European Journal of Special Education Research
ISSN: 2501 - 2428
ISSN-L: 2501 - 2428
Available on-line at: www.oapub.org/edu

doi: 10.5281/zenodo.3464718 Volume 5 | Issue 1 | 2019

WORKING MEMORY AND LEARNING DIFFICULTIES: COEXISTENCE OR A STRONG RELATIONSHIP?

Victoria Zakopoulou[1],
Dimitrios Sarris[2],
Charalampos Zaragkas[3],
Evangelos Tsampalas[4i],
Maria Vergou[5]
[1]Department of Speech and Language Therapy, University of Ioannina, Greece
[2] Laboratory of Special and Curative Education, University of Ioannina, Greece
[3]Department of Preschool Education, University of Ioannina, Epirus, Greece
[4]Elementary School Teacher, Cyprus
[5]Preschool Teacher, Epirus, Greece

Abstract:
This research paper addressed the relationship between Learning Difficulties and Working Memory of a sample of primary students in 10 schools at 4 cities of Cyprus. Students with poor working memory have a low academic achievement, facing difficulties in reading and mathematical thinking. The main objective of the current research is to investigate the possibility of a causative interaction between working memory and the occurrence of learning difficulties in primary school students. Evaluating working memory in students with SLD, the analysis showed that it was significantly lower (p=,000), indicating a strong correlation between working memory and learning difficulties. Specifically, the analysis revealed a statistically significant correlation (p≤.001) between working memory and the variables of digit span, picture memory, pattern memory, grapheme discrimination, phoneme discrimination, and phoneme composition. Adding to the research, the current study stress that in students with learning difficulties the deficits in working memory are in a strong relationship

[i] Correspondence: email tsampalasangelos@gmail.com

with difficulties in specific types of both Sequence Working Memory and Grapheme-phoneme's Awareness.

Keywords: working memory, learning difficulties

1. Introduction

1.1 Memory

The term "memory" is commonly used (a) as a mental record of experiences and (b) as a process of recovering these recorded experiences. Both of these definitions have shortcomings (Lieberman, 2012). Memory refers to one's ability of man to encode, store, maintain, and whenever necessary to recall information and experiences of the past recorded in the brain (Boyer & Wertsh, 2009).

A brain whose composition resembles a hierarchically structured network composed of different functional areas (Shepherd, 1997).

Spear & Riccio (1994) gave to the word "memory" the following three definitions:

1) the location where the information is kept;
2) the area that retains the contents of the experiences;
3) the process one uses to learn (acquire), store, or retrieve (remember).

For Gruber (2011), memory refers to processes and systems that are responsible for storing, retrieving and using information when the original source of information is unavailable. Acquiring information, learning and storing it, allows the person to repeat it successfully, avoiding the mistakes in the information he has gained. However, from the past we remember a very small percentage given that only about 1% of our experiences are stored in the long-term memory (Walker et al., 2002).

According to the American psychologist Eudel Tulving (2006), we are the only living beings able to remember episodes of the past and anticipate future events by deliberately planning their actions.

Essentially, there are three main processes of memory: encoding, storage and retrieval (Cherry, 2018).

- encoding: the information enters a person's memory and creates its own trace;
- storage: the information trace is stored in the memory;
- retrieval: the person recalls the trace, re-activates the experience (Dudai, 2002)

The above processes are not necessarily separate stages that occur sequentially, but represent the process of memory (Forde et al., 2012)

Nevertheless, the mechanism of memory remains one of the great and unresolved problems (Lieberman, 2012; Poo et al, 2016) There are times when we cannot re-activate we once remembered. We may forget things that we have experienced and learned but that we have not eventually stored in our minds (Kelly, 2016). According to the theories of interference, of the 1950s and 1960s, people forget events due to the occurrence of other intrusive events (Crowder, 2015). More recent theories, however, "justify" forgetfulness by giving responsibility to the overloading of recovery points, which in fact is an adaptive aspect of memory (Storm, 2011).

1.2 Working Memory

The cognitive mechanism of working memory is present in almost every kind of routine activity and is changing progressively between the ages of 5 to 17 (Alloway & Alloway, 2013). It is independent of the social background of the individual, the economic situation in which he / she is, the educational level of the parents (Alloway et al., 2014), while it is automatically affected by any experience affecting the executive system (Best & Miller, 2010). Nonetheless, it is a basic function for a wide range of cognitive abilities, such as reading or numeracy skills that are highly dependent on working memory (Swanson & Kim, 2007).

Every day we have the need to keep a moment of time in our memory, critical elements, by storing them until we use them. For example, storing a phone number from the moment we hear it until we call it or retention of information to move from one point to our destination or to measuring and use the right quantities of materials (e.g. shuffler 50 gr of butter with 100 grams of flour and add 75 grams of sugar) when we read a recipe but we cannot look at it anymore (Gathercole & Alloway, 2007). All these short-term storages and use functions do well reflect the term of "Working Memory" (Young, 2000). Baddeley (2007) describes working memory as a brain function that retains, handles and processes temporary information required to perform tasks at any time. It is considered by many to be the "workplace" due to its central role in language processing, thought, and action. It has attracted the attention of researchers because of its importance in cognitive function (Romon & Pison, 2011).

Moreover, with the term of “phonological loop” Baddeley (2007) signified the core significance of working memory in the acquisition of grapheme-phoneme correspondence and hence to reading and writing skills (Steinbrink & Klatte, 2008).

Subsequently, many activities that take place in the classroom and require the students to perform a lot of actions at the same time (e.g. listening to the teacher's instructions, while copying proposals from the board), underline the implementation of working memory (Ghani & Gathercole, 2013; Johnson, Perry & Shamir, 2010).

The difference between short-term and long-term memory is that the first keeps information for a few seconds while the second keeps the processed information permanently. The working memory could be said to be an intermediate memory system in the brain that process the information kept for a few seconds (short-term memory) while transferring it to long-term memory (Young, 2000). It is divided into: (a) verbal (or acoustic) working memory, in which words and numbers are transformed into phonemes being stored for a short time, and (b) visual working memory, in which objects images are stored for a longer period of time, capable of processing our minds. (Habeck et al., 2012)

1.3 Learning Difficulties

Memory and learning are two closely related concepts, although not identical (Sumrall et al., 2016). Learning is the acquisition of skills or knowledge, while memory is the expression of knowledge. Differences between them also exist in the speed at which

they occur. According to the American Psychiatric Society, acquiring a skill slowly but deeply is learning. Direct acquisition is memory (APA, 2016).

The same pattern is shared by the view of Gazzaniga and his colleagues, who define learning as the "*process of acquiring new knowledge*" and memory as "*the insistence on learning*" (Gazzaniga et al., 2015).

Lieberman (2012) describes learning as a change in our behavior due to the acquisition of experience. In cognitive - psychological and constructivist models, learning is described as an information processing, which leads to the construction of new knowledge structures with the continuous completion and change of existing structures (Zollneritsch et al., 2012).

According to the United States National Center of Learning Disabilities (2014), Learning Disabilities is a general term that refers to a heterogeneous group of disorders resulting from severe difficulties in learning and using speech, reading, writing, logic thinking, and mathematical competences, while they are focused on dysfunction of the central nervous system (Case – Smith & Obrien, 2014; Pesova et al, 2014; Rose, 2009).

Difficulty in learning can be seen as deficiency or failure of students in school requirements (Weiss, 1992). These issues of inadequacy or failure can be analyzed from a variety of perspectives: learning conditions, socio-political and economic situations, ideologies but also quality of teaching, methodologies, and teacher training (Zakopoulou et al., 2013). However, the student's individual capacity and disposition (Weiss, 1992) cannot be absent from the analysis. The presence of emotional and behavioral disorders makes difficult to diagnose learning difficulties, while students with such characteristics are at high risk of school failure (Hinshaw, 1992).

For Zielinski (1998, p.13), "*learning difficulties are generally referred to when a student's achievements are lower than tolerable deviations from binding, institutional, social, and individual reference standards, or when the attainment (or failure) of standards is linked to weights that lead to undesirable side effects in behavior, experience or development of the trainee's personality*"). Adding to this, students with learning difficulties come to the fore as a result of apparent or inappropriate behavior, expression, unclear, mainly emotional or emotional conflicts (Lehmann & Eitmann, 2014).

Dumant (1994) separated the learning problems into two types: learning disabilities found in cognitive development of students and learning difficulties due to other child problems, but also beyond. It should be mentioned here that in many countries the term learning disabilities has been associated with the term learning difficulties (Martins, 2008).

In the UK educational community, the term "learning disability" refers to students who have specific learning difficulties (e.g. dyslexia) and do not experience mental problems. Differently, "*learning difficulties*" are described as "*moderate learning difficulties*", "*severe learning difficulties" and "deep learning difficulties*" (Department of Health and Social Care, England, 2010).

Beyond the general name dispute, students with learning difficulties are quite common in schools and range from 12% to 30% of the school population (Westwood, 2014).

Students with learning difficulties are distinguished by general characteristics, such as limited metacognitive skills, organizational difficulties, adaptation and orientation difficulties, and inadequate control (Fletcher, 2012; Anastasiou & Polychronopoulou 2009).

The particular characteristics of students with learning difficulties are:

- Reading deficits are more observable than any other problem in academic performance, while it is estimated that 90% of students with learning difficulties have reading difficulties (Bender, 2008). In particular, the reading readiness problems were defined as the rate of reading (correct words per minute) (Hunt & Marshall, 2006).
- The lack of understanding of what they read and this leads to difficulty in answering questions about the text they have just read (Friend, 2005). Problems with word recognition make difficult for students to understand what this refers to writing difficulties or skip words in writing or even to read words in the wrong order (Gargialo & Kilgo, 2013).
- Deficits in academic attainment in which students with learning difficulties have an unexpectedly slower learning rate. Students with literacy problems also exhibit serious weaknesses in the central strain and in the phonological loop that is evaluated by recalling, for example, digital sequences (Machler & Schuchardt, 2016). However, no weaknesses are necessarily present in the visual-spatial design that is evaluated by the retraction of visual shapes or of motion sequences (Gathercole & Alloway, 2008).

1.4 Working Memory and Learning Difficulties

The poor skills of working memory are relatively common in childhood although students can be supported in their learning needs when they are affected by this problem. The majority of students with deficient working memory experience problems in reading, mathematics and science throughout primary and secondary education (Gathercole, 2014).

But how does a problem in working memory affect learning? Gathercole & Alloway (2007) believe that students with a problem in their working memory experience learning difficulties because they are unable to meet the memory requirements of many structured learning activities, resulting in the re-word of working memory and the loss of critical information needed to complete activities (e.g. Gathercole et al., 2003).

With respect to the relationship between working memory and mathematical abilities, we should take in account that these correlations vary with age and the level of specialist knowledge (Swanson & Saez, 2003). Mathematical deficits are persistent and difficult to compensate over time (Niaz & Logie, 1993).

Researchers have questioned whether working memory being associated with learning difficulties is also related with IQ (Alloway & Gathercole, 2006). Answering to this, research has shown that the peculiarity of correlations between working memory

and success continues, since differences in IQ have been statistically examined in students (Gathercole et al., 2006).

Alloway et al. (2009) suggest that the memory profile differs according to the type of learning difficulties, indicating that students with ADHD are short on behind in visual memory, while previous research has shown that learning difficulties are related to all memory areas (Alloway & Archibald, 2008).

Summarizing, students with deficient working memory capacity face difficulty coping with the multiple demands imposed in the process, such as: writing slow and painful (Lesaux & Siegel, 2003), being aware of phonemes' and words' construction, struggling early (Hooft et al., 2007) in mathematics and problem solving (D' Amico & Guarnena, 2005). It is also well supported that working memory is a reliable indicator of mathematical difficulties during the first year of formal education (Gersten et al., 2005).

All in all, survey findings show that the best way to break the vicious circle of low-performance students' learning problems is to use methods that improve their working memory during writing and reading, relieving them as much as possible more (Alloway, 2014).

2. Purpose of the Survey

The main objective of the current research is to investigate the existence of a strong interaction between working memory and the occurrence of learning difficulties in primary school students.

3. Methodology

This survey was carried out between January 2018 and June 2018 on a sample of 60 students from 10 elementary schools of cities Nikosia, Larnaka, Limassol and Paphos.

3.1 Participants

The sample was selected by random stratified selection and randomization, resulting in the performance of qualitative and quantitative research (Cohen et al, 2007), consisting of two groups. 30 students diagnosed with SLD (they were attended integration classes) composed the working group (LDG), while 30 students of typical learning composed the control group (CG). The mean age for the LDG group was 96.0±5.8 months (range 88 to 113 months) whereas for the CG 93.3±3.4 (range 87 to 100 months), recording a statistically significant difference (Age LDG vs CG p=0.044). Three students in LDG repeated the class. The LDG consisted in 16 boys and 14 girls and the CG 15 boys and 15 girls. The majority of the parents were Greek-Cypriots (Table 1).

Table 1: Sample demographic characteristics

		LDG	CG
Gender	Male/ Female	16/14	15/15
Father	Greek-Cypriot	29	26
	Foreign	1	3
Mother	Greek-Cypriot	28	27
	Foreign	2	3
Father-Occupation	Freelance	15	13
	State employee	6	7
	Private employee	5	10
	Unemployed	4	0
Mother-Occupation	Freelance	3	1
	State employee	4	14
	Private employee	15	13
	Household	8	2

3.2 Tools

Two diagnostic tools were used in the research process: (a) The Working Memory Rating Scale (WMRS), Greek edition (Politimou, Masoura & Kioseoglou, 2015), to measure the working memory of the students and (b) the ATHINA Test, also Greek edition (Paraskevopoulos & Paraskevopoulou, 2011), to determine the occurrence of learning difficulties in specific domains, such as working memory and grapheme-phoneme awareness.

The WMRS is considered to be a commonly applied standardized tool developed on Baddeley's working memory model, with a graded scale of behavior for teachers, targeted to recognize students (5 to 11 years old) with poor working memory (Alloway, Gathercole & Kirkwood, 2008). It completed quickly and results are easily interpreted in four steps: from "no formal" to "very formal". It is a reliable pre-symptom control tool (Andrade & Tannock, 2013) and has been translated into several languages (Politimou, Masoura & Kioseoglou, 2015).

It consists of 20 characteristic descriptions of student with deficits in working memory. The assessment of how characteristic each description is, it is done on a scale of four score points: (0) no typical, (1) sometimes typical, (2) fairly typical, and (3) very typical (Alloway et al., 2009).

It provides an initial, valuable step in detecting potential deficits in working memory. This first recognition can then be estimated in detail with other standardized measurements, such as the Automated Working Memory Assessment (AWMA) (Alloway, 2008).

ATHINA Test (Paraskevopoulos & Paraskevopoulou, 2011) is a test commonly used in Greek for diagnosis of learning difficulties. It is a psychometric scale that evaluates the child's level and development in 14 individual test tasks as well as in five areas of development: mental capacity, direct sequence memory, completion of incomplete representations, grapheme-phoneme's awareness, and neuroscience - psychological maturity.

It benefits from other tests because, although covering the ages of 5 to 9 years old, it can be given to older students who have "severe learning difficulties". At the

same time, it allows the evaluation of all aspects of child development that are considered important for the learning process (Paraskevopoulos et al, 1999).

The general test's statistics define the developmental age, expressed in years and months, showing the amount of maturity of the child and the growth quotient that are integers ranging from 4 to 16 with an average of 10. Similarly, the developmental quotient shows the rhythm, the speed with which the given amount has been won (Paraskevopoulos & Paraskevopoulou, 2011).

4. Statistics

The variables tested were working memory as a dependent variable, while sequence working memory and grapheme-phonemes' awareness were considered independent variables.

Testing the degree of correlation between the above variables, we tried to investigate the following research questions:

- Do students with SLD exhibit deficits in working memory?
- Is working memory correlated with specific tasks of grapheme-phonemes' awareness, such as graphemes' and phonemes' discrimination and phonemes' composition?
- Is working memory correlated with specific tasks of sequence memory, such as numbers, pictures, and schemes memory?

The performance of the participants was assessed correlating the scores in KAEM questionnaire and the scores in specified items of the ATHINA tests. Potential relationship between them was examined using the Pearson correlation coefficient. The significance level was set at 0.05 in all cases and SPSS v22.0 was used for all analyses.

5. Results

Evaluating working memory in students with SLD, the analysis showed that it was significantly lower in LDG (p =.000), indicating a strong correlation between working memory and learning difficulties (see Table 2).

Table 2: Statistically significant correlation between working memory and SLD

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	34.737[a]	2	.000
Likelihood Ratio	44.064	2	.000
N of Valid Cases	60		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 4.50.

It should be noted that we have divided the results of the Working Memory Rating Scale (WMRS) into three categories: The first category included the students with T <55 and normal working memory, in the second category with a rating of 56 <T <65 and borderline W.M and in 3rd class with T score> 65 and abnormal W.M.

We compared the working memory performance between the two groups. Table 3 presents the mean T score for the working memory assessment (KAEM). Percentages in the control group are inversely proportional to those of the working group, as all students showed normal working memory (100%), whereas in the LDG 13% of students displayed normal WM, 47% borderline, and 40% abnormal WM, respectively.

Table 3: Means (SDs) for working memory measures (KAEM) and distribution of students according to the total T score for the two study groups

KAEM

	Mean±STDEV	Grade	Normal	Borderline	Abnormal	Total
LDG	61,7±7,4*	**B**	1 (100%)	0 (0%)	0 (0%)	1
		C	3 (25%)	6 (50%)	3 (25%)	12
		D	0 (0%)	8 (47%)	9 (53%)	17
			4 (13%)	14 (47%)	12 (40%)	30
CG	46,3±2,7	**A**	8 (100%)	0 (0%)	0 (0%)	8
		B	16 (100%)	0 (0%)	0 (0%)	16
		C	6 (100%)	0 (0%)	0 (0%)	6
			30 (100%)	0 (0%)	0 (0%)	30

Note: Normal: T ≤ 55, Borderline: 56-64, Abnormal: T ≥ 65, * p < 0,05.

Aiming to test whether working memory is correlated with variables of sequence working memory and phoneme-grapheme's awareness, linear regression analysis was used (Table 4). The students' performance in three subtests(Numbers Memory, Pictures Memory, Shapes Memory) of ATHINA test regarding the domain of Sequence Working Memory and three subtests (Graphemes Discrimination, Phonemes Discrimination, and Phonemes Composition) with regard to the domain of Grapheme-phoneme's Awareness, was correlated with their scores in KAEM. The analysis revealed a statistically significant correlation between Sequence Working Memory and Grapheme-phoneme's Awareness.

Table 4: Linear regression analysis of the relationship between the 6 subtests consisting on the ATHINA test domains "Sequence Working Memory" and "Grapheme-phoneme's Awareness" and KAEM

				95% C.I.	
		B	**P**	**Lower**	**Upper**
Sequence Working Memory	Numbers Memory	-3.126	.000	-4.0	-2.2
	Pictures Memory	-2.635	.000	-3.5	-1.8
	Shapes Memory	-1.817	.000	-2.7	-0.9
Grapheme-phoneme's Awareness	Graphemes Discrimination	-1.835	.001	-2.9	-0.8
	Phonemes Discrimination	-2.459	.000	-3.1	-1.8
	Phonemes Composition	-2.241	.000	-2.9	-1.5

The statistical analysis of students' performance in ATHINA Test and in the tasks of sequence working memory, hardly are changing the conclusions . On the contrary, they reinforce the view that students with specific learning difficulties have severe deficits in Numbers Memory, Pictures Memory, and Shapes Memory (Table 5).

Table 5: Percentiles of Numbers Memory in ATHINA Test

			Percentiles						
		Group	5	10	25	50	75	90	95
Weighted Average (Definition 1)	Numbers Memory	WG	1.6500	4.0000	5.0000	6.0000	7.0000	7.9000	9.4500
		CG	7.0000	7.0000	8.0000	9.0000	10.0000	12.0000	13.9000
Tukey's Hinges	Numbers Memory	WG			5.0000	6.0000	7.0000		
		CG			8.0000	9.0000	10.0000		

By looking at Table 5 we see the existence of columns called percentiles. These columns show us the distribution of the variable Numbers Memory. The percentages are determined by dividing the values of the variable from lowest to highest. This helps us find the value of the variable at 5%, 10%, 25%, 50%, 75%, 90% and 95%. But for better study, we focus on three percent: the 25% known as the first quartile. 50%, the second quartile, which is a measure of the central voltage of the variable, also known as a mean. Basically, it is the average value of the variable when prices are in ascending (or descending) order, as in our case. It is less sensitive to extreme prices and is therefore considered better than average. Finally, 75% is also known as the third quartile.

Observing Table 5, it is realized that 25% of the students working group (LDG) had Development Quotient = 5 and 75% Development Quotient = 7. On the other side, the students in the control group have a Development Quotient = 8 (25%) and Development Quotient = 10 75%).

In Table 6 we observe that the students of the working group in the 1st quartile (25%), in the 2nd quartile (50% - intermediate) and in the 3nd quartile (75%) have a smaller Developmental Quotient (D.Q) than the control group students.

More analytically:

- In the 1st quartile (25%) the working group in Graphemes Discrimination has a D.Q = 9.75 while the control group has a CA = 12, in Phonemes Discrimination a D.Q = 4 while the control group has a CA = 4. P = 8, and in Phonemes Composition has D.Q = 6.75 while control group PA = 12.

Table 6: Percentiles of Grapheme-phoneme's Awareness in ATHINA Test

Percentiles

		Group	Percentiles						
			5	10	25	50	75	90	95
Weighted Average (Definition 1)	Graphenes Discrimination	W	4.55	8.00	9.75	11.00	13.00	14.00	15.00
		C	11.00	12.00	12.00	12.00	13.25	14.00	14.45
	Phonemes Discrimination	W	4.00	4.00	4.00	6.00	8.00	9.90	10.90
		C	6.55	8.00	8.00	10.00	12.00	12.00	13.00
	Phonemes Composition	W	4.00	6.00	6.75	9.00	10.00	10.00	11.90
		C	6.55	9.20	12.00	12.00	13.00	14.00	15.00
Tukey's Hinges	Graphemes Discrimination	W			10.00	11.00	13.00		
		C			12.00	12.00	13.00		
	Phonemes Discrimination	W			4.00	6.00	8.00		
		C			8.00	10.00	12.00		

Phonemes	W			7.00	9.00	10.00		
Composition	C			12.00	12.00	13.00		

- In the 2nd quadrant (50%), the working group in Graphemes Discrimination has a D.Q = 11, in Phonemes Discrimination a D.Q = 6 and in Phonemes Composition has D.Q = 9. The control group in Graphemes Discrimination has a D.Q = 12, in Phonemes Discrimination D.Q = 10, and in Phonemes Composition D.Q = 12.
- In the 3rd quadrant (75%), the working group in Graphemes Discrimination has a D.Q= 13, in Phonemes Discrimination has D.Q = 8, and in Phonemes Composition has a D.Q=10. The control group in Graphemes Discrimination has a D.Q = 13.25, in Phonemes Discrimination has a D.Q = 12, and in Phonemes Composition has a D.Q =13.

At this point it is good to explain that with the term Developmental Cilimus we mean the z - price group's median scale, with an average of 10 and a standard deviation of 3. Knowing the students' developmental quotients, we can decide on three themes of the psycho - pedagogic diagnostic process:

- Percentage of students in the current survey compared to other students
- The diagnostic category for students
- The intra-individual differences between the individual competences and development sectors of students assessed by ATHINA Test (Paraskevopoulos et al., 1999).

In order to make it even clearer, students are those quotients similar 9, 10 or 11 are 50% of the students of the general population and are considered to be in – normal, while students with growth quotient 7 are considered to be marginally low to inadequate, while those with a quotient 8 they are considered marginal low and account for 16% of the general population. In the present study, the students of the working group (LDG) in 50% were under development quotient 8, and respectively, the students of the control group (CG) in 50% were above the development quotient 9.

5. Discussion

It has been shown (Rothlisberger et al., 2012) that working memory, flexibility and self-restraint are considered as important factors for reading, writing and mathematical thinking skills in early-school students.

Working memory plays an important role in the learning process, in the management of instructions inside and outside the classroom (Lamont & Alloway, 2006) and in the creation of visual information (Baddelley, 2006). Students with poor working memory have a low academic achievement (Gathercole et al., 2003), facing difficulties in reading and mathematical thinking (Gathercole et al., 2008). The effectiveness of working memory in learning process has led researchers to find that many learning difficulties have a direct correlation with deficits in working memory (Alloway & Gathercole, 2006), which this study has shown. The students of the working group showed deficits in Sequence Working Memory and, according to ATHINA Test, specific deficits in Numbers Memory, Pictures Memory, and Shapes Memory. At the

same time, they met difficulties in all three subtests of the Grapheme-phoneme's Awareness domain, Graphemes Discrimination, Phonemes Discrimination, and Phonemes Composition, thus confirming that phonological awareness is highly related to reading (Blachman et al., 1994; Saksida et al., 2016).

The low performances in the WMRS and in the tasks of ATHINA test, such as Sequence Working Memory, lead to the conclusion that deficits in memory, in particular in working memory, contribute to the existence of learning difficulties. However, in order to assess the working memory, there been developed weighted tests that accurately and in detail evaluate it (Gathercole & Baddelley, 1996). Such a weighted test is WMRS (Alloway et. al., 2011) used in this research and showed with absolute clarity that the students in the research group had lower scores on the scale with 22 students being in incomplete to poor working memory and only 8 students on a satisfactory scale.

According to Alloway (2006), formal development students differ from one another to the level of working memory. In our research, students in the control group, typical students, seem to have a different level of working memory but all at a normal level (T <55) with a lower T = 42 and the highest T = 53. The students whose works of working memory are below expected performance then refer to students with deficits in working memory and problems with the *'language learning mechanism'* (Baddelley, Gathercole & Papagno, 1998). Problems, however, are also encountered in the sequence of instructions, copying, mathematics (Hitch & Mcautey 1991) and attentive attention (Martinussen & Tannock, 2006).

Adding to the research, the current study stress that in students with learning difficulties the deficits in working memory are in a strong relationship with difficulties in specific types of both Sequence Working Memory and Grapheme-phoneme's Awareness. Specifically, a complicated framework of deficits between numbers, pictures, shapes memory, phonemes' discrimination and composition, and graphemes' discrimination is delineated. Effectively, this framework constitutes working memory and grapheme-phoneme's awareness as a prerequisite for the acquisition of learning process and mostly, of reading and writing skills. As it becomes obvious, the aforementioned finding enhances the argument that working memory weaknesses are related to SLD (Catts, Gillispie, Leonard, Kail, & Miller, 2002; Preβler, Konen, Hasselhorn & Krajewski, 2014).

Consequently, the necessity of early, correct diagnosis as well as effective early intervention (Fuchs et al., 2012; Zakopoulou et al., 2011) is entirely indicated.

The general diagnosis of SLD that the participants were given, without being specified the domain of difficulty (reading, writing, etc.), was one of the main limitations of the current research. Similar diagnoses slow down the more obstacles they create for teachers, as the last do not have a clear picture of the particular difficulties, which some students may meet in specific learning areas. As a result, teachers are not provided with the appropriate tools the use of which could help these students join the classroom, enhance their self-image and empower them as much as they can to cope with these learning difficulties (Sarris et al., 2017).

For a successful participation in a society attached to education, capacity is considered to be a prerequisite. Those who cannot read and write are prevent their access to higher education, thereby reducing their job choices and their financial situation. They exclude themselves from a variety of social and recreational activities (Biewer & Schutz, 2016; Diehl, 2010).

References

Alloway, T. P (2006). How does working memory work in the classroom? *Educational Research and Reviews, 4*, 134-139.

Alloway, T. P. (2014). *Understanding Working Memory*. London: Sage.

Alloway T. P. & Gathercole S. E. (2006) *Working memory and neurodevelopmental conditions*. Hove, England: Psychology Press.

Alloway, T. P. (2008). Effective screening tools for students with working memory impairments. Retrieved from www.leeds.ac.uk%2Feducol%2Fdocuments%2F177815.doc&usg=AOvVaw35J3Y6R-kVVPmAfF0HuUe5

Alloway, T. P., & Archibald, L. (2008). Working Memory and Learning in Students with Developmental Coordination Disorder and Specific Language Impairment. *Journal of Learning Disabilities, 41*(3), 251-262. doi:10.1177/0022219408315815

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The working memory rating scale: A classroom-based behavioral assessment of working memory. *Learning and Individual Differences, 19*(2), 242-245. doi:10.1016/j.lindif.2008.10.003

Alloway T. P., Rajendran G. & Archibald, L. M. D. (2009). Working Memory in Students with Developmental Disorders. *42*(4), 372-382.

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliot, J. (2011). Evaluating the validity of the Automated Working Memory Assessment. *Educational Psychology, 31*(5), 657-657. doi:10.1080/01443410.2011.596662

Alloway, T. P., & Alloway, R. G. (2013). Working memory across the lifespan: A cross-sectional approach. *Journal of Cognitive Psychology, 25*(1), 84-93. doi:10.1080/20445911. 2012.748027

Alloway, T. P., Alloway, R. G., & Wootan, S. (2014). Home sweet home: Does where you live matter to working memory and other cognitive skills? *Journal of Experimental Child Psychology, 124*, 124-131. doi:10.1016/j.jecp.2013.11.012

Anastasiou, D., & Polychronopoulou, S. (2009). Identification and overidentification of specific learning disabilities (Dyslexia) in Greece. Learning Disability Quarterly, *32*, 55-69. doi:10.2307/27740357

Andrade, B. F., & Tannock, R. (2013). Sustained Impact of Inattention and Hyperactivity-Impulsivity on Peer Problems: Mediating Roles of Prosocial Skills

and Conduct Problems in a Community Sample of Students. *Child Psychiatry & Human Development, 45*(3), 318-328. doi:10.1007/s10578-013-0402-x

Ashbaker, M. H., & Swanson, H. L. (1996). Short-term memory and working memory operations and their contribution to reading in adolescents with and without learning disabilities. *Learning Disabilities Research & Practice, 11*(4), 206-213.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417-423. doi:10.1016/s1364-6613(00)01538-2

Baddeley, A. (2007). *Working memory, thought, and action*. Oxford: Oxford University Press.

Baddeley, A. (2007). Introduction and overview. *Working Memory, Thought, and Action,* 1-14. doi:10.1093/acprof:oso/9780198528012.003.0001

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105*(1), 158-173. doi:10.1037//0033-295x.105.1.158

Bender, W. N. (2008). *Learning disabilities: Characteristics, identification, and teaching strategies*. Boston, MA: Pearson/A & B.

Berger, N. & Schneider, W. (2011). Verhaltensstörungen und Lernschwierigkei- ten in der Schule: Möglichkeiten der Prävention und Intervention. Stuttgart: UTB.

Best, J. R., & Miller, P. H. (2010). A Developmental Perspective on Executive Function. *Child Development, 81*(6), 1641-1660. doi:10.1111/j.1467-8624.2010.01499.x

Biewer, G. & Schütz, S. (2016). Inklusion. In I. Hedderich, G. Biewer, J. Hollenweger & R. Markowetz (Hrsg.), *Handbuch Inklusion und Sonderpädagogik* (S. 123–127). Bad Heilbrunn: Klinkhardt.

Blachman, B. A., Ball, E. W., Black, R. S., & Tangel, D. M. (1994). Kindergarten teachers develop phoneme awareness in low-income, inner-city classrooms. *Reading and Writing,6*(1), 1-18. doi:10.1007/bf01027275

Boyer, P., & Wertsch, J. V. (2009). *Memory in Mind and Culture*. Cambridge: Cambridge University Press.

Case-Smith, J., & OBrien, J. C. (2014). *Occupational therapy for students*. St. Louis: Mosby.

Catts, H. W., Gillispie, M., Leonard, L. B., Kail, R. V., & Miller, C. A. (2002). The role of speed of processing, rapid naming, and phonological awareness in reading achievement. *Journal of Learning Disabilities, 35*(6), 510-525.

Cherry, K. (2018). A Deeper Look Into Human Memory. Retrieved from https://www.verywellmind.com/what-is-memory-2795006

Cohen, L., Manion, L., & Morrison, K. (2007). Research Methods in Education (6th ed.). London and New York, NY: Routledge Falmer

Crowder, R. G. (2015). *Principles of learning and memory*. New York: Psychology Press.

Damico, A., & Guarnera, M. (2005). Exploring working memory in students with low arithmetical achievement. *Learning and Individual Differences, 15*(3), 189-202. doi:10.1016/j.lindif.2005.01.002

Department of Health and Social Care. (2010, November 30). Healthy Lives, Healthy People: Our strategy for public health in England. Retrieved from

https://www.gov.uk/government/publications/healthy-lives-healthy-people-our-strategy-for-public-health-in-england

Diehl, K. (2010). Lesen- und Schreibenlernen. In B. Hartke, K. Koch & K. Diehl (Hrsg.), *Förderung in der schulischen Eingangsstufe* (S. 55–90). Stuttgart: Kohlhammer.

Dudai, Y. (2002). *Memory from A to Z: Keywords, concepts, and beyond*. Oxford University Press New York:

Dumont, R., Whelley, P., Comtois, R., & Levine, B. (1994). Test of Memory and Learning (TOMAL): Test review. *Journal of Psychoeducational Assessment 12* (2), 414–423

Fletcher, J. M. (2012). Classification and Identification of Learning Disabilities. *Learning About Learning Disabilities,* 1-25. doi:10.1016/b978-0-12-388409-1.00001-1

Forde, E. M., & Humphreys, G. W. (2012). *Category specificity in brain and mind*. Hove: Psychology.

Fuchs, D., Compton, D. L., Fuchs, L. S., Bryant, V. J., Hamlett, C. L., & Lambert, W. (2012). First-grade cognitive abilities as long-term predictors of reading comprehension and disability status. *Journal of Learning Disabilities, 45*(3), 217-231.

Nelwan, M., & Kroesbergen, E. H. (2016). Limited Near and Far Transfer Effects of Jungle Memory Working Memory Training on Learning Mathematics in Students with Attentional and Mathematical Difficulties. *Frontiers in Psychology, 7*. doi:10.3389/fpsyg.2016.01384

Gathercole, S. E. (2014). Commentary: Working memory training and ADHD - where does its potential lie? Reflections on Chacko et al. (2014). *Journal of Child Psychology and Psychiatry, 55*(3), 256-257. doi:10.1111/jcpp.12196

Gargiulo, R. M., & Kilgo, J. L. (2013). *An introduction to young students with special needs: Birth through age eight*. Belmont, CA: Wadsworth.

Gathercole, S. E., Lamont, E., & Alloway, T. P. (2006). Working Memory in the Classroom. *Working Memory and Education,* 219-240. doi:10.1016/b978-012554465-8/ 50010-7

Gathercole, S. E., & Alloway, T. P. (2007). *Understanding Working Memory: A classroom guide.* UK: Harcourt Assessment

Gathercole, S. E., Alloway, T. P., Kirkwood, H. J., Elliott, J. G., Holmes, J., & Hilton, K. A. (2008). Attentional and executive function behaviours in students with poor working memory. *Learning and Individual Differences, 18*(2), 214-223. doi:10.1016/j.lindif.2007.10.003

Gathercole, S. E., & Alloway, T. P. (2012). *Working memory and learning: A practical guide for teachers*. Los Angeles: Sage.

Gathercole, S. E., Alloway, T. P., Willis, C., & Adams, A. (2006). Working memory in students with reading disabilities. *Journal of Experimental Child Psychology, 93*(3), 265-281. doi:10.1016/j.jecp.2005.08.003

Gathercole, Brown, & Pickering, S. (2003). Working memory assessments at school entry as longitudinal predictors of National Curriculum attainment levels. Retrieved from https://research-information.bristol.ac.uk/en/publications/working-memory-assessments-at-school-entry-as-longitudinal-predictors-of-national-

curriculum-attainment-levels(354b0a75-a1c9-4e2f-857a-ae4226e82738)/export.html

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2003). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 18*(1), 1-16. doi:10.1002/acp.934

Gazzaniga, M. S., Ivry, R. B., Mangun, G. R., Zani, A., & Proverbio, A. M. (2015). *Neuroscienze cognitive*. Bologna: Zanichelli.

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early Identification and Interventions for Students with Mathematics Difficulties. *Journal of Learning Disabilities, 38*(4), 293-304. doi:10.1177/00222194050380040301

Geary, D. C., Hoard, M. K., & Hamson, C. O. (1999). Numerical and Arithmetical Cognition: Patterns of Functions and Deficits in Students at Risk for a Mathematical Disability. *Journal of Experimental Child Psychology, 74*(3), 213-239. doi:10.1006/jecp.1999.2515

Gelbukh, (ed.) *Computational Linguistics and Intelligent Text Processing*, *Second International Conference, CICLing 2001*, Mexico City, February 2001 Proceedings, 43–52.

Ghani, K. A., & Gathercole, S. E. (2013). Working Memory and Study Skills: A Comparison between Dyslexic and Non-dyslexic Adult Learners. *Procedia - Social and Behavioral Sciences, 97*, 271-277. doi:10.1016/j.sbspro.2013.10.233

Habeck, C., Rakitin, B., Steffener, J., & Stern, Y. (2012). Contrasting visual working memory for verbal and non-verbal material with multivariate analysis of fMRI. *Brain Research, 1467*, 27-41. doi:10.1016/j.brainres.2012.05.045

He, F., Liu, M., Yang, D., Li, M., & Doss, D. (2016). Cognitive models: Piaget, McCarthy, and organizational management. *Proceedings of the Academy of Organizational Culture, Communications, and Conflict, 21*(1), 17-22.

Hinshaw, S. P. (1992). Externalizing behavior problems and academic underachievement in childhood and adolescence: Causal relationships and underlying mechanisms. *Psychological Bulletin, 111*(1), 127-155. doi:10.1037/0033-2909.111.1.127

Hitch, G. J., & Mcauley, E. (1991). Working memory in students with specific arithmetical learning difficulties. *British Journal of Psychology, 82*(3), 375-386. doi:10.1111/j.2044-8295.1991.tb02406.x

Hooft, I. V., Andersson, K., Sejersen, T., Bartfai, A., & Wendt, L. V. (2007). Attention and memory training in students with acquired brain injuries. *Acta Paediatrica, 92*(8), 935-940. doi:10.1111/j.1651-2227.2003.tb00627.x

Hunt, N., & Marshall, K. J. (2006). *Exceptional students and youth: An introduction to special education*. Boston: Houghton Mifflin.

Johnson, E. P., Perry, J., & Shamir, H. (2010). Variability in reading ability gains as a function of computer-assisted instruction method of presentation. *Computers & Education, 55*(1), 209-217. http://dx.doi.org/10.1016/j.compedu.2010.01.006

Kim, H. H. (2004). *Learning disabilities*. San Diego: Greenhaven Press.

Lehmann, M., & Eitmann, J. (2014). *Systemische Lerntherapie Ein integrativer, beziehungs- und ressourcenorientierter Ansatz*. Heidelberg, Neckar: Carl Auer Verlag.

Lerner, J. (2005). *Learning Disabilities*. NY: Houghton Mifflin Company.

Lerner, R. M., & Steinberg, L. D. (2009). *Handbook of adolescent psychology*. Hoboken (N.J.): J. Wiley & Sons.

Lesaux, N. K., & Siegel, L. S. (2003). The Development of Reading in Students Who Speak English as a Second Language. *Developmental Psychology, 39*(6), 1005-1019. doi:10.1037/0012-1649.39.6.1005

Lieberman, D. A. (2012). *Human learning and memory*. Cambridge: Cambridge University Press.

Lustig, C., May, C. P., & Hasher, L. (2001). Working memory span and the role of proactive interference. *Journal of Experimental Psychology: General, 130*(2), 199-207. doi:10.1037//0096-3445.130.2.199.

Lyon, G. R. (1996). Learning Disabilities. *The Future of Students, 6*(1), 54. doi:10.2307/1602494

Maehler, C., & Schuchardt, K. (2016). Working memory in students with specific learning disorders and/or attention deficits. *Learning and Individual Differences,49*, 341-347. doi:10.1016/j.lindif.2016.05.007

Martinussen, R., & Tannock, R. (2006). Working Memory Impairments in Students with Attention-Deficit Hyperactivity Disorder with and Without Comorbid Language Learning Disorders. *Journal of Clinical and Experimental Neuropsychology, 28*(7), 1073-1094. doi:10.1080/13803390500205700

Murata, M., Uchimoto, K., Ma, Q., & Isahara, H. (2001). Magical number seven plus or minus two: Syntactic structure recognition in Japanese and English sentences. In Alexander

Nesbitt, J. A., Neal, L. L., & Hillman, J. W. (2018). Recreation for Exceptional Students And Youth. *Focus on Exceptional Students, 6*(3). doi:10.17161/fec.v6i3.7386

Niaz, M., & Logie, R. H. (1993). Working Memory, Mental Capacity and Science Education: Towards an understanding of the 'working memory overload hypothesis'. *Oxford Review of Education, 19*(4), 511-525. doi:10.1080/0305498930190407

Paraskevopoulos, I. N. & Paraskevopoulou, P. (2011). ATHINA Learning Difficulty Diagnostic Test. Retrieved from http://www.pi-schools.gr/download/publications/epitheorisi/teyxos17/005-039.pdf

Passolunghi, M. C. (2006). Working memory and arithmetic learning disability. In T. P. Alloway & S. E. Gathercole (Eds.), *Working memory and neurodevelopmental disorders* (pp. 113-138). Hove, UK: Psychology Press.

Pesova, B., Sivevska, D., & Runceva, J. (2014). Early intervention and prevention of students with Specific Learning Disabilities. *Procedia. Social and Behavioral Sciences, 149,* 701-708.

Poo, M., Pignatelli, M., Ryan, T. J., Tonegawa, S., Bonhoeffer, T., Martin, K. C., . . . Stevens, C. (2016). What is memory? The present state of the engram. *BMC Biology,14*(1). doi:10.1186/s12915-016-0261-6

Politimou, N., Masoura, E., & Kiosseoglou, G. (2015). Working Memory Rating Scales Utility to Identify Studentss Memory Difficulties in Diverse Educational Environments: Can It Work in Every School? *Applied Cognitive Psychology, 29*(2), 291-298. doi:10.1002/acp.3107

Preßler, A. L., Könen, T., Hasselhorn, M., & Krajewski, K. (2014). Cognitive preconditions of early reading and spelling: a latent-variable approach with longitudinal data. *Reading and Writing*, *27*(2), 383-406.

Roman, A. S. & Pisoni, D. B. (2011). Assessment of working memory capacity in young students using a modified version of Buschke's 'missing scan' task. *Poster session presented at the 5th International Conference on Memory*; York, England.

Rose, J. (2009). *Identifying and Teaching Students and Young People with Dyslexia and Literacy Difficulties* (Rep. No. 1).

Röthlisberger, M., Neuenschwander, R., Cimeli, P., Michel, E., & Roebers, C. M. (2012). Improving executive functions in 5- and 6-year-olds: Evaluation of a small group intervention in prekindergarten and kindergarten students. *Infant and Child Development, 21*(4), 411-429. https://doi.org/10.3389/fpsyg.2015.00525

Saksida, A., Iannuzzi, S., Bogliotti, C., Chaix, Y., Démonet, J.F., Bricout, L., ... & George, F. (2016). Phonological skills, visual attention span, and visual stress in developmental dyslexia. *Developmental Psychology*, *52*(10), 1503.

Sarris, D., Zakopoulou, V., & Tsampalas, E. (2017). Learning paths and learning styles in dyslexia: possibilities and effectiveness - case study of two elementary school students aged 7 years old. *European Journal of Special Education Research, 3*(1). doi: 10.5281/zenodo.1065936

Schuchardt, K., Kunze, J., Grube, D., & Hasselhorn, M. (2006). Arbeitsgedächtnisdefizite bei Kindern mit schwachen Rechen- und Schriftsprachleistungen. *Zeitschrift Für Pädagogische Psychologie,20*(4), 261-268. doi:10.1024/1010-0652.20.4.261

Share, D. L., & Leikin, M. (2004). Language Impairment at School Entry and Later Reading Disability: Connections at Lexical Versus Supralexical Levels of Reading. *Scientific Studies of Reading, 8*(1), 87-110. doi:10.1207/s1532799xssr0801_5

Shepherd, G. M. (1997). *The synaptic organization of the brain: An introduction*. (4th ed.). New York, NY: Oxford University Press.

Sumrall, W., Sumrall, R. & Doss, A. D. (2016). A Review of Memory Theory. *International Journal of Humanities and Social Science, 6*(1).

Spear, N. E., & Riccio, D. C. (1994). *Memory: Phenomena and principles*. Boston: Allyn and Bacon.

Steinbrink C., & Klatte M., 2008. Phonological working memory in German students with poor reading and spelling abilities. Dyslexia, 14(4): 271-290.

Storm, B. C. (2011). The Benefit of Forgetting in Thinking and Remembering. *Current Directions in Psychological Science, 20*(5), 291-295. doi:10.1177/0963721411418469

Swanson, H. L. (1994). Short-Term Memory and Working Memory. *Journal of Learning Disabilities,27*(1), 34-50. doi:10.1177/002221949402700107

Swanson, H. L., & Sachse-Lee, C. (2001). A Subgroup Analysis of Working Memory in Students with Reading Disabilities. *Journal of Learning Disabilities,34*(3), 249-263. doi:10.1177/002221940103400305

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

Swanson, L., & Kim, K. (2007). Working memory, short-term memory, and naming speed as predictors of students mathematical performance. *Intelligence,35*(2), 151-168. doi:10.1016/j.intell.2006.07.001

Swanson, H. L., Harris, K. R., & Graham, S. (2014). *Handbook of learning disabilities*. New York, London: The Guilford Press.

Tulving, E. (2006): Das episodische Gedächtnis: Vom Geist zum Gehirn. In: Welzer, H., & Markowitisch, H.-J.: Warum Menschen sich erinnern können. *Fortschritte der interdisziplinären Gedächtnisforschung.* Stuttgart: Klett-Cotta.

Viki, A., & Papanis, E. (2008). ATHINA Test. Retrieved from http://epapanis.blogspot.com/2007/11/blog-post.html

Walker, M. P., Brakefield, T., Morgan, A., Hobson, J. A., & Stickgold, R. (2002). Practice with sleep makes perfect: sleep-dependent motor skill learning. *Neuron, 35,* 205–211.

Westwood, P. (2014). *Learning and learning difficulties: A handbook for teachers*. Abingdon, Oxon: Routledge, Taylor & Francis Group.

Young, L. M. (2000). Working Memory, Language and Reading. Retrieved 17 October 2018 from http://www.brainresearch.us/Working_Memory.pdf

Zakopoulou, V., Pashou, T., Tzavelas, P., Christodoulides, P., Milona, A., Kolotoura, I. (2013). Learning difficulties: A retrospective study of their co morbidity and continuity as indicators of adult criminal behavior in 18 to 70-year-old prisoners. *Research in Developmental Disabilities*, 34(11), 3660-3671.

Zakopoulou V., Anagnostopoulou A., Christodoulides P., Stavrou L., Sarri I., Mavreas V., Tzoufi M. (2011). An Interpretative Model of Early Indicators of Specific Developmental Dyslexia in Preschool Age. A Comparative Presentation of Three Studies in Greece. *Research in Developmental Disabilities*, *30*, 3003-3016.

Zielinski, W. (1998). *Lernschwierigkeiten: Ursachen - Diagnostik - Intervention*. Stuttgart: Kohlhammer.