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Prognostic factors of reading difficulties in preschool age

SUMMARY OF DOCTORAL DISSERTATION

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VILNIAUS UNIVERSITETAS

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Skaitymo sunkumų prognostiniai veiksniai ikimokykliniame amžiuje

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1. INTRODUCTION

Reading disorders in Lithuania, as in many countries, are diagnosed only when a child starts attending school. At the same time, it is recognized that educational assistance at younger age is more effective (Foorman, Francis, Shaywitz, Shaywitz, & Fletcher, 1997), and the importance of early identification and intervention for children with dyslexia is being stressed (Snowling, 2013). The need of help for children to overcome reading difficulties is stimulating researchers' interest in early prediction of reading disorders, and research into risk factors for predicting dyslexia is on the rise. Of particular importance here are longitudinal studies showing that reading disorders can be predicted as early as preschool age based on a variety of risk factors (Lyytinen, Erskine, Kujala, Ojanen, & Richardson, 2009; Muter & Snowling, 2009; Krasowicz-Kupis, Bogdanowicz, & Wiejak, 2014; etc.).

Based on developmental models of learning to read (Ehri, 1987; Frith, 1986), with the onset of formalized reading instruction in school, children move to an emergent literacy or alphabetic stage where they acquire decoding skills. It is already known that the development of decoding skills varies depending on the writing system being taught to read (Seymour, Aro, & Erskine, 2003). Language transparency (spelling–sound consistency) is considered to be the most important dimension that makes writing systems different, but there are more (Share & Safra, 2019). The Lithuanian language belongs to the transparent writing systems (Gedutienė, 2017). Although the results of research conducted in transparent foreign languages are most relevant to us, they obtain different impact of the same factors (such as phonological awareness) on reading variation, so we cannot rely on them directly. Therefore, a separate study is needed in order to answer the question which factors most accurately

predict possible difficulties in the acquisition of reading skills in Lithuanian.

Scientific research on dyslexia has burgeoned during the past 50 years, and a great deal is now known about its nature, aetiology and assessment (Snowling, 2013). However, only one theory of dyslexia so far has attempted to account for all the empirical evidence of sensory and motor disorders in dyslexics (Ramus, 2006). Uniquely, the general magnocellular theory accounts for reading disability both through auditory–phonological and visual–spatial deficits (Ramus et al., 2003; Ramus, 2004). In order to make a comprehensive list of risk factors for reading difficulties, this work will be guided by the general magnocellular theory, and the research model will include all the factors from its behavioral level that affect reading, i.e. phonological awareness, rapid automatized naming, short-term auditory memory, and auditory and visual processing (Figure 1).

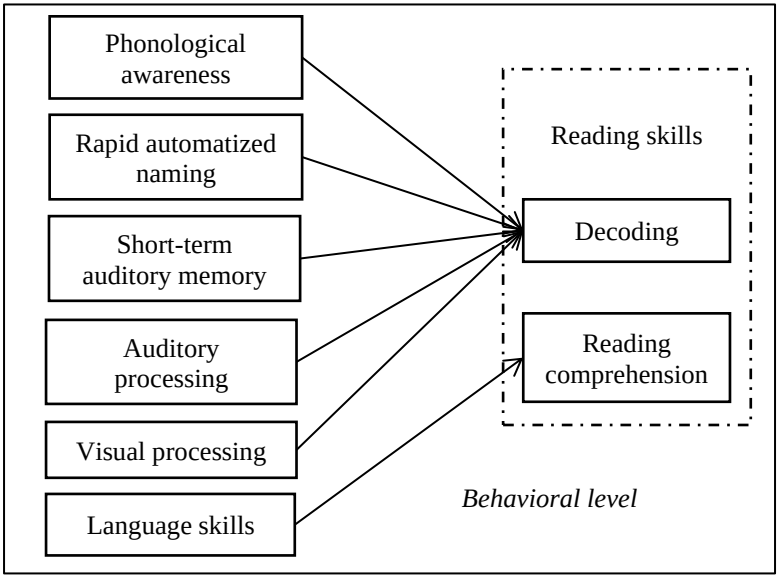

Figure 1. Factors explaining differences in reading skills (theoretical model of work)

This work follows an integrated approach to reading disorders, encompassing not only decoding but also reading comprehension difficulties. Therefore, the general magnocellular theory has been supplemented with a two-dimensional model of reading disorders (Gough & Tunmer, 1986; Tunmer, 2008), also including in the theoretical model of this work broader nonphonological language skills that are considered important for reading comprehension (Bishop & Snowling, 2004) (Figure 1). This study will attempt to answer the question of whether dyslexia is a deficit specific to written language or may be the outcome of oral language weakness in the language in which a child is trying to learn to read (Tallal, 2006)?

A review of research on the links between phonological awareness and reading skills would suggest that phonological awareness at some level is linked to the beginnings of literacy development and its deficiency is related to reading disorders. However, the importance of phonological awareness for reading differs greatly from orthography to orthography, and depends upon script, language, and teaching practices themselves (i.e. how and when is phonological awareness taught?) across cultures (McBride, 2016). Some reviews of research suggest that in more transparent scripts, such as the Lithuanian language, the importance of phonological awareness for predicting subsequent reading may be relatively little (Gedutienė, 2010). The aim of this study will be to find out whether the influence of phonological awareness in predicting reading in Lithuanian will remain significant, at the same time analyzing other phonological abilities, i.e. rapid automatized naming and short-term auditory memory?

Deficits in phonological skills appear to be at the heart of reading disability; however, the nature of this impairment is not yet known (Baldeweg, Richardson, Watkins, Foale, & Gruzelier, 1999; Zhang & McBride-Chang, 2010). Many studies have focused on question whether phonological deficits related to reading failure are speech specific or derived from more basic auditory processing deficits? Many individuals with dyslexia also present impairments in auditory

temporal processing and speech perception, but it remains debated whether these more basic perceptual impairments play a role in causing the reading problem. Longitudinal studies may help clarifying this issue by assessing preschool children before they receive reading instruction and by following them up through literacy development (Boets et al., 2011). In some countries (the United States, Australia, New Zealand, the United Kingdom) Auditory Processing Disorder (APD) is frequently diagnosed (Dawes & Bishop, 2009), however, in Lithuania so far only peripheral hearing tests are performed, and central auditory processing disorders are not diagnosed. What is new is that in this study, together with other phonological and language factors that predict reading, we planned to assess the indicators of auditory processing in order to determine their influence on differences in reading skills.

Information on factors predicting reading difficulties can be gathered quickly and easily from teachers and parents using dyslexia risk scales, which is much more effective compared to an individual testing of a child. Including both parents and teachers as informants at the time of initial screening for dyslexia is an invaluable addition to the assessment process (Ching, Ho, Chan, Chung, & Lo, 2014), however, the question arises as to whether the information provided by parents and teachers is equally valuable in predicting future reading difficulties for children in later years? Studies aimed to compare the prognostic value of information provided by different informants on risk factors for a child's reading difficulties have not been found in the literature. In order to fill the existing gap, in this study information on the risk of reading difficulties in preschool age will be collected using questionnaires from parents, child educators (pre-primary teachers) and educational support professionals (speech therapists), which will allow us to compare the predictive value of information gathered from different sources.

The aim of the longitudinal study – to determine the risk factors in preschool age, which predict students' reading difficulties in the first and second grades.

Research questions

1. How do reading skills in the first and second school years differ between students who have been identified as being at risk for reading difficulties at preschool age and their peers who are not at such risk?
2. What differences in children's language development and cognitive abilities and functions in preschool age are highlighted by comparing groups at risk of reading difficulties with non-risk children?
3. Which cognitive abilities and functions of a child in preschool age best explain/predict the differences in reading skills (decoding, reading comprehension) of first and second grade students? Are decoding and reading comprehension predicted by different factors?
4. Is the information about the risk characteristics of reading difficulties provided by parents and educators at preschool age equally valuable in predicting future reading outcomes for at-risk and non-at-risk children in later years?
5. What information about a child's risk of reading difficulties and his or her cognitive abilities and functions at preschool age is important in predicting his or her reading difficulties in the first school years? Based on what criteria (cutoff scores) can the prognostic validity of the recognition of reading difficulties be ensured, i.e. the maximum sensitivity and specificity of risk group selection achieved?

2. METHODS

2.1. Participants of the study

The Ist stage of the study included children who attended a pre-primary group during the 2016–2017 school year in one of the twelve randomly selected preschools in Vilnius providing education in Lithuanian language. 1–2 pre-primary groups from each preschool participated in the study. The study also involved children's parents, speech therapists, pre-primary, 1st grade (IInd stage, one year later) and 2nd grade (IIIrd stage, two years later) teachers. Parents, pre-primary teachers and speech therapists completed *the Dyslexia Risk Questionnaire* (further in text DRQ) for 284 children (Table 1). Based on DRQ scores, 47 children at risk of reading difficulties were selected for further longitudinal study. Criterion for the selection: the sum of parents' and/or pre-primary teacher's DRQ scores $\geq (M + 0{,}875*SD)$ and/or the sum of speech therapist's DRQ scores $\geq 0{,}875*M$. For each child at risk of reading difficulties, another child with no risk of reading difficulties was selected from the same pre-primary group considering gender and month of birth. A total of 49 children without risk of reading difficulties were selected. Risk (M = 80,74 months, SD = 3,40) and non-risk (M = 81,45 months, SD = 3,19) groups did not differ by age (t = 1,05, df = 94, p = 0,297).

Table 1. *Participants of the study*

Stage of the study	Participants	Gender						Total
		Male		Female		Both parents		
		n	%	n	%	n	%	N
	Sample of the screening stage							
I	Children	144	50,7	140	49,3	-	-	284
I	Parents	30	11,8	215	84,3	8	3,1	255[a]
	Subjects							
I–III	Children	59	61,5	37	38,5	-	-	96
I–III	Risk group	29	61,7	18	38,3	-	-	47
I–III	Non-risk group	30	61,2	19	38,8	-	-	49
	Informants							
I–III	Parents	7	7,3	82	85,4	6	6,3	96[b]
I	Pre-primary teachers	-	-	23	100,0	-	-	23
I	Speech therapists	-	-	10	100,0	-	-	10
II	1st grade teachers	-	-	65	100,0	-	-	65
III	2nd grade teachers	-	-	60	100,0	-	-	60

Note. [a] Parents of two children did not specify who completed the DRQ. [b] Parents of one child did not specify who completed the DRQ.

2.2. Means of assessment

PARENTS, TEACHERS	CHILDREN
Ist stage (2016–2017 school year, pre-primary group)	
• *The Dyslexia Risk Questionnaire* (DRQ): - Version for parents (DRQ-P) - Version for pre-primary teachers (DRQ-T) - Version for speech therapists (DRQ-S)	• Phonological abilities: - Object Naming (RAN-o) - Color Naming (RAN-c) - Phonological Awareness (PA) - Short-Term Auditory Memory (STAM) • Language skills: Vocabulary (VOC) • Visual-motor abilities: Human Figure Copying (HFC) • Non-verbal reasoning ability: Colored Progressive Matrices (CPM) • Auditory and visual processing tasks
IInd stage (2017–2018 school year, 1st Grade)	
• Questionnaire: - For parents - For 1st grade teachers	• Rapid automatized naming: - Number Naming (RAN-n) - Letter Naming (RAN-l) • Reading skills tasks
IIIrd stage (2018–2019 school year, 2nd Grade)	
• Questionnaire: - For parents - For 2nd grade teachers	• Reading skills tasks • National Examination Center (NEC) Reading Test

Figure 2. Measures of the longitudinal study

Dyslexia Risk Questionnaire (DRQ) (M. Bogdanowicz, 1993; R. Gedutienė, 2015). DRQ consists of two versions: version for parents/foster parents (DRQ-P) and version for specialists (teachers, DRQ-T / speech therapists, DRQ-S). DRQ-P version consists of three parts:

I. *Information about the child.* In this part, parents are asked to write child's name, gender, birth date, the language he/she speaks at home, to mark which child's hand is predominant when he/she writes/paints. Parents are required to indicate diagnosed child's disorders (visual, hearing, movement and neurological, speech and language). Parents are asked to mark if a child received the speech therapist's help in preschool age.
II. *Information about the difficulties experienced by parents*. Parents are asked to indicate, whether they themselves experienced difficulties learning to read and write in primary school.
III. *50 items*, describing the indicators of the risk of reading and writing difficulties. These items are grouped into 8 scales: *Difficulties of letter recognition and letter-sound acquisition, Difficulties of phonological awareness, Difficulties of spoken language – correct pronunciation, Difficulties of spoken language – expression of thoughts, Attention difficulties, Memory difficulties, Difficulties of motor coordination and spatial orientation, Difficulties of fine motor skills*.

DRQ-T / DRQ-S version consists of two parts:

I. *Information about the child*. In this part, the specialists (teachers/speech therapists) are asked to write child's name, gender, birth date, the language he/she speaks at home, to mark which child's hand is predominant when he/she writes/paints. Specialists are required to indicate diagnosed child's disorders (visual, hearing, movement and neurological, speech and language, intellectual and developmental). Specialists are asked to mark if a child received the speech therapists' help in preschool age.

II. *50 items*, describing the indicators of the risk of reading and writing difficulties (the same as DRQ-P).

50 items in both versions are rated in the 4-score scale to indicate the intensity or frequency of each behavior: from 1 (not characteristic for a child) to 4 (characteristic of a child). Before scoring the DRQ total score, the ratings of items were recoded: 1 (not characteristic for a child) into 0, ….4 (characteristic of a child) into 3. The reliability of all DRQ versions is very good: DRQ-P Cronbach $\alpha = 0{,}93$ (n = 218), DRQ-T Cronbach $\alpha = 0{,}97$ (n = 187), DRQ-S Cronbach $\alpha = 0{,}96$ (n = 46).

The Rapid Naming Scale (RAN) is designed to measure the ability of 4- to 7-year-old children to relate visual and linguistic information by rapidly naming familiar visual stimuli. The child is given 4 tasks: *Object Naming* (RAN-o), *Color Naming* (RAN-c) (Gintilienė, Girdzijauskienė, Butkienė, & Eismontaitė, 2015), *Number Naming* (RAN-n) and *Letter Naming* (RAN-l) (RAN-n and RAN-l tasks were designed specifically for this study). During each task the child has to list as quickly as possible a sequence of 40 objects (colors, numbers, letters) randomly made up from 5 different objects (colors, numbers, letters). The indicator – completion time (in sec) separately for RAN-o, RAN-c, RAN-n and RAN-l.

Colored Progressive Matrices (CPM) (Raven, Court, & Raven, 1998) measure the non-verbal reasoning ability or the eductive component of general abilities (*g* factor) in 5- to 11-year-old children. CPM consists of 36 tasks – drawings with a missing part. The child has to find the missing part of the drawing from the six alternative answers at the bottom of the drawing and show it. The indicator is the sum of the correct answers of the child. The split-half reliability of the CPM (after Spearman-Brown correction) is 0,84 (n = 288; Gintilienė et al., 2015). The CPM Spearman-Brown coefficient obtained in this study is 0,82 (n = 96).

The Phonological Awareness Scale (PA) is designed to measure the ability of 4- to 7-year-old children to perceive and analyze speech sounds, manipulate the structure of speech sounds, understand a word as a sound entity, and perform phoneme analysis and synthesis (Gintilienė et al., 2015). The child is given 12 tasks where he or she has to: *compare, distinguish* and *recognize* words of similar sound and rhythmic composition, *split* a word into syllables, *merge* meaningless syllables or separate sounds into a word. The indicator is the sum of the correct answers of the child. Internal consistency estimate of reliability of PA (Cronbach's alpha) is 0,78 (n = 288; Gintilienė et al., 2015). In this study, PA Cronbach's $\alpha = 0,72$ (n = 95).

The task of *Human Figure Copying* (HFC) is designed to measure the visual-motor activity (concentration of visual attention, spatial perception, sensorymotor coordination and fine movement accuracy) of 4- to 7-year-old children (Gintilienė et al., 2015). The child is asked to accurately copy a figure composed of different elements. The indicator is the amount of errors made. Internal consistency estimate of reliability of HFC (Cronbach's alpha) is 0,59 (n = 288; Gintilienė et al., 2015). In this study, HFC Cronbach's $\alpha = 0,59$ (n = 95).

The Vocabulary Scale (VOC) examines 4- to 7-year-old children's language skills that are related to learning and reproducing verbal informatikon (Gintilienė et al., 2015). The child is asked to describe (explain the meaning of) 20 words. The indicator is the sum of the correct answers of the child. The first two words are sample tasks that are not evaluated nor added to the total. Internal consistency estimate of reliability of VOC (Cronbach's alpha) is 0,73 (n = 288; Gintilienė et al., 2015). The Cronbach's α for this study was $\alpha = 0,79$ (n = 95).

The Short-Term Auditory Memory Scale (STAM) is designed to measure a child's short-term auditory memory – the ability to memorize and repeat numbers' and letters' sequences of varying

lengths in the same order in which the researcher presents them. The STAM scale was designed specifically for this study. The researcher reads to the child numbers'/letters' sequences of increasing length (beginning with 2 numbers, 2 letters, then 3, 4, etc.). The child is asked to memorize the sequence and repeat the numbers/letters in the same order. STAM consists of 12 sequences (6 sequences of letters and 6 sequences of numbers). Numbers/letters are read at a rate of one character per second. There is no time limit for performing STAM. The task is terminated when the child performs three consecutive tasks incorrectly. 1 point is given for each correctly remembered and repeated sequence. The total score is calculated. The split-half reliability of the STAM (after Spearman-Brown correction) obtained in this study is 0,73 (n = 94).

Auditory and visual processing tasks are designed to measure low-level auditory and visual functions. Subjects are presented with 1 visual and 5 different auditory processing tasks suitable for children from 5 years of age (Brain-Boy® Main Manual, 2015). All tasks are presented using the Brain-Boy device, auditory processing tasks – also using headphones. For all 6 tasks, the researcher presses the appropriate buttons on the device when the subject submits his or her answer. The device automatically terminates the task when the subject makes three errors in a sequence of seven sets of stimuli. The indicator: the value reached before the first incorrect answer. This estimate is displayed on the device screen and the researcher overwrites it in the study protocol.

1. *Visual order threshold*. This task tests the tact frequency of the brain at seeing (i.e. its processing speed). The subject is presented with two short flashes of light in a row, one on each side of the device (where LEDs are integrated). The child is asked to show on which side he or she saw the first flash of light. If the subject answers correctly, the pause interval between light flashes shortens, if incorrectly – it

lengthens. The indicator: the shortest time interval (expressed in ms) that a child can notice between two visual stimuli.

2. *Auditory order threshold*. This task tests the tact frequency of the brain at hearing (i.e. its processing speed). The subject is presented with two sounds in a row, one sound on each side of the headphones. The child is asked to show in which ear he or she heard the first sound. If the subject answers correctly, the pause interval between sounds shortens, if incorrectly – it lengthens. The indicator: the shortest time interval (expressed in ms) that a child can notice between two auditory stimuli.

3. *Spatial/directional hearing*. The subject is presented with two sounds, the time interval between which is so small that the two sounds are perceived as one coming from one side. The child is asked to show in which side of his or her head he or she heard the sound. If the subject answers correctly, the sound approaches the center of the head, if incorrectly – it moves away from it. The indicator: the smallest time difference (expressed in μs) that the brain has enough to determine the direction from which the sounds came.

4. *Pitch discrimination*. The subject is presented with two sounds in a row. The child is asked to say which sound was lower – first or second. If the subject answers correctly, the pitch difference decreases, if incorrectly – the difference increases. The indicator: the smallest pitch difference between two tones (expressed as a percentage) that a child can recognize.

5. *Auditory frequency-pattern discrimination*. The ability to recognize and name minimal frequency differences in a sequence of sounds is assessed. The subject is presented with three sounds in a row. Two sounds are the same, one sound is different from the rest in its frequency. The child is asked to say which sound was different – first, second or third. If the subject answers correctly, the sounds shorten and the intervals between them decrease, if incorrectly – the sounds lengthen and the intervals between them increase. The indicator: the shortest duration of sounds and intervals between them (expressed in

ms), when the child is able to recognize and name frequency differences in the sequence of sounds.

6. *Auditory duration-pattern discrimination*. The ability to recognize and name minimal duration differences in a sequence of sounds is assessed. The subject is presented with three sounds in a row. Two sounds are the same, one sound is different from the rest in its duration, it is longer. The child is asked to say which sound was longer – first, second or third. If the subject answers correctly, the sounds shorten and the intervals between them decrease, if incorrectly – the sounds lengthen and the intervals between them increase. The indicator: the shortest duration of sounds and intervals between them (expressed in ms), when the child is able to recognize and name duration differences in the sequence of sounds.

Reading skills in the 1st grade were assessed in 4 different tasks. Tasks were designed specifically for this study based on similar tasks (Gedutienė et al., 2008).

1. *Reading real words*. The ability of a child to read single words correctly within 1 minute (real words reading speed) is being assessed. The subject is presented with a sheet of paper where 128 single words of one to four syllables length are written in a row. The child is asked to read them out loud as quickly as possible. The indicator is the number of words read correctly.

2. *Reading pseudo words*. The ability of a child to read single pseudo words correctly within 1 minute (pseudo words reading speed) is being assessed. The subject is presented with a sheet of paper where 92 single pseudo words of two syllables length are written in a row. The child is asked to read them out loud as quickly as possible. The indicator is the number of pseudo words read correctly.

3. *Reading the text*. The ability of a child to read the text aloud without errors (reading accuracy) is being assessed. The subject is asked to read the text of 11 sentences aloud (6–7 words per sentence on average). The text is suitable for 6- to 8-year-olds (Kiselienė &

Virketienė, 2017). The missed word counts as an error. If a child spontaneously corrects a mistake, it is not counted as an error. If the subject is unable to read, the maximum number of errors (70) is given. The indicator is the number of words read incorrectly.

4. *Text reading comprehension*. The ability of a child to understand the text read (reading comprehension) is being assessed. After the child reads the text of Task 3, the text is being covered and 8 open-ended questions are being asked. The child can list several (3, 4 and 6) correct answer variants to 3 questions. 1 point is given for each correct answer (answer variant). The indicator is the sum of the correct answers of the child.

The standardized diagnostic reading (text comprehension) test for 2nd grade students from The National Student Achievement Test (National Examination Center, 2019; hereinafter – NEC Reading Test) is designed to assess the reading achievements of Lithuanian 2nd grade students according to the same criteria. NEC Reading Test indicators: number of points scored; result group; the part of points collected in individual areas of subject content (finding clearly presented information; drawing direct conclusions; interpretation and integration of ideas; evaluation of text content, language and text elements) and areas of learning processes (knowledge and comprehension; applications; higher thinking skills).

Questionnaires for parents and teachers. At the end of grades 1 and 2, parents and teachers were asked to complete a questionnaire about the child's learning, etc. The following variables were used for the study:

1. *Ratings of children's reading* provided by teachers and parents at the end of grades 1 and 2. Parents rated their child's reading by choosing one of 4 answers: "Not at all successful", "Below average", "Average", "Above average", teachers in the 1st grade – by choosing one of 5 answers: "Very low", "Slightly below average", "Average",

"Slightly above average", "Well above average", in the 2nd grade – by choosing one of 4 answers: "Unsatisfactory", "Satisfactory", "Base", "Upper". Responses were recoded into: 1 (Not at all successful / Very low / Unsatisfactory), <...>, 4 (Above average / Upper), 5 (Well above average).

2. *Child's assessment in the Pedagogical Psychological Service (PPS)*. In grade 2, parents and teachers were asked if the child had been assessed in the PPS.

2.3. Research procedure

Stage I (pre-primary group). In Spring 2017 parents were given a letter via their child's preschool inviting them to participate in the longitudinal study. Written informed consents were obtained from the parents regarding their children's participation in the study. Parents, pre-primary teachers and speech therapists completed the DRQ for each child. During two individual meetings, each lasting 20–30 minutes, the 96 subjects selected for the study were given RAN-o, RAN-c, CPM, PA, HFC, VOC (during the first meeting) and STAM, auditory and visual processing (during the second meeting) tasks.

Stage II (1st grade). In Spring 2018 parents of the study subjects were given a letter via their child's school (30 schools in total; 29 public, 1 private) inviting them to participate in the IInd stage of the study. Parents and teachers completed a questionnaire asking them to rate the child's reading. RAN-n, RAN-l and reading skills tasks were performed with 92 subjects during one individual meeting lasting 15–20 minutes.

Stage III (2nd grade). In Spring 2019 parents of the study subjects were given a letter via their child's school (30 schools in total; 28 public, 2 private) inviting them to participate in the IIIrd stage of the study. Parents and teachers completed a questionnaire asking them to rate the child's reading and indicate if the child had been assessed in

the PPS. With the parent consent the NEC Reading Test results of 78 subjects were obtained from schools.

All individual meetings with children took place in a separate room at the child educational institution.

2.4. Data analysis

Results of the study were processed with IBM SPSS 26 software package. Raw scores were used for the analysis (except for the sum of CPM which was transferred to the percentile). Normality of the data distribution was evaluated. Not normally distributed variables were transformed. Comparisons of risk and non-risk groups were made using Chi-square criterion or Student's t-test. Multiple regression analyses were performed. Correlations (simple and partial) were calculated using the Pearson correlation coefficient. Correlation coefficients were compared based on a statistical comparison criterion. Analyses were performed on both original and transformed data to verify that relationships with the original variables remained. ROC curves were plotted.

3. RESUTLS

3.1. Reading indicators of first and second grade students: comparative analysis of risk and non-risk groups

The intergroup comparison showed that all reading indices in the 1st and 2nd grades of the risk group were significantly worse than in the non-risk group (Table 2). This suggests that children with higher levels of risk of reading and writing difficulties in preschool age performed significantly worse one and two years later than children with less severe signs of risk of reading and writing difficulties, i.e. whose sum of the DRQ points did not show a deviation.

Table 2. *Intergroup comparison of reading results in grades 1 and 2*

	Risk group			Non-risk group					
Reading indicator	n	*M*	*(SD)*	n	*M*	*(SD)*	*t*	*df*	*p*
Reading skills in 1st grade									
Real words reading speed	45	23,78	(15,94)	47	49,72	(21,86)	6,52	84	**<0,001**
Pseudo words reading speed	45	15,24	(10,35)	46	30,02	(15,39)	5,38	79	**<0,001**
Text reading accuracy (errors)	45	22,40	(22,94)	47	5,36	(7,08)	-5,86	73	**<0,001**
Text reading comprehension	38	6,03	(3,42)	47	8,87	(2,92)	4,14	83	**<0,001**
NEC Reading Test in 2nd grade									
The estimates (total score)	35	11,80	(3,84)	40	14,70	(1,47)	-4,05	48	**<0,001**
Finding clearly presented information	35	81,43	(23,75)	40	98,13	(6,67)	-4,39	47	**<0,001**
Drawing direct conclusions	35	73,57	(27,08)	40	89,38	(18,68)	-2,65	67	**0,010**
Interpretation and integration of ideas	35	65,71	(34,15)	40	88,50	(17,48)	-2,90	73	**0,005**
Evaluation of text content, language and text elements	35	77,14	(27,75)	40	92,51	(19,22)	-2,80	61	**0,007**
Knowledge and comprehension	35	76,57	(23,51)	40	94,00	(11,28)	-4,07	66	**<0,001**
Applications	35	73,81	(25,66)	40	89,99	(15,01)	-2,47	73	**0,016**
Higher thinking skills	35	70,86	(30,43)	40	92,00	(13,44)	-3,05	65	**0,003**

Note. *M* – mean, *SD* – standard deviation. Statistically significant differences are highlighted in bold.

3.2. Comparative analysis of language development characteristics and cognitive abilities and functions of risk and non-risk groups

Language and speech difficulties/disorders in preschool age were statistically significantly more common among at-risk children than among non-at-risk children ($\chi^2 = 30{,}87$, $df = 1$, $p < 0{,}001$) (Table 3). Similarly, statistically significantly more at-risk children than non-at-risk children attended a speech therapist in preschool age ($\chi^2 = 34{,}30$, $df = 1$, $p < 0{,}001$) (Table 3).

Table 3. *Incidence of language and speech difficulties/disorders in preschool age and attendance of speech therapist among at-risk and non-at-risk groups*

	Risk group		Non-risk group	
	n	%	n	%
Has language and speech difficulties/disorders	33	70,2	7	14,3
Has no language and speech difficulties/disorders	14	29,8	42	85,7
Attended a speech therapist in preschool age	36	76,6	8	16,3
Did not attend a speech therapist in preschool age	11	23,4	40	81,6

Risk and non-risk groups differed significantly in phonological abilities (rapid automatized naming, phonological awareness, short-term auditory memory), language skills (vocabulary), visual-motor activity, visual processing (visual order threshold) and auditory processing (auditory order threshold, auditory frequency- and duration-pattern discrimination) (Table 4).

Table 4. *Intergroup comparison of cognitive activity indicators*

	Risk group			Non-risk group					
Indicator	n	*M*	*(SD)*	n	*M*	*(SD)*	*t*	*df*	*p*
Rapid object naming	47	56,55	(19,93)	49	42,69	(8,10)	5,63	94	**<0,001**
Rapid color naming	44	57,59	(18,66)	48	42,15	(7,94)	4,84	90	**<0,001**
Rapid number naming	45	35,04	(22,24)	47	23,21	(5,34)	5,94	90	**<0,001**
Rapid letter naming	44	32,30	(14,26)	47	22,79	(4,82)	5,97	89	**<0,001**
Phonological awareness	46	6,57	(2,54)	49	9,35	(2,14)	5,78	93	**<0,001**
Short-term auditory memory	45	4,07	(1,42)	49	5,39	(1,08)	5,11	92	**<0,001**
Language skills: vocabulary	46	8,65	(3,85)	49	12,02	(3,50)	4,47	93	**<0,001**
Visual-motor abilities	46	8,22	(2,51)	49	5,90	(2,79)	-4,25	93	**<0,001**
CPM (percentile)	47	57,28	(25,66)	49	67,80	(25,74)	2,00	94	**0,048**
Auditory and visual processing									
Visual order threshold	43	87,07	(84,05)	48	53,98	(30,75)	-2,34	89	**0,022**
Auditory order threshold	39	195,26	(123,74)	46	117,48	(55,66)	-3,76	83	**<0,001**
Spatial/directional hearing	38	148,26	(86,43)	46	122,30	(74,27)	-1,48	82	0,143
Pitch discrimination	15	34,27	(7,92)	18	30,67	(15,59)	-0,81	31	0,424
Auditory frequency-pattern discrimination	17	300,00	(134,07)	32	196,91	(106,86)	-2,94	47	**0,005**
Auditory duration-pattern discrimination	32	238,13	(104,93)	44	172,39	(63,17)	-3,37	74	**0,001**

3.3. Variables of cognitive activity of preschool children, predicting reading skills in grades 1 and 2

Multiple regression analyzes were performed to determine which indicators of a child's cognitive activity in preschool age best predict decoding skills in grade 1. Three multiple regression models were tested:

1) *Phonological theory model* that included all 3 phonological abilities as independent variables: phonological awareness, rapid object and color naming, and short-term auditory memory;
2) *Rapid auditory processing theory model* that included auditory processing skills (2 auditory processing functions with the strongest correlations with decoding skills: auditory order threshold and auditory frequency-pattern discrimination) as independent variables in addition to phonological abilities;
3) *Magnocellular theory model* that included visual processing skills (visual order threshold) as independent variables in addition to phonological abilities and auditory processing skills.

Multiple regression analysis showed that real words reading speed in grade 1 is best explained by *phonological theory model* (highest R^2) (Table 5). The impact of phonological awareness in predicting real words reading speed in Lithuanian did not remain significant, at the same time analyzing other phonological abilities, i.e. rapid automatized naming and short-term auditory memory (Table 5, Model 1). Vocabulary was not a significant factor in predicting real words reading speed: in 1st model $\beta = 0{,}09$, $p = 0{,}362$; in 2nd and 3rd models $\beta = -0{,}17$, $p = 0{,}148$.

Table 5. *Predicting real words reading speed of first grade students (n = 92) from cognitive activity indicators in preschool age (multiple regression)*

Independent variables	Dependent variable: Real words reading speed					
	Beta (β)	*p*	ΔR^2	*F*	*p*	R^2
1) Phonological theory model						
Phonological awareness	0,13	0,192		25,07	**<0,001**	0,47
Rapid object naming	0,35	**0,005**	0,39			
Rapid color naming	0,26	**0,041**	0,03			
Short-term auditory memory	0,20	**0,030**	0,05			
2) Rapid auditory processing theory model						
Phonological awareness	0,20	0,106		17,41	**<0,001**	0,45
Rapid object naming	0,55	**<0,001**	0,39			
Rapid color naming	0,29	0,088				
Short-term auditory memory	0,21	0,104				
Auditory order threshold	-0,25	**0,045**	0,06			
Auditory frequency-pattern discrimination	-0,17	0,251				
3) Magnocellular theory model						
Phonological awareness	0,20	0,106		17,41	**<0,001**	0,45
Rapid object naming	0,55	**<0,001**	0,39			
Rapid color naming	0,29	0,088				
Short-term auditory memory	0,21	0,104				
Auditory order threshold	-0,25	**0,045**	0,06			
Auditory frequency-pattern discrimination	-0,17	0,251				
Visual order threshold	-0,15	0,323				

Note. Statistically significant results are highlighted in bold.

Multiple regression analysis showed that pseudo words reading speed in grade 1 is best explained by *magnocellular theory model* (highest R^2), in which pseudo words reading speed is best predicted by rapid color naming and visual order threshold (Table 6, Model 3). In *phonological theory model* the impact of phonological awareness and short-term auditory memory did not remain significant, at the same time analyzing rapid automatized naming (Table 6, Model 1). Vocabulary was not a significant factor in predicting pseudo words reading speed: in 1st model $\beta = 0{,}16$, $p = 0{,}076$; in 2nd model $\beta = 0{,}16$, $p = 0{,}220$; in 3rd model $\beta = 0{,}16$, $p = 0{,}208$.

Text reading accuracy in grade 1 is also best explained by *magnocellular theory model* (highest R^2), in which text reading accuracy is best predicted by phonological awareness, rapid color naming and visual order threshold (Table 7, Model 3). In *phonological theory model* the impact of phonological awareness remained significant for the first time, at the same time analyzing other phonological abilities, which we cannot say about short-term auditory memory (Table 7, Model 1). Vocabulary was not a significant factor in predicting text reading accuracy: in 1st model $\beta = -0{,}18$, $p = 0{,}075$; in 2nd model $\beta = -0{,}18$, $p = 0{,}194$; in 3rd model $\beta = -0{,}18$, $p = 0{,}173$.

To determine which variables in pre-primary group best predict reading comprehension in grade 1 and the results of NEC Reading (text comprehension) Test in grade 2, multiple regression analyzes were performed. The multiple regression model is based on the *Simple View of Reading* (*two-dimensional model of reading disorders*) (Gough & Tunmer, 1986; Tunmer, 2008; Bishop & Snowling, 2004). Language skills (vocabulary) and all 3 phonological abilities (phonological awareness, rapid object and color naming, short-term auditory memory) were included in the model as independent variables.

Table 6. *Predicting pseudo words reading speed of first grade students (n = 91) from cognitive activity indicators in preschool age (multiple regression)*

Independent variables	Dependent variable: Pseudo words reading speed					
	Beta (β)	*p*	ΔR^2	*F*	*p*	R^2
1) Phonological theory model						
Phonological awareness	0,17	0,079		24,92	**<0,001**	0,37
Rapid object naming	0,33	**0,015**	0,04			
Rapid color naming	0,33	**0,014**	0,33			
Short-term auditory memory	0,19	0,054				
2) Rapid auditory processing theory model						
Phonological awareness	0,13	0,344		14,06	**<0,001**	0,40
Rapid object naming	0,28	0,132				
Rapid color naming	0,48	**<0,001**	0,33			
Short-term auditory memory	0,16	0,244				
Auditory order threshold	-0,29	**0,027**	0,07			
Auditory frequency-pattern discrimination	-0,22	0,163				
3) Magnocellular theory model						
Phonological awareness	0,13	0,333		15,06	**<0,001**	0,42
Rapid object naming	0,22	0,227				
Rapid color naming	0,48	**<0,001**	0,33			
Short-term auditory memory	0,16	0,241				
Auditory order threshold	-0,16	0,275				
Auditory frequency-pattern discrimination	-0,22	0,140				
Visual order threshold	-0,32	**0,014**	0,09			

Table 7. *Predicting text reading accuracy of first grade students (n = 92) from cognitive activity indicators in preschool age (multiple regression)*

Independent variables	Dependent variable: Text reading accuracy					
	Beta (β)	*p*	ΔR^2	*F*	*p*	R^2
1) Phonological theory model						
Phonological awareness	-0,33	**0,001**	0,08	24,05	**<0,001**	0,36
Rapid object naming	-0,15	0,239				
Rapid color naming	-0,38	**<0,001**	0,28			
Short-term auditory memory	-0,18	0,101				
2) Rapid auditory processing theory model						
Phonological awareness	-0,28	**0,040**	0,08	10,16	**<0,001**	0,42
Rapid object naming	-0,11	0,552				
Rapid color naming	-0,31	**0,026**	0,28			
Short-term auditory memory	-0,13	0,372				
Auditory order threshold	0,26	**0,045**	0,06			
Auditory frequency-pattern discrimination	0,17	0,260				
3) Magnocellular theory model						
Phonological awareness	-0,28	**0,037**	0,06	12,04	**<0,001**	0,46
Rapid object naming	-0,04	0,844				
Rapid color naming	-0,30	**0,027**	0,28			
Short-term auditory memory	-0,12	0,391				
Auditory order threshold	0,11	0,454				
Auditory frequency-pattern discrimination	0,15	0,287				
Visual order threshold	0,34	**0,007**	0,12			

Multiple regression analysis showed that text reading comprehension in grade 1 is best predicted by vocabulary and rapid color naming (Table 8). It should be noted that none of the visual or auditory processing functions is correlated with text reading

comprehension at least moderately. This suggests that reading comprehension requires other skills.

Table 8. *Predicting text reading comprehension of first grade students (n = 85) from cognitive activity indicators in preschool age (multiple regression)*

Independent variables	Dependent variable: Text reading comprehension					
	Beta (β)	*p*	ΔR^2	*F*	*p*	R^2
Vocabulary	0,47	**<0,001**	0,32	26,59	**<0,001**	0,40
Phonological awareness	0,10	0,355				
Rapid object naming	0,13	0,317				
Rapid color naming	0,30	**0,001**	0,08			
Short-term auditory memory	0,04	0,737				

The results of NEC Reading (text comprehension) Test in grade 2 are best predicted by vocabulary and phonological awareness (Table 9).

Table 9. *Predicting the results of NEC Reading Test of second grade students (n = 75) from cognitive activity indicators in preschool age (multiple regression)*

Independent variables	Dependent variable: NEC Reading Test					
	Beta (β)	*p*	ΔR^2	*F*	*p*	R^2
Vocabulary	-0,40	**<0,001**	0,34	25,50	**<0,001**	0,44
Phonological awareness	-0,36	**0,001**	0,10			
Rapid object naming	-0,11	0,257				
Rapid color naming	-0,11	0,303				
Short-term auditory memory	-0,06	0,602				

3.4. Prognostic value of information provided by parents and educators on the risk indicators of reading difficulties in preschool children

The risk indicators of reading and writing difficulties assessed by parents, pre-primary teachers, and speech therapists when children attended the pre-primary group are related to reading indicators in grades 1 and 2 (Table 10).

Table 10. *Correlations between DRQ estimates of different informants and reading indicators in grades 1 (g1) and 2 (g2)*

	DRQ-P		DRQ-T		DRQ-S	
Reading indicator	*r*	n	*r*	n	*r*	n
Reading estimates						
Real words reading speed, g1	-0,45**	92	-0,61**	92	-0,46**	35
Pseudo words reading speed, g1	-0,43**	91	-0,54**	91	-0,39*	35
Text reading accuracy, g1	0,47**	92	0,62**	92	0,49**	35
Text reading comprehension, g1	-0,21	85	-0,49**	85	-0,56**	29
NEC Reading Test, g2	0,46**	73	0,57**	73	0,57**	22
Reading ratings (opinion of parents and teachers)						
Reading rated by parents, g1	-0,35**	88	-0,49**	88	-0,54**	33
Reading rated by parents, g2	-0,43**	81	-0,36**	81	-0,18	27
Reading rated by teachers, g1	-0,46**	94	-0,72**	94	-0,59**	36
Reading rated by teachers, g2	-0,44**	88	-0,66**	88	-0,53**	32

Note. * $p < 0,05$. ** $p < 0,01$.

Estimates of pre-primary teachers‘ completed DRQ are stronger than parents‘ completed DRQ related to children's real words reading speed, text reading accuracy and comprehension in grade 1, and children‘s reading rated by 1st and 2nd grade teachers (Table 11).

Table 11. *Comparison of correlations between DRQ estimates of different informants and reading indicators in grades 1 (g1) and 2 (g2)*

	DRQ-T and DRQ-P		DRQ-T and DRQ-S		DRQ-P and DRQ-S	
Reading indicator	z	*p*	z	*p*	z	*p*
Reading estimates						
Real words reading speed, g1	**2,27**	**0,012**	-1,01	0,156	0,10	0,461
Pseudo words reading speed, g1	1,46	0,073	-0,98	0,163	-0,28	0,390
Text reading accuracy, g1	**-2,17**	**0,015**	0,93	0,178	-0,15	0,440
Text reading comprehension, g1	**3,27**	**0,001**	0,45	0,325	1,87	0,031
NEC Reading Test, g2	-1,25	0,105	0,01	0,495	-0,54	0,295
Reading ratings (opinion of parents and teachers)						
Reading rated by parents, g1	1,70	0,045	0,33	0,372	1,12	0,132
Reading rated by parents, g2	-0,77	0,221	-0,86	0,196	-1,19	0,117
Reading rated by teachers, g1	**4,01**	**0,000**	-1,10	0,135	0,94	0,173
Reading rated by teachers, g2	**3,00**	**0,001**	-0,92	0,179	0,54	0,294

Note. Statistically significant results are highlighted in bold.

3.5. Indicators in preschool age predicting reading difficulties in first and second grade students

ROC curves were calculated to determine which variables assessed in preschool age best differentiate subjects whose:

1) reading skills in grade 1 were the worst (lowest 10 % of the study sample results; lowest 20 % of the study sample results);
2) NEC Reading Test results in grade 2 were the worst (lowest 10 % of the results in Lithuania);
3) reading at the end of the 2nd grade was rated by the teachers as unsatisfactory or satisfactory;
4) and who have been assessed in the Pedagogical Psychological Service (PPS) from the pre-primary group to grade 2 and who have been diagnosed with a language disorder (assessed before the second semester of grade 2) or a reading disorder (assessed in the second semester of grade 2).

The results of the study show that reading difficulties are best differentiated by DRQ-T (Table 12).

On the basis of the ROC curve analyses, we determined that classifying individuals with DRQ-T scores greater than 33 as having reading difficulties in grades 1 and 2 resulted in the best balance between sensitivity and 1 – specificity. Table 13 shows the breakdown when using the 33 DRQ-T cutoff compared to reading difficulties in grade 2; sensitivity represented by the proportion of true positives correctly identified with the cutoff (76,5–90,0 %) and specificity the proportion of true negatives correctly identified by scoring below or at the DRQ-T cutoff (79,5–83,1 %.).

Table 12. *Differentiation of students with reading difficulties according to the measurements made in the pre-primary group (compilation of ROC curves)*

Variable	AUC average	How many reading difficulties indicators are predicted (out of 11)
DRQ-T	0,84	11
Rapid color naming	0,82	11
Rapid object naming	0,80	11
DRQ-S	0,80	11
Phonological awareness	0,78	11
Short-term auditory memory	0,77	11
DRQ-P	0,75	9
Auditory order threshold	0,77	8
Language skills: vocabulary	0,78	7
Visual order threshold	0,77	7
Visual-motor abilities	0,72	6
Auditory frequency-pattern discrimination	0,91	4
CPM (percentile)	0,68	4
Spatial/directional hearing	0,69	2

Note. AUC – *Area Under the Curve*.

Table 13. *Classification of subjects with and without reading difficulties in grade 2 based on DRQ-T cutoff score = 33*

	NEC Reading Test (total score), n (%)	
	Lowest 10 % of the results	20–90 % of the results
DRQ-T > 33	8 (88,9)[a]	12 (18,8)
DRQ-T ≤ 33	1 (11,1)	52 (81,2)[b]
	Reading rated by teachers, n (%)	
	Unsatisfactory-Satisfactory	Base-Upper
DRQ-T > 33	13 (76,5)[a]	12 (16,9)
DRQ-T ≤ 33	4 (23,5)	59 (83,1)[b]
	Assessment in the Pedagogical Psychological Service, n (%)	
	Language/reading disorder	Not assessed
DRQ-T > 33	9 (90,0)[a]	16 (20,5)
DRQ-T ≤ 33	1 (10,0)	62 (79,5)[b]

Note. [a] Sensitivity. [b] Specificity.

CONCLUSIONS

1. First- and second-grade students, who were identified as having a risk of reading difficulties using *the Dyslexia Risk Questionnaire* (DRQ) in preschool age, read words and text inaccurately and slowly and understood the text significantly worse than their peers who were not at risk for reading difficulties.
2. Preschool children at risk of reading difficulties differed from peers without risk of reading difficulties in the following important language development characteristics and cognitive abilities and functions:
    2.1. more children from the risk group (70 %) had language and speech difficulties/disorders compared to children from the non-risk group (14 %), and a larger number of children from the risk group (77 %) received speech therapist assistance in pre-primary group compared to children from the non-risk group (16 %);
    2.2. the abilities of at-risk children required to consolidate reading skills are lower than those of non-at-risk children, i.e. at-risk children demonstrate poorer phonological abilities (phonological awareness, rapid automatized naming, short-term auditory memory), language skills (vocabulary) and visual-motor abilities;
    2.3. at-risk children have insufficiently developed low-level auditory and visual functions, i.e. their processing speed of visual and auditory information is slower, and their ability to recognize and name minimal frequency and duration differences in a sequence of sounds is worse, compared to those of non-at-risk children.
3. Decoding and reading comprehension skills of first- and second-grade students are best predicted by different cognitive abilities and functions at preschool age:
    3.1. decoding skills in 1st grade: real words reading speed – rapid automatized naming and short-term auditory memory,

pseudo words reading speed – rapid automatized naming and processing speed of visual information, text reading accuracy – rapid automatized naming, phonological awareness and processing speed of visual information;

3.2. reading comprehension in 1st and 2nd grades: text reading comprehension in 1st grade – language skills (vocabulary) and rapid automatized naming, the results of National Examination Center Reading (text comprehension) Test in 2nd grade – language skills (vocabulary) and phonological awareness.

4. In order to predict the future reading results of at-risk and non-at-risk children in grades 1 and 2, it is more valuable to rely on information provided by educators than parents on risk indicators of reading difficulties observed in preschool age.
5. It is recommended to identify the risk of reading difficulties already at preschool age based on the teacher-completed *Dyslexia Risk Questionnaire* (DRQ-T) cutoff score of 33, also taking into account rapid object and color naming scores, speech therapist-completed *Dyslexia Risk Questionnaire* (DRQ-S) total score, and information on parental difficulties in learning to read and write.

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