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Research Article

Children 'at Risk' of Specific Learning Disorder: Individualized Diagnostic Profiles and Interventions

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Abstract

Background: The development of individualized diagnostic profiles of children 'at risk' of Specific Learning Disorder (SLD) and the implementation of a well-suited to individual's specific needs intervention program, could be of high significance for the early investigation of SLD.

Materials and Methods: We assessed twenty children 5.4 to 6.0 years old aiming to the accomplishment of the following key-milestones: (a) implementation of an adequate cluster of diagnostic procedures, (b) formulation of individualized diagnostic profiles 'at risk' of SLD, and (c) implementation of intervention program, tailored to the individual's profile.

Results: According to the results, early extent of weaknesses was determined in the domains of working memory ($p = .010$), visuo-spatial abilities ($p = .028$), and phonological awareness ($p < .001$).

Conclusions: Consequently, three profiles 'at risk' of SLD emerged in a multifaceted complexity, indicating weaknesses in the above domains. A well-structured 8-month early intervention program resulted in high improvement of the intervention group's progress (p=.001).

Keywords: Specific Learning Disorder; Early Individualized Diagnosis and Intervention; Working Memory; Phonological Awareness; Visuo-spatial Abilities

Abbreviations

ND: Neurodevelopmental Disorders; DSM-5TM: Diagnostic and Statistical Manual of Mental Disorders; SLD: Specific Learning Disorder; SLI: Specific Language Impairment; CBCL: Child Behavior Checklist; WPPSI-III: Wechsler Preschool and Primary Scale of Intelligence; IQ: Intelligence Quotient; EDIT: Early Dyslexia Identification Test

Introduction

With the term 'Neurodevelopmental Disorders' (ND) a broad range of conditions was firstly introduced in American Psychiatric Association's fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5TM). They 'manifest early in development, often before the child enters grade school, and are characterized by developmental deficits that produce impairments of personal, social, academic, or occupational functioning' [1]. Under this category, six disorders are comprised, such as Intellectual disability, Communication disorders, Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder, Neurodevelopmental motor disorders, and Specific Learning Disorder (SLD) [2].

SLD is a multifactorial neurodevelopmental disorder, caused by dysfunctions of one or more biological, neurological, cognitive, psycho-emotional [3], and/or linguistic domains [4] that affect the individual's ability to acquire one or more specific learning or academic skills, such as reading, written expression, and mathematics [5].

Relevant literature reviews also report additional deficits in both understanding and cognitive mechanisms of working memory, perception and attention [6]. With regard to the DSM-5TM classification, SLD is considered as a single overarching diagnostic category [7]. However, available research findings suggest that different subtypes of SLD (e.g. impairment in reading and in mathematics, with which the terms 'dyslexia' and 'dyscalculia' are consistent, respectively) share weaknesses in cognitive functions, such as working memory [8], phonological processing [9], and visuo-spatial abilities [10].

Based on the above conceptual approach, in this paper we opted to use the term SLD as a more comprehensive term than 'dyslexia' or 'dyscalculia'. We believe that the early features of SLD are more representative of our aims to investigate whether the aforementioned weaknesses constitute individualized diagnostic preschool profiles of SLD that could help us design an effective intervention program.

Early diagnosis and intervention

In preschool years, SLD is preceded by delays in attention, language, or motor skills [1]. Usually, children 'at risk' of SLD manifest (a) poor mobility, delayed spatio-temporal orientation [11]; (b) atypical lateralization of lexical processing [12]; and (c) difficulties with drawing, differentiating elements and blending them into a whole, the use of prepositional phrases, phonological working memory, time management, learning to read and write their own names, linguistic perception and sound deletion, and pronunciation [13].

According to recent studies, children with significant difficulties in working memory tend to perform poorly in a variety of cognitive, academic, and behavioral tasks [14], including the reading process [15].

However, identifying factors in the earliest occurrence of SLD is not easy for the children or their families, as the symptoms may not be always obvious and the assessment process can be multi-stepped, frustrating and time-consuming [16,17]. Assessment should include individualized screening and diagnosis, along with further information gathering steps in order to determine the

SLD's clinical profile, as well as a systematic, intensive, individualized intervention plan [18]. It is crucial to emphasize that the symptomatology of developmental disorders may fluctuate over time. The diagnosis depends on specialists' theoretical approaches, which often happen to differ, thus resulting in the "emergence" of different types of disorders or in one's inability to accept their comorbidity. Consequently, this raises concerns about the accuracy of both diagnoses and the proposed interventions [19].

Moreover, a process of a valid and timely systematic evaluation should be formed at an individual level in order for proper and effective interventions to be established. As Fuchs., *et al*. (2012) [20] suggest, an effective individualized intervention plan should be based not only on cognitive deficits, but also on children's potential. It is suggested that the earlier remedial interventions are applied, the more longitudinally effective for children with SLD they will be [21].

All in all, the intervention for SLD should be multi-factorial and also adaptable to other shortcomings and potential disabilities of the child. The therapist should be flexible, using whatever approach is considered appropriate for the child. As Petretto and Masala (2017) [22] aptly mention, three key elements should be taken into account for the definition and implementation of any kind of intervention for SLD: the specific phase of the individual's life, specific instrumental academic abilities, and specific cognitive and neuropsychological functions.

Objectives

Based on the above theoretical principles, the main aim of the current pilot study was to evaluate the effectiveness of individual profiling in appropriate intervention for SLD at the preschool age.

Conceptually, in the proposed research, specific domains of SLD structure were investigated that are considered (DSM-5TM) to be potentially dysfunctional and re-trainable, as follows: (a) working memory (series of numbers, pictures, and shapes), (b) visuo-spatial abilities (copying shapes; sketching; graphemes discrimination; writing a word), and (c) phonological awareness (phonemes composition and discrimination).

In this perspective, we designed a well-structured methodological approach in order to reach the following three key-milestones: (a) implementation of a cluster of adequate diagnostic procedures for determining the early extent of particular difficulties, (b) formulation of individualized diagnostic profiles, and (c) construction and implementation of early intervention programs, tailored to the individuals' diagnostic profiles.

Aiming to achieve the above milestones, we posed the following research questions:

- Are weaknesses observed in the domains of working memory, phonological awareness, and visuo-spatial abilities related to the weaknesses of cognitive profile of SLD in its early occurrence?
- Is the individualized assessment of SLD suggested as appropriate for an accurate and concrete early diagnosis and a relative effective intervention for SLD?

Method

The methodological approach we developed includes the following phases:

- Definition of the sample
- Implementation of a comprehensive diagnostic procedure
- Identification of children being 'at risk' of SLD as well as selection of the intervention and the control group
- Elicitation and formulation of specific diagnostic profiles
- Designing and implementation of an appropriate intervention program, tailored to individuals' needs, as illustrated in the diagnostic profiles
- Evaluation of the intervention group's progress in two phases: intermediate, at the end of the 3rd month from the beginning of the intervention, and final, at the end of the 8th month of the applied intervention
- Comparison of the performance between intervention and control group, upon completion of the intervention program

It is worth noting that both the evaluation and the intervention processes were implemented at the laboratory of New Approaches in Developmental Disorders of the University of Ioannina by one psychologist and four speech pathologists, who were blind to the children's allocation.

Participants

The whole survey complied with ethics, as adopted by the General Assembly of the World Medical Association [23], and has been approved by the Scientific Council of the University Hospital of Ioannina.

All the participants were recruited from the Health and Care Center at the University Hospital, where children and adolescents are referred to for clinical reasons related to neurodevelopmental disorders.

The main criteria for participation in the study were that the children needed to be Greek, monolingual, 5-6 years old (the average of the sample was 65 months and 20 days), and attending kindergarten school (the sample was in the 2nd year of the kindergarten school). As our target was a homogeneous clinical picture of the sample, we excluded children with intellectual disabilities, Autistic Spectrum Disorder (ASD), Specific Language Impairment (SLI), and any neurological disorder.

Based on children's initial diagnoses received from the Health and Care Center, only 20 of those children were found to fulfill the above criteria. These children were asked to participate in the current pilot study, in the implementation of an 8-month intervention program, and in the final evaluation. The participants' parents were asked to sign a consent form, thus agreeing to their child's participation, and were informed that no personal information would be publicized, while they had the right to withdraw their child from the survey at any given time.

All parents agreed to allow their children to participate in the initial and the final diagnosis, while only 12 agreed to their children's participation in the intervention phase of the survey.

It is worth mentioning that the aforementioned exclusionary procedures, the homogeneity of the sample regarding age and education, and the obligation to obtain the parents' consent, were all considered prerequisites, thus limiting the final sample size. However, a small sample size could be considered [24] appropriate for this pilot study, whose target was not only to identify early cognitive profiles of SLD, but mainly to apply individualized intervention programs suited to these profiles for a period of 8 months.

Materials

Aiming at a comprehensive and accurate identification of the children's individual difficulties and a more effective intervention, we implemented appropriate diagnostic measurements, as well as adequate intervention methods, as follows.

Developmental history

The following information was derived from the personal history: father's and mother's age, pregnancy duration, findings of prenatal U/S and nuchal translucency, exposure to harmful factors during pregnancy, delivery procedure, birth weight and head circumference, medical problems during the neonatal period, and developmental milestones.

Based on the data from the developmental history, no evidence was found to indicate problems during pregnancy or the children's early life, and no deviations in the achievement of the kinesthetic and speech developmental stages were recorded. However, in all histories there were references regarding delays in the production of one or more phonemes as well as difficulties in phonological development.

The child behavior checklist (CBCL)

In order to assess the occurrence of behavioral and/or emotional problems, the parents of all the participating children were asked to complete the Greek version of the Child Behavior Checklist for Ages 1½ to 5 (CBCL 1½–5), one of the forms included in The Achenbach System of Empirically Based Assessment (ASEBA) [25]. ASEBA is a multi-level system assessing externalizing and internalizing behavior problems as well as competencies. The CBCL (1½–5) form provides scores creating profiles classified in normal, borderline and clinical ranges for Total Problems, Internalizing, Externalizing, and 7 syndromes: Emotionally Reactive, Anxious, Depressed, Aggressive Behavior, Attention Problems, Somatic Complaints, and Withdrawn.

The CBCL (1½–5) forms were used in the initial assessment while no profiles in clinical ranges were reported (only two cases' profiles were ranked as borderline) [26].

Diagnostic tests

Three specific, standardized to Greek conditions, diagnostic tests were used in combination, providing measurement and eval-

uation of intelligence (verbal and performance scales), motor abilities, as well as language and cognitive skills at pre-school age. The combined use of these tests yielded the comprehensive identification of learning difficulties in their early onset, contributing to the formulation of individualized diagnostic profiles, thus informing well adapted intervention programs.

Intelligence test

The Greek edition of Wechsler Preschool and Primary Scale of Intelligence [27] was administered. WPPSI-III is aimed at children aged 2.6 to 7.3 years. Specifically, it refers to infancy up to the first school age and examines a variety of the child's cognitive skills, as follows: (a) the Verbal Scale includes general concepts, mathematical thinking, problem-perception similarities, and (b) the Performance Scale includes image completion, labyrinths, geometric shapes, color matching, and cube shapes. WPPSI-III includes a variety of modules to measure the various aspects of the child's cognitive functioning.

It consists of modules divided into three categories: the main ones that are mandatory for calculating verbal performance and intelligence index, the complementary ones that provide information on cognitive abilities, and the optional ones that detect cognitive functions. Modules are administered in a specific sequence depending on the age of the child.

Due to the fact that the sample consisted of children over 4 years of age, only the subtests targeted at higher age-range grouping were considered, as follows: design copying, information, visual distinction, vocabulary, image categorization, symbol search-matching, word finding, coding, understanding (general knowledge), image observability, similarities, lexicon understanding, puzzles, and image naming.

The test was administered at the initial evaluation stage of the current survey to the whole sample (control and intervention group). Interestingly, 8 out of 20 participants reported a deviation of 18 points between Verbal (the lower score) and Performance Quotient, with the general Intelligence Quotient (IQ) maintaining at normal levels.

Tests of early learning disorders

Two screening tests were applied:

- **Early Dyslexia Identification Test [28]:** EDIT is a screening tool (mean degree of reliability 0.98) that was created to respond to the identification of early signs and trends of the occurrence of developmental dyslexia in kindergartners (5.4 to 6 years old). It is a 20-minute individually administered test, and all material is provided to the examiner in a specific order during the test's implementation. Three sectors, related to developmental dyslexia's profile, are evaluated: (a) Visuo-spatial Abilities, (b) Phonological Awareness, and (c) Working Memory.
- **ATHINA Test [29]:** ATHINA is a diagnostic test of difficulties in learning (mean degree of reliability 0.85), referring to children aged 5 to 8 years. It consists of fourteen main subtests and one complementary. It evaluates a wide range of cognitive, perceptual, psycholinguistic, and motor processes. These subtests identify the growth rate focusing on the following five sectors: (a) Verbal Intelligence, (b) Working Memory, (c) Integration of Incomplete Performances, (d) Grapho-phonological Awareness, and (e) Neuro-psychological Maturity.

Both the EDIT and ATHINA tests were administered at three evaluation stages: (a) initial (control and intervention group); (b) intermediate (intervention group: after four months); (c) final (control and intervention group: after eight months).

Intervention methods

In accordance with the individuals' difficulties, as reflected in their cognitive profiles, the following two intervention methods were considered as the most helpful in constructing the individual's intervention program that was applied in a period of eight months.

ProAnaGraPho method [30] is an intervention method guided to support children between 5-7 years old with early occurrence of neurological developmental disorders, including SLD. A total of 79 exercises are designed, aiming at the acquisition of 11 sub-sectors that compose three main sectors, such as: (a) Visuo-spatial Abilities (six sub-sectors are included: Body Shape, Spatial Orientation, Temporal Sequences, Right-left Discrimination, Ordering, and Visuo-motor coordination); (b) Working Memory (three sub-sectors are included: Visual Working Memory, Audio Working Memory,

and Sequence Working Memory); (c) Grapho-phonological Awareness (two sub-sectors are included: Phonological Awareness and Phoneme-grapheme Correspondence). The implementation of ProAnaGraPho lasted for eight months.

Graphogame method [31] is a computerized intervention game targeted to the acquisition of reading skills. Graphogame is designed to provide intensive training, for the rapid recognition of the graph-to-voice relationship and further reading skills, with the aim to enhance children overcoming the difficulty of storing/retrieving information that prevents the development of reading skills. The process of the game starts from the letter-level, progressing to the syllable and ending at the word-level. Children learn the alphabet and its sounds through this process. The Greek version of Graphogame [32] was applied from the 4th month of the intervention period in combination with the Grapho-phonological Awareness sector of the ProAnaGraPho method.

Procedure

Defining the tested variables

The common variables tested in this survey, which were included in both diagnostic tests (EDIT and ATHINA), derived from the following tasks (Table 1):

- **Verbal Intelligence:** Evaluates children's verbal intelligence by testing the degree of their understanding and use of vocabulary, and their ability to analyse and correlate words with rational thinking.
- **Working Memory:** Evaluates children's ability to retrieve symbols (numbers, pictures, shapes) from short-term and working memory, without any logical interrelation.
- Phonological Awareness: evaluates children's acquisition of phonemes awareness with regard to their ability to compose and discriminate phonemes.
- **Visuo-spatial Abilities:** Evaluates children's acquisition of spatial and logico-mathematical knowledge (visuo-spatial attention) through sketching and copying shapes, whilst testing their ability to discriminate graphemes, and consequently write their name.

Defining the pre-schoolers 'at risk' of SLD

The main selection criterion for children being 'at risk' of SLD was considered to be their overall low performance on the EDIT test (t <20). The low performance on the ATHINA Test was also taken into consideration, adding to the formulation of a comprehensive diagnostic profile of each participant.

Variables	Verbal Intelligence		Short-term Sequence Memory		Visuo-spatial Abilities		Phonological Awareness	
Tests	ATHINA	EDIT	ATHINA	EDIT	ATHINA	EDIT	ATHINA	EDIT
Tasks	VC	-	NM	-		S	PhD	PhD
	V	-	PM	-	CSh	CSh	PhC	PhC
			ShM	-	GD	NW		

Table 1: Variables Resulting From the Tasks of ATHINA and EDIT Tests.

Note. VC= Verbal Correspondence; NM= Numbers Memory; S= Sketching; PhD= Phonemes Discrimination; V= Vocabulary; PM= Pictures Memory; CSh= Copy Shapes; PhC= Phonemes Composition; ShM= Shapes Memory; GD= Grapheme Discrimination; NW= Name Writing.

All the outcome measures were collected by a psychologist who was blind to the children's allocation. Following the results of the diagnostic approach, 10 children were defined to be 'at risk' of SLD (they composed the intervention group), while 10 did not meet the early symptoms of SLD (they composed the control group).

Specifically, the intervention group consisted of six boys and four girls diagnosed 'at risk' of SLD. Similarly, the control group consisted of six boys and four girls with no early symptoms of SLD.

Eliciting and formulating individualized diagnostic profiles

In order to create properly customized diagnostic profiles, we grouped the tasks of ATHINA and EDIT test in which a number of children 'at risk' of SLD occasionally failed. Estimating the total number of the failed tasks, we found out that all the children 'at risk' failed in tasks 8 and 9 (from ATHINA and EDIT test, respectively), except for the task of Numbers Memory (Table 2).

Children 'at risk' of SLD	ID	2	3	6	10	11	12	13	14	15	N of infants
Variables	Tasks	Performance									
Sequence Memory	NM	P	P	F	F	F	F	P	F	F	6
	PM	F	F	F	F	F	F	F	F	F	9
	ShM	F	F	F	F	F	F	F	F	F	9
Phonological Awareness	PhC	F	F	F	F	F	F	F	F	F	9
	PhD	F	F	F	F	F	F	F	F	F	9
Visuo-spatial Abilities	S	F	F	F	F	F	F	F	F	F	9
	CSh	F	F	F	F	F	F	F	F	F	9
	GD	F	F	F	F	F	F	F	F	F	9
	NW	F	F	F	F	F	F	F	F	F	9
N of Failed Tasks		8	8	9	9	9	9	8	9	9	

Table 2: Performance of children 'at risk' of SLD.

F= Failed; P= Passed; NM= Numbers Memory; PM= Pictures Memory; ShM= Shapes Memory; PhC= Phonemes Composition; PhD= Phonemes Discrimination; S= Sketching; CSh= Copy Shapes; GD= Grapheme Discrimination; NW= Name Writing.

Considering the variables reflecting the tasks of the above tests, the ones in which the 10 children 'at risk' failed, were finalized in the following: (a) Sequence Memory, (b) Visuo-spatial Abilities, and (c) Phonological Awareness.

As a result, three common diagnostic profiles were elicited, each one of them including a combination of the defined variables and related tasks (Figure 1), as follows: (a) Visuo-spatial Abilities and Phonological Awareness, (b) Visuo-spatial Abilities, Phonological Awareness, and Sequence Memory, and (c) Phonological Awareness and Sequence Memory.

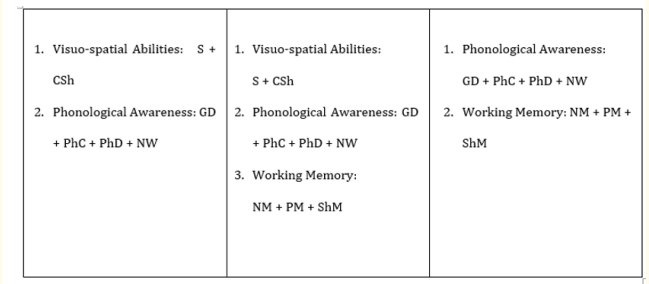

Figure 1: Three classified diagnostic profiles.

Defining and formulating an individualized intervention program

Guided by the aforementioned profiles, we produced a respective individualized intervention program adapted to the particular difficulties that each child faced in specific tasks and variables of the two diagnostic tools.

In a conceptual plan to implement this intervention program, we assigned a number of combined exercises from specific parts of

ProAnaGraPho method (Table 3) to each child of the intervention group three times per week, over an 8-month intervention period.

ID	Implementation of an intervention program adjusted to individualized diagnostic profiles
2	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (43 exercises); (ii) Phonological Awareness (14 exercises)
3	ProAnaGraPho and Graphogame: (i) Phonological Awareness (19 exercises); (ii) Sequence Memory (14 exercises)
6	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (42 exercises); (ii) Sequence Memory (16 exercises)
10	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (14 exercises); (ii) Phonological Awareness (14 exercises)
11	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (14 exercises); (ii) Phonological Awareness (14 exercises); (iii) Sequence Memory (14 exercises)
12	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (42 exercises); (ii) Phonological Awareness (13 exercises)
13	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (14 exercises); (ii) Phonological Awareness (2 exercises); (iii) Sequence Memory (7 exercises)
14	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (21 exercises); (ii) Phonological Awareness (14 exercises)
15	ProAnaGraPho and Graphogame: (i) Phonological Awareness (14 exercises); (ii) Sequence Memory (14 exercises)
19	ProAnaGraPho and Graphogame: (i) Visuo-spatial Abilities (20 exercises); (ii) Phonological Awareness (14 exercises); (iii) Sequence Memory (8 exercises)

Table 3: Individualized intervention program.

As it became evident from the diagnostic profiles, the variable of Phonological Awareness was the most prevalent in all children's profiles. Based on this finding, it was considered necessary to strengthen this domain by using the Graphogame method, which was applied in the last phase of the intervention period.

Statistics

We assessed the participants' performance before and after the intervention and examined the differences by using the Wilcoxon Signed Ranks test when considering comparisons of measurements in two time points, and by applying Friedman's non-parametric statistic when comparing initial, intermediate and final measurements. In the case of the Friedman test, we examined non-parametric multiple comparisons in order to adjust all p-value estimations. We assessed differences in the percentage of missions between the intervention and the control group with Fisher's exact test, since the Pearson Chi Square assumptions were not met. Significance was set at 0.05 in all cases and SPSS v22.0 was used for all analyses.

Results

Regarding the recorded missions in the defined variables, we observed statistically significant differences between the two groups; specifically, in Working Memory ($p = .010$), Visuo-spatial Abilities ($p = .028$), and Phonological Awareness ($p < .001$). In total, significantly higher percentages were recorded in the missions by the intervention group ($p = .003$).

However, after the completion of the intervention program, a statistically significant minimization of the missions of the intervention group's achievement was recorded in all the tasks that constitute the defined variables, in both EDIT and ATHINA tests ($p = .008$ and $p = .016$), respectively (Table 4).

We observed a highly significant improvement of the intervention group's performance in the tasks that constitute the defined variables at the initial, intermediate and final evaluation (Table 5). From the multiple comparisons, it seems that improvement has already been observed since the intermediate stage with $p = .040$, while the difference is stronger at the end of the intervention ($p = .001$). It must mentioned that the improvement between the intermediate and the final stage is not statistically significant ($p = .867$) (Table 6).

We tested the progress in the sectors of ProAnaGraPho method through a scoring scale applied within the method. The scale evaluates the progress by counting the number of successfully completed exercises out of the total number of exercises included in each sector. To this effect, a key consideration was the number of ses-

ID	Intervention	Gender	EDIT Missions begin	EDIT Missions end	p	ATHINA Missions begin	ATHINA Missions end	p
2	Yes	Male	7	0	.008*	10	4	.016*
3	Yes	Female	5	1		6	5	
6	Yes	Female	3	4		7	8	
10	Yes	Male	2	0		2	3	
11	Yes	Male	3	0		9	0	
12	Yes	Female	7	1		6	0	
13	Yes	Male	5	0		7	1	
14	Yes	Female	5	2		9	6	
15	Yes	Male	3	0		6	1	
19	Yes	Male	5	2		7	0	

Table 4: Statistically significant improvement of intervention group with missions in the total of sectors of EDIT and ATHINA test.

* Wilcoxon signed ranks test.

Tasks constituting the defined variables	Intervention Group		
	Initial – final p	Initial – midterm p	midterm – final p
Sketching	.031	.500	.125
Copying Shapes	.025	.250	1.000
Graphemes Discrimination	.063*	.125	1.000
Name Writing	.016	.500	.063*
Phonemes Discrimination	.025	.250	1.000
Phonemes Composition	.025	.500	1.000
Numbers Memory	.063*	.250	-
Pictures Memory	.063*	.250	1.000
Shapes Memory	.050	.375	1.000

Table 5: *A* Statistically Significant Improvement Can Be Observed Within the First 3 Months of the Intervention.

Note. N = 10. *borderline non significant.

Intervention group – Control group	Test Statistic	Std. Error	Std. Test statistic	Sig.	Adj. Sig.
Successes at the beginning - intermediate successes	-1.167	.471	-2.475	.013	.040
Successes at the beginning - successes after completion	-1.167	.471	-3.536	.000	.001
Intermediate successes - successes after completion	-.500	.471	-1.061	.289	.867

Table 6: Estimation of the progress of the two groups' performance during the intervention program.

sions required in order for children to successfully complete each exercise per sector (Table 7).

Accordingly, we administered specific tasks of Graphogame to the intervention group after the third month of the intervention. Each participant was assigned different tasks based on their needs. The tasks were categorized in three major groups: (a) Letters, (b) Syllables, and (c) Words. We used the mean and standard deviation of the outcomes from the tasks played to amplify the estimation of the Phonemes Discrimination, Phonemes Composition and Graphemes Discrimination tasks.

ID	ATHINA and EDIT missions	Number of successfully completed exercises in the total of exercises per sector	Progress in 11 sub-sectors of three main sectors of ProAnaGraPho										
			A1	A2	A3	A4	A5	A6	B1	B2	B3	G1	G2
2	17	A1:8/8; A2:7/7; A3:7/7; A4: 7/7; A5:7/7; A6:7/7; G1:7/7; G2:7/7	↗	↗	↗	↗	↗	↗	-	-	-	↗	↗
3	11	B1:6/6; B2:7/7; B3:6/6; G1:7/7; G2:7/7	-	-	-	-	-	-	↗	↗	↗	↗	↗
6	10	A1:7/7; A2:7/7; A3:7/7; A4:7/7; A5:7/7; A6:7/7; B2:8/8; B3:8/8	↗	↗	↗	↗	↘	↗	-	↗	↗	-	-
10	4	A5:7/7; A6:7/7; G1:7/7; G2:7/7	-	-	-	-	↗	↗	-	-	-	↗	↗
11	12	A2:7/7; A5:7/7; B2:7/7; B3:7/7; G1:7/7; G2:7/7	-	↗	-	-	↗	-	-	↗	↗	↗	↗
12	13	A1:8/8; A2:/77; A3:7/7; A4: 7/7; A5:7/7; A6:6/6; G1:7/7; G2:6/7	↗	↗	↗	↗	↗	↗	-	-	-	↗	↗
13	12	A5:7/7; A6:7/7; B3:7/7; G1:1/1; G2:1/1	-	-	-	-	↗	↗	-	-	↗	↗	↗
14	14	A4:7/7; A5:7/7; A6:7/7; G1:7/7; G2:7/7	-	-	-	↗	↗	↗	-	-	-	↗	↗
15	9	B2:8/8; B3:6/6; G1:7/7; G2:7/7	-	-	-	-	-	-	-	↗	↗	↗	↗
19	12	A2:6/6; A4:8/8; A6:6/6; B2:1/1;B3:7/7; G1:7/7; G2:7/7	-	↗	-	↗	-	↗	-	↗	↗	↗	↗

Table 7: Progress of the intervention group's performance in ProAnaGraPho sectors.
A1= Body Shape; A2= Spatial Orientation; A3= Temporal Sequences; A4= Right-Left Discrimination; A5= Ordering; A6= Visuo-motor coordination; B1= Visual Working Memory; B2= Audio Working Memory; B3= Sequence Working Memory; G1= Phonological Awareness; G2= Phoneme-grapheme Correspondence.

The total playing time was recorded, as well as the total playing time on the basic games (Table 8). The percentage of successful answers was over 70% in almost every case except for one child.

Discussion

In the current pilot study, we aimed, firstly, to investigate how to implement a sequence of diagnostic procedures in order to identify reliable specific profiles of young children 'at risk' of SLD; and, secondly, to profile an individualized well-adaptive intervention program in order to minimize children's risk of developing SLD in school years.

Defining reliable early predictors of SLD; the role of a comprehensive assessment

The fact that individuals with specific learning disorders constitute a heterogeneous and multifarious population requires a universal understanding of the nature and complexity of the inherent and particular causes of these difficulties [7]. However, aiming to tackle this core diversity, we need more than a unique diagnostic and intervention model, but in any case, diagnoses and interventions must be accurate, objective and effective in helping learners to overcome their weaknesses [19].

According to the results derived from the applied tests, the children 'at risk' of SLD displayed significant difficulties ($p = .003$) in

Playing time statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Total playing time	10	648.74	58658.79	24219.60	18811.90
Total basic game playing time	10	259.41	16139.43	7848.00	5215.77
ID	Syllables	Words	Letters	Total playing time (sec)	Percent %
3	13	10	0	41568	74
6	0	0	13	4560	52
2	0	2	3	2635	81
15	1	0	1	649	97
14	0	26	0	58659	71
13	0	16	0	30102	84
12	4	2	0	31479	95
10	2	11	0	35183	87
11	0	16	0	21934	74
19	0	25	4	15428	88

Table 8: Total playing time and playing times of intervention group in specific categories of Graphogame.

all the tested variables: working memory ($p = .010$), visuo-spatial abilities ($p = .028$), and phonological awareness ($p < .001$). This finding is in line with the DSM-5TM early diagnostic criteria referring to delays or disorders in language, or impaired cognitive processing.

Through the implementation of a comprehensive assessment, we provided most of the information related to individuals' development, resulting thus in the formulation of diagnostic profiles constructed by specific 'at risk' of SLD signs [33]. We formulated the diagnostic approach by using data provided by a grid of assessments (one behavior questionnaire, one intelligence test and two tests of learning difficulties). Utilizing all data of these measures, we recorded, classified, merged, and evaluated each piece of information provided by the corresponding measures separately and in combination, thus creating diagnostic profiles that potentially reflected the individual's weaknesses in specific domains. This finding comes to add to the research needed to make accurate predictions for children 'at risk' of SLD, mainly as regards the individual level [16].

As far as the intelligence test (WPPSI-III) is concerned, we should mention that it was not used as a measure of diagnosis of SLD, but as an additional measure, adequate to clarify specific parts of the cognitive profile of SLD. Interestingly, a significant discrepancy was observed between the scores of performance and verbal intelligence quotient, in all children 'at risk' of SLD. Particularly, the verbal IQ was constantly lower than that of performance scale (a discrepancy of 18 points was recorded).

In conjunction with the finding from studies referring to low verbal IQ observed in students with dyslexia even from the first grade [34], the current finding highlights the achievement gap that appears in students with dyslexia, stressing that it can be measured earlier than the first grade.

If the results derived by the other measures could be combined, an effective relationship between these weaknesses and weaknesses in connecting the alphabetic with the phonemic code, or recognizing the printed symbols using morphological codes, could be acknowledged through the intelligence test [35].

Eliciting early diagnostic profiles 'at risk' of SLD

Three 'at risk' of SLD diagnostic profiles emerged, reflecting systematic weaknesses in specific cognitive abilities. Each diagnostic profile is constructed by a combination of the tested vari-

ables, as follows: 1st profile: Visuo-spatial Abilities and Phonological Awareness; 2nd profile: Visuo-spatial Abilities and Phonological Awareness and Working Memory; 3rd profile: Phonological Awareness and Working Memory.

As it is shown, the elicited individualized diagnostic profiles display weaknesses not only in one domain but in a combination of three specific domains, indicating weaknesses in specific cognitive abilities, such as working memory, awareness of phonemes and graphemes, and visuo-spatial attention.

These findings merit consideration, as, initially, they are in line with the results of studies that correlate the early assessment of SLD with cognitive abilities. Moreover, they corroborate the argument that children 'at risk' of SLD could meet difficulties in a broader range of factors and, indeed, under combined interactions between them [17].

Remarkable interactions were also discerned between specific sub-components, which eventually construct the weakness in each affected domain (see Figure 2 for the combined interactions between sub-components of the tested variables).

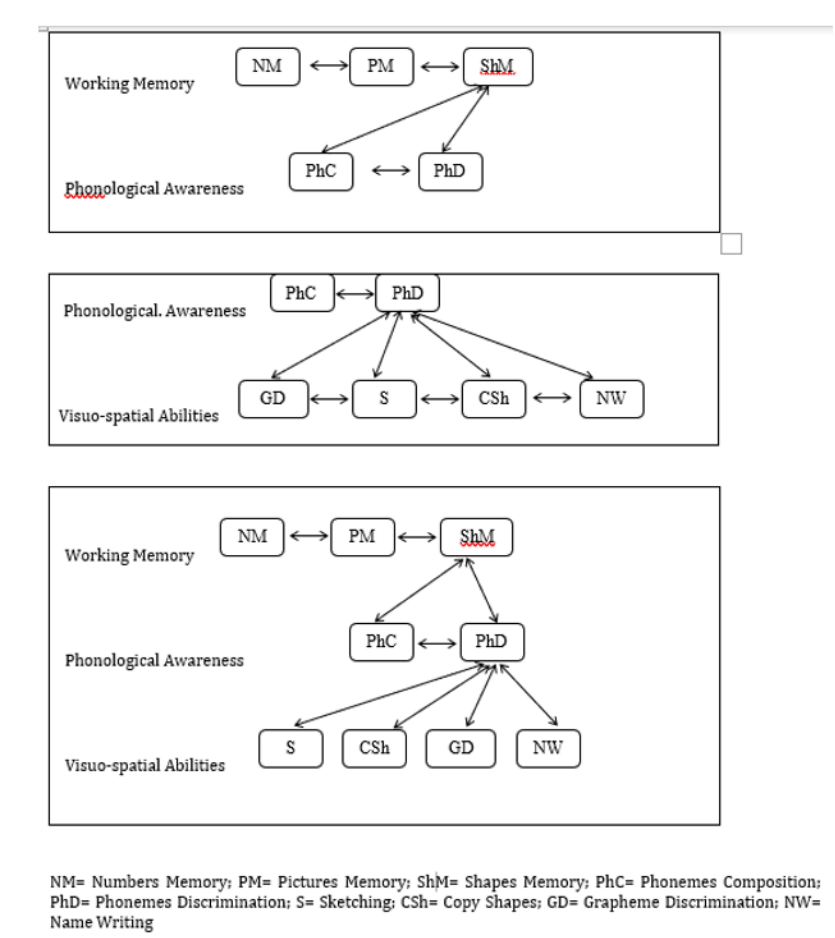

Figure 2: Combined interactions between sub-components of the tested variables.pyrolysis of agro-residue.

In an attempt to interpret these sub-interactions, we can assume the following interactions in the 1st profile: difficulties in retrieving and elaborating sequence information (numbers, pictures, and shapes) through working memory (Working Memory) interact with difficulties in composing and discriminating phonemes (Phonological Awareness). In turn, they interact with difficulties in sketching, copying shapes, discriminating letters, and writing a word (Visuo-spatial Abilities).

Similarly, in the 2nd profile we can discern that difficulties in discriminating letters and writing a word (Visuo-spatial Abilities) are affected not only by those in composing and discriminating phonemes (Phonological Awareness), but also, by those that attribute spatial and logical/mathematical characteristics (up-down, left-right, etc.) to sketching and copying shapes (Visuo-spatial Abilities).

Finally, the 3rd profile represents all types of combinations of the tested variables, as they were developed in both of the above profiles, as follows: difficulties in components of Working Memory interact with difficulties in components of Phonological Awareness, which in turn interact with difficulties in components of Visuo-spatial Abilities.

The significance of early predictors of SLD

The role of phonological awareness

As it is shown, the difficulties in the domain of phonological awareness seem to be predominant in the three 'at risk' of SLD diagnostic profiles. Researchers, such as Gathercole and Baddeley (1993) [36], believe that phonological awareness in reading acquisition of an alphabetically written text is linked to the alphabetical knowledge of this pattern. The awareness that each letter corresponds to a phoneme, including the awareness of the syllable units and the phonemes of each language, helps the child to decode various words and, mainly, unknown ones.

Research on children who have not yet learned to read confirms that phonological awareness has emerged as the most powerful predictor of later reading skills and can, therefore, be a criterion for predicting future reading difficulties in most alphabetic systems [37].

However, the constructional characteristics of the alphabetic writing system should be taken into account for a better understanding of this finding (Greek is considered to be a transparent language, without many phonological inconsistencies) [38].

Despite the overwhelming evidence from both behavioral and neuroimaging studies [39] about the great role of phonological awareness in the reading process, a complete understanding of the phenomenon remains unclear. Thus, we acknowledge the multifactorial nature of SLD, referring to the phonological deficit as one of the multiple deficits that interact to cause reading difficulty.

In line with the above, through the occurrence of difficulties only in this domain we could not constitute an 'at risk' profile of SLD. Solely through the phonological deficits we cannot explain the variant difficulties that children with SLD face. Besides, as it is increasingly being supported, phonological awareness is considered to be a strong rather than a causal indicator of SLD, as not all individuals with SLD will have a phonological deficit and not all children with a phonological difficulty will have SLD [40].

The role of working memory

Working Memory was also revealed as the second dominant variable in two out of the three diagnostic profiles. Particularly, difficulties co-occurred in a combination between Working Memory and Phonological Awareness and in a third kind of combination, that of Working Memory with Phonological Awareness and Visuo-motor Abilities. Undoubtedly, the finding seems in line with research results supporting that working memory weaknesses are related to SLD and should be investigated at the early onset of SLD [14].

Trying to understand the constructive mechanism of this underlying relationship, we could discern the function of phonological working memory; a multi-component system that consists of the central executive unit, the phonological loop and the visuospatial sketchpad, which is considered to be responsible for storage and executive processes of phonological information [41].

The role of visuo-spatial abilities

An additional interest of the research area also focused on the visuo-spatial sketchpad and its relationship with reading deficits in children. According to the model described by Baddeley (2012) [42], the visuo-spatial factor specializes in the short-term storage and processing of visual and spatial information. Due to an absence of satisfactory performance in such controlled processing tasks, an

inability to respond to visual and verbal memory tests occurs, thus resulting in a more generalized deficit in this area.

Adding to the above theory, the finding of significant missions recorded in the variable of Visuo-motor Abilities (p = .028) and its relevant tasks, such as Sketching (p = .031) and Copying Shapes (p = .025), as well as in the task of Graphemes Discrimination (p = .025) reflect weaknesses in visuo-spatial attention. This finding is in line with the results of researches supporting that children 'at risk' of SLD exhibit early disorders in visual spatial attention [43] cross-dominance, left-right discrimination, grapho-motor ability, body shape, spatio-temporal orientation and visual-motor abilities.

Eventually, all the tested variables signify main cognitive deficits that could be regarded as the core risk factors of SLD occurrence. In addition, in agreement with the view that we cannot test the reading skill per se in preschoolers [17], cognitive factors seem to be the best predictor for early diagnosis of SLD.

Regarding the relationships between the cognitive factors studied, we saw that they were nested in three diagnostic profiles, each one of them representing difficulties in more than one affected domain and, consequently, complicated combinations between these domains and their components.

Besides, as it has already been observed in other studies [9], all the cognitive factors we studied here were considered as ultimate powerful factors for the acquisition of reading and writing skills, thus demanding constant as well as continuous training and enhancement. To this effect, Papadopoulos*., et al*. (2010) [32] support that phonological processing is firmly proximal to reading.

Specifically, with our findings we reinforce the multi-factorial approach of SLD translated by the theory of multiple deficit models, according to which phonological awareness is the core deficit, but is not sufficient to establish a safe early diagnosis of SLD. To this end, in all formulated profiles deficits were indicated in at least two or three predictive factors, where phonological awareness was the predominant factor [44].

Formulating an effective early intervention program

Through the systematic implementation of a well-structured 8-month intervention program, attuned to the individual's difficulties, we achieved a significant amelioration of these difficulties before the child's entry into school.

The delineation of the intervention program was based on the following:

- The criteria posed for determining the diagnostic profiles of children 'at risk' of SLD
- The utilization of those intervention methods that fulfill the diagnostic criteria
- The configuration of each individualized intervention, which will be adjusted in accordance with common conditions, such as the intervention period, the order of the activities to be implemented depending on the degree of missions in respective variables, and the implementation of intermediate and final reevaluation of the progress.

The effectiveness of the intervention applied was confirmed through the high improvement of the intervention group's progress (p =.003) even from the first 3 months of the intervention period (p =.040), while it culminated upon completion of the intervention (p =.001).

Specifically, upon completion of the intervention program, we can emphasize the following: (a) the children performed positively in particular sections, (b) the phonological awareness emerged as the most important predicting-contributing factor, and (c) the children recorded great progress in the three variables simultaneously, indicating strong interrelations and contributing significantly to the early acquisition of reading and writing skills.

The fact that between the intermediate and the final phase of the evaluation there was no statistically significant difference, indicates that having early understood the mechanisms of phonological awareness and having improved their working memory, as well as their visuo-spatial abilities, these children were progressively familiarized with the characteristics and functionality of written symbols [35]. It is accepted that an intensive intervention program for children with SLD consisting of techniques which address the difficulties in phonological awareness, can lead to the acquisition of these skills and to long-lasting regularization in written speech [20].

For the treatment of difficulties that occurred in the variables of Visuo-spatial Abilities, Working Memory, and Phonological Awareness, a vast range of exercises (approximately 75 exercises) included in the method of ProAnaGraPho, was implemented by

each child of the intervention group. Specifically, the whole intervention group exhibited a positive upward trend in most of the sectors of ProAnaGraPho method, as it is advocated by the significant improvement observed after the completion of the intervention, in comparison to the control group ($p = .001$).

However, the significant degree of missions ($p < .003$) that the intervention group recorded in all the three tested variables indicated systematic and complex difficulties. Thus, it was considered imperative to strengthen these children more, specifically in pre-reading skills, such as grapho-phoneme correspondence and syllables as well as words composition, implementing the Graphogame.

Although the short implementation of Graphogame (it was applied only for the two last months of the intervention period) did not lead to safe conclusions, the satisfactory percentage of 70% of correct answers observed in tasks of Words, Syllables, and Letters cannot be underestimated. Besides, this positive score in combination with the progress recorded in relative tasks of ProAnaGraPho, highlights Graphogame's effect on the improvement achieved by the intervention group in Name Writing ($p = .016$), Phonemes Discrimination ($p = .025$), and Phonemes Composition ($p = .025$), as they were evaluated after the completion of the intervention.

Lovio*., et al*. (2012) [45] found affirmative results for the use of Graphogame, defining a considerable improvement in phonological processing as well as sound recognition. Papadopoulos*., et al*. (2010) [32] also observed improvement in reading skills in a survey conducted with 56 Greek-speaking children aged 6-7 with reading difficulties (participating in a 5-week program).

Overall, the above findings seem to confirm that in order for an intervention to be most effective and suitable for children's individual needs, it should be comprehensive, systematic, well structured, and multi-sensory [40]. Targeted at the elimination of early symptoms of SLD, an intervention should include training children in coding and decoding language sounds, remembering the names of letters and numbers, recognizing and writing letters and their own names, composing phonemes to build a word, or segmenting words as well as isolating phonemes in a word (DSM-5TM).

The limitations that we must acknowledge in this pilot study are the small number of participants and the absence of a follow-up on their learning process after school entry. Although it is quite difficult to implement a comprehensive diagnostic and intervention approach for a particular period with a big sample, we believe that the implementation of longitudinal studies using larger samples must be conducted.

Conclusion

In the present pilot study, we attempted to indicate that using comprehensive diagnostic procedures allows us to identify early disabilities in specific developmental domains related to the learning process, such as working memory, phonological awareness, and visuo-spatial abilities. Therefore, we become able to modulate correct individualized profiles with unique limits in these domains.

The role of individualized profiles is revealed to be rather decisive in the formulation of rigorously structured re-educational methods that, in turn, by targeting the amelioration of the defined difficulties, can result in children's early acquisition of right learning skills and suitable learning strategies, even at preschool age.

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Conflict of Interest

We have no conflicts of interest to disclose.

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