal of the International Neuropsychological Society*, *8*, 425–435.

Strien, J. (1999). 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. *Child Neuropsychology*, *5*, 145-153.

Stuebing, K. K., Fletcher, J. M., LeDoux, J. M., Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2002). Validity of IQ discrepancy classifications of reading disabilities: A metaanalysis. *American Educational Research Journal, 39,* 469-518.

Swanson, H. L. (1983a). Effects of rehearsal activity and level of word processing on learning disabled and normal readers' free recall. *Journal of General Psychology*, *108*, 61–72.

Swanson, H. L. (1983b). A study of nonstrategic linguistic coding on visual recall of learning disabled and normal readers. *Journal of Learning Disabilities, 16*, 209-216.

Swanson, H. L. (1986). Do semantic memory deficiencies underlie learning disabled readers' encoding processes? *Journal of Experimental Child Psychology, 41,* 461-488.

Swanson, H. L., Cooney, J. B., & McNamara, J. K. (2004). Learning disabilities and memory. In B. Y. L. Wong (Ed.), *Learning about learning disabilities (3rd edition)* (pp. 41-92). Amsterdam: Elsevier Academic Press.

Swanson, H. L., & Saez, L. (2003). Memory difficulties in children and adults with learning disabilities. In H. L. Swanson, K. R. Harris, & S. Graham, (Eds.), *Handbook of Learning Disabilities* (pp. 182-198). New York: The Guildford Press.

Tijms, J. (2004). Verbal memory and phonological processing in dyslexia. *Journal of Research in Reading*, *27*, 300-310.

Tulving, E. (1968). Theoretical issues in free recall. In T. R. Dixon and D. L. Horton (Eds.), *Verbal behavior and general behavior theory* (pp. 2-36). Englewood Cliffs, N.J.: Prentice Hall.

Vellutino, F. & Fletcher, J. M. (2007). Developmental Dyslexia. In M. J. Snowling & C. Hulme (Eds.) *The science of reading: A handbook* (pp.362-378). UK: Blackwell Publishing.

Vellutino, F. Fletcher, J., Snowling M., & Scanlon, D. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45,* 2-40.

Vellutino, F. R., Tunmer, W. E., Jaccard, J. J. Chen, R. (2007). Components of reading ability: Multivariate evidence for a convergent skills model of reading development. *Scientific Studies of Reading, 11*, 3-32.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1994). Development of reading-related phonological processing abilities: New evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology*, *30*, 73-87.

Author Note

Part of this research was funded by a grant awarded to Department of Psychology, University of Athens (O.P. Project II "Construction and Standardisation of 12 screening tools (criteria) for learning disabilities" (1.1 – 1.1.3., 2006-2008).

Correspondence concerning this article should be addressed to Fotini Polychroni, PhD, Department of Psychology, School of Philosophy, University of Athens, University Campus, Ilissia 157 84, Athens, Greece. E-mail: fpolychr@psych.uoa.gr.

Endtnotes

[1] To address the relative lack of assessment measures for reading difficulties, recent efforts in assessment (O.P. projects funded by the European Community and the Department of Education of Greece) have resulted in the construction and standardization of a number of screening measures for learning disabilities measuring different areas, i.e., reading, writing, memory, speech and language, executive functions, psychosocial adjustment etc. The present study employs two of these tools.

[2] *F* ratios and degrees of freedom for within-subjects effects are adjusted using Huynh–Feldt adjustment for violation of sphericity.

[3] *F* ratios and degrees of freedom for within-subjects effects are adjusted using Huynh–Feldt adjustment for violation of sphericity.