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C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

LANGUAGE AS A MODERATOR OF MEMORY-RELATED PROCESSES IN CHILDREN WITH DEVELOPMENTAL DYSLEXIA

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SUMMARY

Background: It has often been suggested that language functions may affect memory performance, partly explaining why children with developmental dyslexia often present with memory deficits on psychological testing. The goal of this study was to determine whether or not language functions differentially moderate memory performance in developmental dyslexia.

Material/ Methods: The experimental group consisted of 30 children diagnosed with dyslexia and dysgraphia. The control group consisted of 30 pupils with no deficits diagnosed, matched to the clinical group for age and IQ. In order to analyse linguistic functioning, we used the Controlled Oral Word Association Test (COWAT), the Phonological-Semantic Interference Test, and the Token Test – 36. The Logical Memory, Word List, and Spatial Span subtests from Wechsler Memory Scale (WMS) III and the Rey-Osterrieth Complex Figure were used to analyze memory functions.

Results: Regression analysis revealed that language moderated memory in both groups. However, the impact of language on memory was particularly strong in the dyslexic children, especially in verbal tasks based on phonological aspects of language. For children with isolated dyslexia, no association was found between language and visuo-spatial functioning.

Conclusions: Our study shows that language differentially moderates specific memory domains in developmental dyslexia. However, visuo-spatial problems in children dyslexia do not seem to be related to dyslexia-associated language impairment.

Key words: specific learning difficulties, language, memory, visuo-spatial functioning

INTRODUCTION

Effective diagnostics, whether of somatic diseases, developmental disturbances, or mental illnesses, is only possible when all those involved in the diagnostic process use the same nomenclature, regard the same symptoms as diagnostic, and consequently apply similar methods of treatment and therapy. This is possible only when a unified classification of disorders is used. At present, diagnosticians in both psychiatry and clinical psychology most often refer to categorial classifications, among which are two medical classifications: the International Statistical Classification of Diseases and Related Health Problems – Tenth Edition (ICD-10; WHO, 1992) and the Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition-Text Revision (DSM-IV-TR; APA, 2000). In the categorial approach, qualitative differences are assumed to exist between disturbed and normal behaviors, and on this basis separate categories and classes of disorders are created. In order to establish an accurate diagnosis it is necessary to specify the axial symptoms for a given disorder and the additional symptoms which are commonly, but not always observed in the clinical picture of the disorder. Problems with both language and memory are listed as axial in many disorders. Memory deficits constitute an axial symptom for entire categories of disturbances. In the European ICD-10 (WHO, 1992) these are listed as "Organic, including symptomatic, mental disorders". In this group the basic symptoms of the disorders fall into two groups:

- syndromes in which the most important axial symptoms involve cognitive functions;
- symptoms with disturbances in the domains of perception (hallucinations), mentation, and mood and affect.

Memory deficits are also mentioned as characteristic, but not axial in many disturbances in child development. Based on the medical classifications, we can say that disturbances affecting children or beginning in childhood in which problems with memory processes are listed include intellectual impairment, learning disorders, and disorders of expressive language (cf. APA, 2000; WHO, 1992).

Problems of a linguistic nature are also observed in the clinical picture of these disorders. The relation between memory and language has been explored by neuropsychologists since the middle of the 20th century, especially in respect to aphasia (Pachalska 2003; Pachalska & MacQueen, 2001, 2005). In the classical model, the connection between processes of memory and language was described in accordance with the concept of working memory (Baddeley & Hitch, 1974). In this model the role of language in processing memory material was emphasized by distinguishing the "phonological loop", which constitutes a system for the rehearsal of verbal information. The linguistic aspect of working memory has been the focus of much neuropsychological research, involving both patients and healthy individuals (Jodzio, 2003).

In reference to long term memory, also, the role of language has been incorporated in a general theory of memory. Tulving (2002), on the basis of the format

of the information stored in memory, distinguished "semantic memory," which is an organized store of knowledge about the meaning of words and concepts, or remembered facts.

Current research has of course gone far beyond Baddeley's concept of working memory, or Tulving's semantic memory; however, the connection between language and memory has not only not been disproven, but in fact emphasized.

One example of a disturbance in which both linguistic and memory-related problems co-occur is "specific learning difficulties," also known as developmental dyslexia. It is important to bear in mind that this disorder does not result from a diminished capacity for understanding and creating concepts, or for critical thinking, but is characterized by a diminished capacity to acquire and use speech, writing, or mathematical symbols. According to a definition widely used in Poland, "dyslexia is a syndrome of disturbances of higher mental activities, which manifest themselves in the form of specific learning difficulties in reading and writing. They are conditioned by partial disturbances of the psychomotor development of the functions participating in reading and writing activities and their integration. Among the developmental deficits of cognitive functions, disturbances of linguistic functions are of paramount importance. These disturbances include the phonological aspect of language, which is a prerequisite for the possibility of linguistic communication" (Bogdanowicz, 2003, p. 495). The role of a language deficit in the pathomechanism of dyslexia has been emphasized by many authors (cf. Bogdanowicz, 2011; Krasowicz-Kupis, 2008; Snowling, 2000), who point out that the basis for the language problems is a deficit of phonological awareness, which makes it difficult to differentiate speech sounds and manipulate them freely. The nature of these language problems draws attention to memory-related processes, since it is precisely the serious difficulties encountered by dyslexic children in tasks requiring the performance of operations with phonemes that signal problems in verbal working memory (Kibby & Cohen, 2008; Lipowska, 2011; Pachalska et al., 2007).

Children with dyslexia are also observed to have visuo-spatial deficits, which in the early stage of education can cause problems in recognizing letters, remembering their sequences in words, remembering the graphic image of a word, and, at a later age, difficulties in orientation on a map, etc. (Brunswick et al., 2010; Lipowska, 2011; Lipowska et al., 2011; Pachalska et al., 2012). These problems result from several factors, including dysfunctions of working memory, which also has a "visuo-spatial sketchbook," a system for processing spatial information supplied to the brain by the visual apparatus (Mati-Zissi & Zafiropoulou, 2003). Poorer functioning of semantic memory is also noted, which, along with linguistic difficulties, constitutes an axial symptom of specific learning difficulties in learning to read and write (Mahnaz et al., 2009).

It is important to bear in mind that these problems affect a broad spectrum of memory processes, both verbal and non-verbal. The question arises, then, as to whether or not the axial language deficit in dyslexia is a moderator of the deficits in both verbal and visuo-spatial memory.

MATERIAL AND METHODS

The research was conducted in Poland with a population of 60 persons. The experimental group consisted of 30 boys from 4th to 6th grade, diagnosed with developmental dyslexia. The control group consisted of 30 boys with no diagnosed deficits, matched to the clinical group in terms of age (the mean age in the control group was 11.6, SD = 0.7, while in the dyslexia group the mean age was 11.4, SD = 0.4) and handedness.

All of the participants were native Polish speakers and met the following criteria:

- normal or above-average intelligence;
- standard educational opportunities;
- normal or corrected to normal visual and auditory acuity;
- no gross sensory deficit;
- no gross behavioral problems;
- no history of neurological disease.

The tests were carried out individually with each child. IQ was assessed with the Wechsler Intelligence Scale for Children (WISC-R; Matczak et al., 2008). The mean IQ in the control group was 108.4 (SD = 7.5); in the dyslexia group, 106.4 (SD = 11.9). All the subjects with dyslexia were also diagnosed with dysgraphia.
In order to analyze memory functioning, we used the following instruments:

- the Rey-Osterrieth Complex Figure Test (Strupczewska, 1990);
- the Logical Memory, Word List and Spatial Span subtests from the Wechsler Memory Scale – third edition (WMS – III; Wechsler, 1998).

The Logical Memory and Word List subtests from the WMS-III were used to measure the level of functioning of verbal memory. The Logical Memory subtest measures the capacity of episodic memory, that is, the ability to remember and recall events and situations that form a logical sequence in the form of a thematic unit (Wechsler, 1998). This subtest contains two short stories, which the subject is asked to reproduce immediately and after a delay. The Word List subtest requires the subject to learn a list of 12 unrelated words presented orally, in four successive trials. The examiner also reads an additional word list that serves as a distractor, and then asks the subjects to repeat the initial word list. The procedure of repeating the trial after a delay is also used in this subtest.

The Spatial Span subtest from the WMS-III is used to test the functioning of visuo-spatial memory; it is a visual counterpart of the well-known Digit Span subtest from the WISC-R and the Wechsler Adult Intelligence Scale (WAIS). The subject is shown a series of moves on a three-dimensional board containing six square blocks, numbered 1-10 on the examiner's side. The subject's task is to repeat the sequences of moves forward and back.

The Rey-Osterrieth Complex Figure Test, as adapted by Strupczewska (1990), is based on developmental norms expected for children in the Polish population. The child's task is to copy the figure without time limitations. The test was conducted in two phases. In the first phase (copying), the task was to make an exact

copy of the figure from the model. Then, three minutes after the completion of the first phase, without prior warning, the examiner asked the subject to make another copy of the figure, this time from memory (reproduction). In both phases the time needed to make the drawing was measured. The interpretation and evaluation of both drawings (copying and reproduction) is done on the basis of three criteria: the type of reproduction (based on a qualitative analysis), the number of points obtained, and the drawing time.

In order to measure the level of language functions, we used:

- the Controlled Oral Word Association Test (COWAT; Pachalska, 2007);
- Pachalska and Lipowska's Phonological-Semantic Interference Test (2006);
- The Token Test – 36 (Kościesza & Krasowicz-Kupis, 1995).

The COWAT was used to evaluate verbal fluency. The subject's task is to say as many words beginning with the letter "K" as they can in 60 seconds. The second part of the test involves naming the largest possible number of examples from a particular semantic group; in this case, animals. The third and most complex task requires the production of the largest possible number of objects that can be purchased in a supermarket and begin with the letter "M"; in this case, it is necessary to refer to both a phonetic and a semantic category.

The Phonological-Semantic Interference Test (Pachalska & Lipowska, 2006) has been developed in order to test the phonological competence of children who have already finished the third grade. This test evaluates the child's auditory memory, ability to concentrate, and especially skill at manipulating phonemes. It consists of four subtests (ten trials each). The test is conducted in the form of a game, which involves finding words that are hiding in other words. In successive trials it is possible to obtain a new word after removing a sound from the root of the presented word, a sound from a non-word, a syllable from a word, and finally, in the forth trial, an entire word from a sentence.

The Token Test – 36 (Kościesza & Krasowicz, 1995), which is the Polish version of the Token Test for Children (McGhree et al., 2007), provided information on the children's comprehension of linguistic utterances, for both developmental and clinical purposes.

RESULTS

We obtained interesting results in our research on the functioning of verbal memory. Both of the subtests from the WMS-III, Logical Memory and Word List, serve to diagnose disturbances of verbal memory, but only in the Logical Memory subtest is it possible to rely on content clues. Interestingly, our subjects with dyslexia did not differ in the level of recalling logical material. The level of performance in the tasks requiring both immediate and delayed recall was very similar in both groups. Nothing in the available literature has ever suggested the existence of any particular problems in dyslexic children in respect to episodic memory, and some researchers have even suggested that content clues play a compensatory role in memory tasks involving verbal material (Menghini et al.,

2010). However, in the tasks requiring the recall of a list of non-related words, the dyslexic children obtained significantly lower scores in all trials ($p = 0.000$). This result would seem to indicate that the foundation of this problem is linguistic, the more so, that comparative research on children with dyslexia, children with ADHD, and children with both dyslexia and ADHD has shown that hyperactive children have greater difficulties in this respect, which seems to be caused by a deficit in the pre-attentive buffer (Lipowska, 2011).

In the domain of visuo-spatial memory, the dyslexic children obtained significantly lower scores than the control group in the task requiring the reproduction of movements backward in the Spatial Span subtest from the WMS-II ($t = 2.2$; $p = 0.035$) and copying the Rey-Osterrieth Complex Figure ($t = 3.2$; $p = 0.001$). The problems the children with dyslexia encountered in copying the drawing clearly indicate a deficit in visuo-spatial organization (cf. Mati-Zissi et al., 2003; Brunswick et al., 2010; Lipowska et al., 2011), the importance of which is more and more often emphasized in the pathomechanism of specific learning difficulties (cf. Bogdanowicz et al., 2009; Lipowska, 2011).

As initially hypothesized, the children with dyslexia displayed a significantly lower level of linguistic functioning than the normal controls, which is obvious if one accepts the concept of the linguistic foundation of specific learning difficulties (cf. Bogdanowicz, 2011; Krasowicz-Kupis, 2008; Snowling, 2000). Particularly significant differences occurred in respect to phonological competence ($t = 4.0$; $p = 0.001$), measured by means of the Phonological-Semantic Interference Test (Pachalska & Lipowska, 2006), and also in respect to verbal fluency ($t = 3.6$; $p = 0.001$). All the subjects experienced the least difficulty with the task of naming animals, i.e. the task requiring the collection of words according to semantic category; the next most difficult task involved a phonological category (words beginning with “K”); and the most difficult task involved the simultaneous application of both phonological and semantic categories (cf. Lipowska et al., 2008).

Having found clear indications of a language deficit, we were able to make a detailed analysis of the importance of language functions for particular aspects of memory. To begin with, we analyzed the relationship between language and logical verbal memory, measured by the Logical Memory subtest of the WMS-III, the parameters for which are immediate auditory memory, learning, and the percentage of remembered information. Since in respect to verbal memory based on content cues the children with dyslexia did not differ significantly from the control group, it is hardly surprising that we obtained an acceptable model of multiple regression only for immediate auditory memory, where language functions accounted for 36% of the variance in immediate auditory memory ($F = 8.9$; $p = 0.000$). An analysis of partial correlation revealed that immediate auditory memory is associated only with the level of semantic fluency ($r = 0.33$; $\beta = 0.34$; $p = 0.006$). It is possible, then, that given the phonological deficit characteristic for dyslexia, the possibility of referring to content is particularly useful in remembering logical verbal material.

Much more essential information concerning the relationship between language and memory was obtained by analyzing the role of language as a moderator of memory-related processes in respect to verbal memory as measured by the Word List, where it is not possible to refer to content or rely on semantic information. In the group of children with dyslexia we obtained an acceptable model of multiple regression for immediate memory and learning (see Fig. 1), which explains 29% of the variance in immediate memory (F = 5.9; p = 0.003) and 18% of the variance in learning (F = 6.0; p = 0.001).

A detailed analysis of partial correlations indicated that immediate memory is correlated with the skill of removing a word from a sentence in the PSI test (r = 0.42; β = 0.43; p = 0.001) and removing sounds from a word (r = 0.30; β = 0.29; p = 0.007).

Learning is also correlated with the skill of removing a word from a sentence (r = 0.30; β = 0.31; p = 0.018) and removing sounds from the word (r = 0.28; β = 0.30; p = 0.024) on the PSI test), as well as the level of phonological fluency as measured by the COWAT (r = 0.31; β = 0.30; p = 0.009).

Despite the fact that we had found obvious problems in children with dyslexia relating to both language functions and visuo-spatial memory, we did not obtain an acceptable model of multiple regression that would indicate relations between language functioning and visual or visuo-spatial memory in this group of children. Apparently the below-normal scores achieved by these children in the Rey-Osterrieth Complex Figure, and in the task requiring the repetition of movements backwards in the Spatial Span subtest from the WMS-III, are not associated with the level of linguistic functioning.

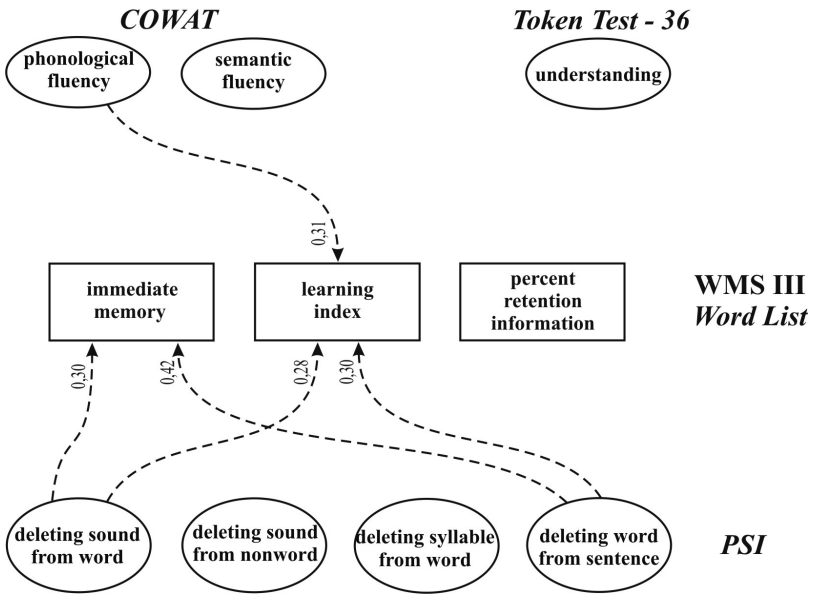

Fig. 1. Language as a moderator of memory-related processes in respect to verbal memory (measured by the Word List – WMS –III)

DISCUSSION

A language deficit, especially a phonological deficit, occurs in most persons with developmental dyslexia. Its intensity is also essential due to the moderating role it plays in the functioning of memory related processes. However, one of the most interesting results from the present study is the lack of any moderating connections between language functions and visual or visuo-spatial memory (given, of course, the existence of disturbances in both language functions and visuo-spatial memory) in the dyslexic children. This constitutes yet another argument against the narrow understanding of the pathomechanism of dyslexia as a strictly linguistic problem (Krasowicz-Kupis, 2008), or even a purely phonological deficit (cf. Snowling, 2000). A diagnosis limited to only one aspect, the linguistic, may give an incomplete picture of the actual pathogenic mechanisms, and for that reason it is essential in the process of diagnosis to evaluate not only language functions, but also visual and visuo-spatial functions (Bogdanowicz et al., 2009; Lipowska, 2011; Lipowska, et al., 2011). It may be worth mentioning in this context that there is also research indicating that disturbances of visuo-spatial functions are connected to language difficulties (cf. Facoetti et al., 2010).

Familiarity with the specific character of the cognitive functioning of dyslexic children is essential, not only for diagnosticians and therapists, but also for the teachers and parents of children with specific learning difficulties. This can be inferred from European statistics, which indicate that specific learning difficulties affect about 10-15% of the population (WHO, 1992). In the present social and cultural conditions, children have contact with writing beginning at a very young age, and without mastering the requisite skills, it is impossible to function adequately, not only in the context of education, but also in daily life.

In working with children who have developmental dyslexia, and who constitute such a large percentage of the school population, it is vital to apply specific methods that are adapted not only to the deficits, but also to the strong points of these children. While preparing teaching materials, the teacher should refer as often as possible to content clues that facilitate memory. It is also essential to refer to detailed information from the diagnosis, so as not to treat all children with the diagnosis of “specific learning difficulties” in exactly the same way, and to appreciate the heterogeneity of the problems experienced by this group. In particular, differing educational and therapeutic interventions should be planned for children with a dominant phonological deficit and those with more intense visuo-spatial problems.

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