Gramotnost, pregramotnost a vzdělávání

Odborný recenzovaný časopis zaměřený na problematiku čtenářské, matematické, informační a přírodovědecké gramotnosti a pregramotnosti

3/2023 ročník VII

PEDAGOGICKÁ FAKULTA
Univerzita Karlova

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Univerzita Karlova, Pedagogická fakulta
Praha, 2023

Dear Readers,

We are pleased to present the third issue of the seventh volume of the journal *Literacy, Pre-literacy, and Education*. This "Varia" issue offers a diverse range of research studies, each focusing on different aspects of literacy development in children and students. Specifically, you will find three research studies and one report. The studies address various areas of reading and mathematical skill development in school-aged children. The first study introduces a new diagnostic tool for identifying dyslexia, the second explores predictors of arithmetic skill development, and the third examines the environmental factors influencing reading literacy. The report provides an overview of the T-Conference, which gave high school students the opportunity to present their scientific projects and develop research skills.

One of the key articles is a study by Martina Zubáková and Lucie Krajčovičová, which introduces a new diagnostic tool for assessing dyslexia in primary school students. The Silent Word Reading Test, introduced within the Slovak context, shows promising results in diagnosing dyslexia, which can significantly improve the identification and support of affected children.

Another notable study is by Kateřina Skalová Pražáková, Klára Špačková, and Anna Kucharská, focusing on predictors of arithmetic skill development in early school-aged children. This study brings essential insights into how various performance factors, such as executive functions and spatial abilities, impact the level of arithmetic skills, especially in children struggling with mathematics.

Hana Sotáková's study delves into the influence of the environment on the development of reading literacy in first-grade students. The findings suggest that family and school environments play a crucial role in shaping reading skills and that these factors should be considered in the diagnosis and intervention for children with specific learning disorders.

This issue also includes a report by Monika Kadrnožková on the first annual T-Conference, which provided a platform for high school students to present their scientific work. This event, focused on natural sciences, technology, and social sciences, contributed to the development of young researchers' skills and enabled them to engage with experts in these fields.

All contributions in this issue highlight the importance of an interdisciplinary approach to education and the integration of theory with practice. The authors bring forward new findings that can enrich not only educational practice but also diagnostic and intervention strategies within schools and advisory services. We look forward to your feedback and hope that you will find valuable insights and inspiration from this edition for your own practice.

We wish you an engaging and insightful read.

On behalf of the editorial team,
Anna Kucharská
and Monika Kadrnožková

GRAMOTNOST, PREGRAMOTNOST
A VZDĚLÁVÁNÍ, 7, 3, 5—34 VÝZKUMNÁ STUDIE

The Test of Silent Word Reading as a Diagnostic Tool for The Identification of Dyslexia in Pupils of School Age

Martina Zubáková, Lucia Krajčovičová

Abstract: The paper introduces a new Slovak diagnostic tool, the Test of Silent Word Reading, designed to assess the fluency of silent reading at word level. This brief test takes only 3 minutes, making it suitable for individual and group administration. It comprises two distinct forms, A and B, facilitating repeated testing for monitoring reading progress. Building on a pilot survey conducted among primary education pupils, the test demonstrated acceptable reliability and strong concurrent validity. The study's objective was to investigate whether pupils diagnosed with dyslexia perform worse on the Test of Silent Word Reading than their non-dyslexic counterparts and whether this test could be utilized for diagnostic purposes in the future. Analyzing a sample of 23 pupils diagnosed with dyslexia and 23 control pupils without dyslexia from grades 2 to 5 in primary schools, the study confirmed that dyslexic pupils performed significantly worse in both versions of the test (A and B), as evidenced by the observed scores, raw scores, errors, and percentage correct. However, there were no statistically significant differences between the two groups in terms of correction parameters. The observed differences exhibited a moderately strong effect size. The study's findings suggest that the Test of Silent Word Reading holds promise for future diagnostic applications in identifying dyslexia among school-age children in clinical and educational settings.

Key words: Test of Silent Word Reading, silent reading fluency, dyslexia diagnosis, school age

Abstrakt: Príspevok predstavuje nový slovenský diagnostický nástroj Test tichého čítania slov, ktorý je zameraný na hodnotenie plynulosti tichého čítania na úrovni slov. Ide o krátky, rýchly, 3-minútový test, ktorý je možno administrovať individuálnou aj skupinovou formou. Test má dve rôzne formy, A a B, ktoré môžu slúžiť na opakovanú administráciu a identifikáciu pokroku v čítaní. Na základe predchádzajúceho pilotného prieskumu na súbore žiakov primárneho vzdelávania bola preukázaná jeho akceptovateľná reliabilita a solídna súbežná validita. Cieľom výskumu bolo overiť, či žiaci s diagnostikovanou dyslexiou podávajú v Teste tichého čítania slov

 DOI: 10.14712/25337890.4526

slabšie výkony ako žiaci bez dyslexie a či predstavený test by mohol v budúcnosti slúžiť aj na diagnostické účely. Na výskumnom súbore 23 žiakov s diagnostikovanou dyslexiou a 23 kontrolných žiakov bez dyslexie 2. – 5. ročníka základných škôl sa potvrdilo, že žiaci s dyslexiou dosahujú štatisticky významne horšie výkony v oboch verziách testu, A aj B, v sledovaných skóre – hrubé skóre, chyby a percento správnosti, avšak v parametri opravy neexistujú medzi týmito skupinami štatisticky významné rozdiely. Preukázané rozdiely majú z hľadiska hodnotenia veľkosti efektu stredne silný efekt. Výsledky výskumu naznačujú, že Test tichého čítania slov môže v budúcnosti slúžiť na diagnostické účely pri stanovovaní diagnózy dyslexia u detí v školskom veku v klinickej i školskej praxi.

Kľúčové slová: Test tichého čítania slov, plynulosť tichého čítania, diagnostika dyslexie, školský vek

Introduction

Reading plays a crucial role in today's society, serving as a fundamental indicator of literacy and a necessary component of social activities such as communication, education, and engagement with social media. This intricate process of deriving meaning from abstract written symbols stands as the primary means of accessing information in our modern age (Handler & Fierson, 2011). Accurate and fluent reading comprehension is indispensable for daily life, cognition, education, and workplace functionality (Krieber et al., 2016).

Difficulties in reading pose a significant challenge for individuals, manifesting in poor comprehension of text, limited vocabulary, and a negative attitude towards reading (Lyon, Shaywitz & Shaywitz, 2003). Moreover, reading difficulties can have broader repercussions, such as hindering educational attainment and influencing career choices (Morris & Turnbull, 2007).

Dyslexia as a subtype of developmental learning disorders

Developmental learning disorders are globally acknowledged as a diverse range of disorders affecting academic abilities and are included in all major diagnostic classifications, such as the Diagnostic and Statistical Manual of Mental Disorders and the International Classification of Diseases (Grigorenko et al., 2020).

In the latest, 11th revision of the International Classification of Diseases (WHO, 2019), dyslexia is classified under Developmental learning disorders (code 6A03) and more specifically defined as a Developmental learning disorder with impairment in reading (code 6A03.0). It is characterized by significant and persistent difficulties in acquiring academic reading-related skills, such as word reading accuracy, reading fluency, and reading comprehension. The individual's reading performance falls significantly below the expected level for their chronological age and level of intellect, resulting in substantial impairment in academic or occupational functioning. A developmental learning disorder with impairment in reading is not attributed to disorders of intellectual development, sensory impairment, neurological disorders, lack of access to education, lack of proficiency in the language of academic instruction, or psychosocial disadvantage.

The European Dyslexia Association (EDA, 2020) reports that dyslexia affects approximately 9–12% of the population, with a severe form observed in 2–4% of school-age children. In Slovakia, 3.2% of children were integrated into primary schools in 2019 (Slovak Centre of Scientific and Technical Information, 2020). However, it's important to note that this figure encompasses all developmental learning disorders and not only dyslexia. This suggests a significant underdiagnosis of dyslexia, or probably captures only the most severe disorders, which means that at least 6% of children are not identified and consequently do not receive appropriate support.

Dyslexia is a developmental learning disorder with a neurobiological origin (Lou et al., 2019), manifests in varying degrees of severity (Shaywitz & Shaywitz, 2005), and persists into adulthood (Vellutino et al., 2004).

Depending on its manifestations, dyslexia can significantly influence the life decisions of individuals, as they may opt to avoid studies and career paths that require extensive reading. In addition to being a considerable barrier to academic success, dyslexia has been shown to have a detrimental impact on employment and career progression (Morris & Turnbull, 2007).

Schulte-Körne (2010), drawing on various research studies on the psychological well-being of children and adolescents with dyslexia, concludes that 40 to 60% of individuals in this group experience psychological issues, including anxiety and depression. This percentage is notably higher than the general prevalence of mental disorders, which, according to data from the German Child and Adolescent Mental Health Survey, ranges between 5 and 18%, depending on the diagnostic criteria. Children with dyslexia, even in elementary school, often encounter negative thoughts, depression, a melancholic mood, and anxiety related to school. They frequently feel excluded, unaccepted, and rejected by teachers. The rate of negative thoughts and suicide attempts is three times higher in adolescents with dyslexia, the occurrence of depression is twice as common, and anxiety disorders are up to three times more frequent.

To mitigate the significant psychosocial implications of dyslexia, it is crucial to promptly identify students experiencing reading difficulties and offer them appropriate compensatory strategies or sufficient support for the enhancement of their reading skills. Reliable diagnostic tools are essential for the early identification of these children, enabling the identification of dyslexia reliably, both within educational settings and counselling services.

Oral versus silent reading

Reading can occur in two ways: as oral reading, where students read aloud with appropriate phrasing, or silently, where the text is processed automatically without oral output (Wissinger et al., 2023). Currently, research has shown that oral and silent reading are different constructs, not only on a behavioural level (Robinson, 2019) but also on a neurobiological level. In neurotypical children, both reading modes are processed in distinct neuroanatomical regions (Xia et al., 2018).

While oral and silent reading share the same fundamental processes and strategies, reading aloud entails more ongoing processes than reading silently. The primary distinction between these two reading modes lies in verbalization (Krieber et al., 2017); in other words, when reading aloud, speech production must be coordinated with ongoing language perception, including the pronunciation of words, intonation, etc. (Kim, Petcher & Vortius, 2019). Because oral reading necessitates the production of understandable speech, it is considerably slower compared to silent reading (Laubrock & Kliegl, 2015). Silent reading is less demanding than oral reading due to the additional demands caused by oculomotor movements synchronized with articulatory processes in silent reading (Krieber et al., 2017).

Silent reading typically emerges in development after oral reading (Laubrock & Kliegl, 2015). In elementary school, during reading instruction, the emphasis swiftly shifts from decoding aloud to silent reading. As students advance and gain proficiency in oral reading, they tend to gravitate towards silent reading, where they also display enhanced speed (Krieber et al., 2017). Within the first three years of formal education, children may not clearly prefer either reading mode (Smyrnakis et al., 2021), but after this period, silent reading becomes the favoured approach (van den Boer, van Bergen & de Jong, 2014), and for adept readers, the primary method (Rayner, 1998). Research confirms that oral reading is slower than silent reading, not only among children but also adolescents (van den Boer, Bazen, & de Bree, 2022). Typical readers read 4–9%

faster when reading silently compared to reading aloud (van den Boer et al., 2014; van den Boer et al., 2022).

Reading fluency is a multifaceted construct that exhibits bidirectional relationships with other language abilities (Berninger et al., 2010). An essential aspect of functional reading is fluency. Fluency in oral reading can be delineated by three primary components: automaticity of word recognition (i.e., speed), decoding accuracy, and appropriate utilization of prosodic features of speech during reading (Kuhn & Stahl, 2003). Norton and Wolf (2012) conceptualize "fluency" in a more complex way than merely the pace and precision of oral reading, recognizing that much of our reading occurs silently. They define it as the "fluency of understanding" of the text, indicating a manner of reading in which all perceptual, linguistic, and cognitive processes operate precisely and automatically, allowing ample time and cognitive resources for comprehension and deeper reflection. Conversely, van den Boer et al. (2022) construe fluency in a narrower sense, focusing on word recognition, particularly the number of syllables a reader can accurately identify within a given time frame. They characterize reading fluency as the metric of reading that most effectively distinguishes between proficient and struggling readers.

The findings of the study conducted by Psyridou et al. (2023) confirm that silent reading fluency can bolster reading comprehension in typical readers during the early years of formal education. Conversely, proficient reading comprehension can also enhance silent reading fluency in later grades. In a study by Prior et al. (2011), which involved 173 children in grades 1 through 7, a comparison between oral and silent reading in relation to reading comprehension was made. The results indicated that oral reading is the optimal approach for comprehending text from 1st to 5th grades. By 6th grade, neither reading mode demonstrated superiority over the other in terms of comprehension. Nevertheless, silent reading has been shown to enhance reading comprehension starting in the 7th grade.

The minimum number of words read aloud for successful comprehension by English pupils in the 2nd grade of elementary school is 63 words per minute (Burns et al., 2011). This figure corresponds to the socially acceptable rate of reading, which ranges from 60 to 70 words per minute (Matějček, 1974). In contrast, Slovak pupils already meet this criterion at the beginning of the second grade (October/November), with their average speed reaching 63 words per minute, which increases to 79 words per minute by the end of the school year (Zubáková & Mikulajová, 2021).

The relationship between speed and comprehension is more pronounced among typical readers than among struggling readers. Fourth-grade English speakers who could accurately read between 120–140 words per minute, equivalent to the pace of conversational speech, exhibited superior comprehension. Conversely, an increase in reading speed had an adverse effect on reading comprehension. Although some typical students reached speeds of nearly 200 words per minute, such rapidity did not necessarily correlate with improved comprehension. It appears that proficient readers require a higher speed (at least 70 words/min.) to achieve average comprehension levels, whereas children with dyslexia typically exhibit much lower speeds (at least 40 words/min.) (O'Connor, 2018).

The average silent reading speed for adults is 12.5 syllables per second, nearly twice the pace of reading aloud. Silent reading speed tends to increase from adolescence through the completion of university studies, while the rate of reading aloud remains relatively constant. As a result, silent reading fluency typically improves until early adulthood, establishing it as the quickest and most efficient mode of reading (Ciuffo et al., 2017).

Although the linguistic-cognitive precursors of oral reading are relatively well-documented across different language typologies (e.g., Caravolas et al., 2012), there is still insufficient scientific investigation into whether this also applies to silent reading. The results of a longitudinal study by Bar-Kochva (2013) of Hebrew-speaking children, spanning from preschool age to the end of the second year of elementary school, indicate that the language-cognitive skills fundamental to learning to read aloud are also essential for the development of silent reading. In another study by van den Boer et al. (2014) involving Dutch fourth graders, they examined key abilities for both oral and silent reading, discovering that rapid automatic naming is more predictive of reading aloud, whereas visual attention span is more closely associated with silent reading.

Silent Reading Fluency and Its Diagnostic Significance

There is now evidence indicating that children and adolescents with dyslexia read more slowly in both reading modes than their peers without reading difficulties (van den Boer et al., 2022). Impairments in reading fluency can be regarded as persistent behavioural markers of dyslexia into adulthood (Christodoulou et al., 2014).

For many years, conclusions drawn from English research, characterized by its outlier orthography, have demonstrated limited validity for other language typologies (Share, 2008). Orthographic transparency has been shown to significantly influence the manifestation of dyslexia, with dyslexic symptoms being less pronounced in languages with transparent orthographies (Reis et al., 2020).

The most recent meta-analysis (Carioti et al., 2021) indicates that in non-transparent languages, individuals with dyslexia experience impaired reading accuracy, whereas fluency (in terms of reading speed) can be regarded as language-non-specific or universal. The developmental pathways of reading vary across languages and are significantly influenced by orthographic depth. While typical and dyslexic school-age readers exhibit higher levels of reading accuracy in transparent languages, this language-specific effect of dyslexia diminishes in adulthood. It has been established that lexical reading (i.e., reading words) poses greater challenges in non-transparent languages, whereas non-lexical decoding (i.e., reading pseudowords) appears to be language non-specific. Consequently, reading speed (referred to as the automaticity deficit) can be considered a more consistent marker of dyslexia than reading accuracy, irrespective of age, as achieving a ceiling level in accuracy becomes easier in adulthood. Many individuals with dyslexia can attain a reasonable level of proficiency in reading during adulthood, although mild but persistent decoding difficulties persist, such as slow reading and reading with considerable effort (Gagliano et al., 2015).

Students diagnosed with dyslexia encounter challenges with reading fluency, which can impede their reading comprehension (Robinson, Meisinger & Joyner, 2019). An American longitudinal study (Robinson, 2019) investigated the relationships between oral and silent reading fluency and comprehension in 2nd, 3rd, 4th, and 5th graders diagnosed with dyslexia. The children underwent a battery of tests during two testing periods within a year, conducted at the beginning and end of the school year. Read-aloud accuracy was identified as the most significant component of fluency affecting text-level reading comprehension in both reading modes. The study's findings suggest that oral reading promotes the development of silent reading, although this relationship is not reciprocal. Silent reading fluency does not affect oral reading comprehension performance, while proficient oral reading enhances comprehension in both reading aloud and silent reading. Thus, it can be inferred that oral reading fluency, rather than silent reading fluency, significantly contributes to reading comprehension.

Van den Boer et al. (2022) compared both reading modes in children and adolescents with and without dyslexia. They found that while reading fluency was similar in both modes in typically developing children, silent reading was faster in adolescents. However, in children and adolescents with dyslexia, the deficit in silent reading was comparable to or even greater than the deficit in oral reading, highlighting the importance of assessing both modes of reading.

Silent reading fluency is inherently less observable, rendering its assessment more challenging and less reliable compared to oral reading fluency (Ciuffo et al., 2017). Nonetheless, when evaluating reading skills, it is crucial to assess both modalities. One compelling reason for this approach is that dyslexia diagnosis often relies on deficient performance in oral reading fluency, while support strategies apply mainly to the area of silent reading. Therefore, it is imperative to incorporate both modes of reading into the diagnostic process, not only to evaluate them but also to concentrate on enhancing both aspects as part of the intervention (van den Boer et al., 2022).

Currently, eye movement tracking technology is regarded as the most objective means of assessing silent reading, enabling precise data collection regarding an individual's reading habits. However, this diagnostic approach is notably constrained, as it necessitates strict conditions to be met (e.g., subjects must remain motionless while reading and be supervised by trained administrators). While eye tracking offers detailed insights into eye movements during reading, it does not furnish information regarding language processing, including reading comprehension (Ciuffo et al., 2017).

Van den Boer et al. (2014) note that most research studies have focused primarily on oral reading, even though silent reading is the primary reading mode for advanced readers. Although in schools, once the reading technique is mastered, the focus shifts to independent silent reading, the same shift is not seen in practice when diagnosing dyslexia. Even though Slovak-speaking children are already accurate in reading aloud words and pseudowords by the end of the first grade (Schöffelová & Mikulajová, 2012), most diagnostic tests in school practice focus on assessing reading skills through oral reading.

There are now several standardized tests available internationally that can be used to evaluate silent reading fluency. These tests assess silent reading at various levels, including word, sentence, and text. Some of the most well-known standardized tests for evaluating silent reading among English speakers include:

Gray Silent Reading Tests – GRST (Wiederholt & Blalock, 2000) consist of several short text passages that are developmentally ordered, each followed by multiple-choice questions. The test offers norms for individuals aged 7 to 25.

Test of Silent Reading Efficiency and Comprehension – TOSREC (Wagner et al., 2010) evaluates silent reading efficiency (i.e., speed and accuracy) and comprehension at sentence level. Students are tasked with reading and verifying the truthfulness of as many sentences as possible. The test provides norms for grades one through twelve of formal education.

Other options for assessing silent reading fluency include tests such as the Test of Silent Contextual Reading Fluency – TOSCRF (Hammill, Wiederholt & Allen, 2014) and the Test of Silent Word Reading Fluency – TOSWRF (Mather et al., 2014). The TOSCRF evaluates basic contextual reading skills (i.e., word identification, lexical and semantic skills, and comprehension) by presenting examinees with a series of short passages where words are printed in capital letters without spaces. Their task is to mark the boundaries of the words in the sentences. This test provides norms for individuals aged 7 to 24 years. In contrast, the TOSWRF measures the ability to accurately and efficiently recognize isolated words presented in a solid block of text without spaces and sorted by reading difficulty. Examinees are tasked with marking word boundaries with vertical lines within a time limit. This test offers norms for individuals aged 6 to 24 years. A meta-analysis examining the validity of the TOSCRF and TOSWRF (Wissinger et al., 2023) revealed that scores on these tests strongly correlate with students' performance on a wide range of other tests assessing reading competence.

Currently, Slovakia offers several standardized tests for assessing silent reading. The first is the Picture-Word Matching Test from the MABEL battery (Caravolas et al., 2018), which provides norms for 1st and 2nd-grade elementary school students. The second option is the Test of Word Completion (Mikulajová, Vencelová & Caravolas, 2012), which offers norms for elementary, middle, and high school students. Additionally, two subtests from the Reading Battery for Older Pupils – Čí(s)ta (Žovinec & Dufeková, 2014), namely Word division and Text comprehension, provide benchmark standards for 8th and 9th-grade middle and high school students.

To address the necessity of evaluating silent reading fluency among Slovak-speaking children at the word level, for screening, diagnosis, and monitoring progress in therapy, a new Slovak test was developed – the Test of Silent Word Reading. This test was inspired by the TOSWRF mentioned above (Mather et al., 2014). In the empirical section, we emphasize its diagnostic potential in counselling and school practice.

Defining the research problem

Currently, the assessment of reading fluency is widely regarded as one of the most reliable indicators of dyslexia, irrespective of age and language typology (Carioti et al., 2021). In the international literature, inconsistencies in the interpretation of the concept of reading fluency are apparent (cf. Kuhn & Stahl, 2003; Norton & Wolf, 2012; van den Boer et al., 2022). In our research, we conceptualize silent reading fluency following van der Boer et al. (2002), defining it as the number of correctly identified words within a specified time frame. The Test of Silent Word Reading (TSWR) assesses silent reading fluency, measuring how quickly and accurately learners recognize lexical words. Drawing on prior research in the domain of silent reading among children with dyslexia, we hypothesize that students with dyslexia will exhibit poorer performance in silent reading fluency (van den Boer et al., 2022), in terms of accuracy indicated by the frequency of errors (Váryová, 2012), and, given the documented impairment of executive functions in dyslexia (Varvara et al., 2014), in the frequency of corrections made.

Research objective and hypotheses

This research aims to compare the performance of two groups of pupils in grades 2–5 of primary school: pupils diagnosed with dyslexia and a control group without dyslexia, using the Test of Silent Word Reading (TSWR). In the formulated hypothesis (H), we posit that statistically significant differences will exist between pupils with dyslexia and those without dyslexia in the TSWR, across both versions (A and B), and across all observed assessment parameters, namely: H1) raw scores; H2) number of errors; H3) number of corrections; and H4) percentage of correctness.

Research implementation

The research was conducted in June and September 2021. Initially, we approached the principals of selected primary schools in Bratislava and Central Slovakia to request their assistance and cooperation in conducting the study. Our first step involved identifying and testing pupils diagnosed with dyslexia. Subsequently, we identified and administered tests to a control group—comprising pupils without dyslexia—matched to the set of dyslexic children. Parents of the approached pupils provided informed consent for their child's participation in the study. Dyslexic pupils underwent screening in June 2021, while non-dyslexic pupils underwent screening in September 2021.

Research methods

Test of Silent Word Reading (Zubáková, experimental version)

The TSWR is a screening tool inspired by the English TOSWRF (Test of Silent Word Reading Fluency; Mather, N. et al., 2014). This test focuses on assessing silent reading fluency based on speed and accuracy. It consists of sequentially arranged lexical words in lines without spaces. The examinee's task is to swiftly identify the words and demarcate them with a vertical line at word boundaries within a 3-minute time limit. The TSWR can be administered to individual pupils or in group settings. Two test forms (Version A and Version B) allow for repeated testing of the same pupils without affecting their performance due to familiarity with the test material. Each version comprises 196 words. A comprehensive description of the test's development and its linguistic underpinnings is available in a study by Zubáková and Bekečová (2022). Before the actual testing, a practice session ensures that learners understand the task. Scoring in the TSWR is straightforward, with 1 point awarded for each correctly separated word. Four types of scores are provided: 1) a raw score, which is the sum of all correctly separated words; 2) errors, indicating the number of incorrectly separated words; 3) corrections, representing items initially separated incorrectly but then corrected through a specially designated mark; and 4) percentage correct, denoting the proportion of correctly separated words out of all separated items.

Reading Test with Word Completion (Mikulajová, Vencelová & Caravolas, 2012)

This is a standardized diagnostic tool designed for pupils in grades 1 to 9 of primary school. There are two versions of this assessment tool: a simpler version tailored for younger pupils in grades 1-4 of primary school, consisting of single-word selections, and a more complex version intended for older pupils, which includes the standards for the two-word version applicable for grades 4-9 of primary school. The test evaluates reading comprehension at the sentence/short passage level within a defined time interval. The examinee's task is to read the sentences silently and identify the target word from multiple offered options by underlining it. This task engages semantic, lexical, and phonological language skills, as well as working memory. The lexical-semantic way of reading is employed. Each correctly underlined word earns the pupil one point. The reading performance score (raw score) is the sum of all correctly completed words. The reading accuracy score gauges comprehension level regardless of reading speed; it is computed by dividing the raw score by the total number of items (correctly and incorrectly completed) and multiplying by 100, yielding the percentage of correctly completed words (percentage correct). The test can be administered either in groups or individually.

Graded Word Spelling (Caravolas et al., 2018)

This test is a component of the Multilanguage Assessment Battery of Early Literacy (MABEL), a comprehensive assessment tool designed to evaluate early literacy skills and map the ability to spell increasingly complex words. The assessment encompasses various spelling rules, including graphotactic, morphological, and morphophonological principles, and also assesses knowledge of selected words. Dictated words incorporate different types of inconsistencies. Words within the test are arranged in ascending order of difficulty and vary in syllable length (ranging from 1 to 3 syllables) as well as syllable structure, including variations with and without consonant clusters. During administration of the test, the administrator dictates each word three times: initially as the target word, then within a short phrase, and finally as the target word again. This repetition ensures that the pupil hears the target word multiple times, facilitating comprehension and recall. The test can be administered to individuals or groups, allowing for flexibility in testing environments. Each correctly spelled word earns the test taker one point, while incorrectly spelled words receive zero points. The gross score is calculated by adding up all the correctly spelled words.

Advanced Spelling Test for Upper-Level Pupils (Vencelová, Mikulajová & Caravolas, 2012)

This spelling test is tailored for pupils in the second stage of primary school, encompassing grades 4th through 9th. The assessment comprises 50 target words, each dictated to the pupils up to three times to minimize errors resulting from misunderstanding the target words. The test aims to evaluate the spelling proficiency of older pupils, particularly focusing on their ability to accurately spell 'i' and 'y' after consonants in the root of a word, as well as after consonants in a grammatical morpheme at the end of a word. In evaluating spelling performance, a clear distinction is drawn between specific errors, referring to deviations from the correct spelling of the target graphemes, and non-specific errors, encompassing all other inaccuracies excluding the target graphemes. Each correctly spelled target grapheme in a dictated word earns the pupil one point. The raw score is derived from the total number of words in which the pupil correctly spelled the target grapheme. Furthermore, the non-specific error score indicates the total number of errors made by the pupil outside the designated target spelling phenomena. Testing can be conducted both individually and in group settings to accommodate different instructional contexts.

Participants

The research sample comprised two distinct cohorts of pupils spanning grades 2 through 5 within the primary school setting: 1) pupils devoid of dyslexia or any officially diagnosed developmental learning disorders (such as dysorthographia, dysgraphia, dyscalculia), and 2) pupils diagnosed with dyslexia at a Counselling and Prevention Centre. Initially, 35 pupils were assessed in each group during the research's preliminary phase, which took place during the months of June and September in 2021.

The investigative process commenced with the evaluation of a cohort of pupils identified as having dyslexia, followed by their pairing with non-dyslexic counterparts through a method of pairwise selection based on a corresponding grade level. A fundamental prerequisite for inclusion in the dyslexic group was the verification of a developmental learning disorder, specifically dyslexia, by a qualified professional. Conversely, pupils without dyslexia were admitted to the control group based on parental affirmation of the absence of any neurodevelopmental disorders. In addition to the administration of the TSWR (versions A and B), both cohorts underwent assessment utilizing the Reading Test with Word Completion (Mikulajová, Vencelová & Caravolas 2012). The examination comprised single-word completion tasks for pupils in grades 2 through 4 and two-word completion tasks for those in grade 5. Furthermore, spelling proficiency was evaluated through the implementation of the Graded Word Spelling assessment for pupils in grades 2 through 4 (Caravolas et al., 2018), while students in grade 5 took the Advanced Spelling Test for Upper-Level Pupils (Vencelová, Mikulajová & Caravolas, 2012).

Despite the child's designated status (diagnosis of dyslexia versus non-dyslexic pupil), we established our inclusion criteria for the 'dyslexic' and 'non-dyslexic' groups to ensure that they remained mutually exclusive. This decision was motivated by the longstanding unfavourable situation in Slovakia, where the Minimum Diagnostic Standards for Developmental Learning Disorders were not established until 2019 (National Institute for Education, 2019), resulting in considerable variation in diagnostic procedures among Counselling and Prevention Centres. We also recognized the possibility of children with poor reading or spelling performance being included in the cohort of non-dyslexic pupils due to the historical underdiagnosis of developmental learning disorder in Slovakia. For these reasons, we decided that only pupils meeting predefined criteria could be included in each group. For each pupil, we evaluated performance in reading and spelling skills using a standardized test. In establishing the criteria, we drew inspiration from the guidelines outlined by van den Boer et al. (2022) and admitted only those children to the dyslexic group who demonstrated an elevated risk (below the 10th percentile) in at least one of the administered tests. Conversely, pupils without dyslexia were required to perform above the risk threshold (above the 10th percentile) in both tests for inclusion. Pupils who did not meet the specified criteria in their respective groups were excluded from the research population.

The ultimate research sample comprised 46 pupils spanning grades 2 through 5 in primary school, specifically 23 pupils diagnosed with dyslexia and an

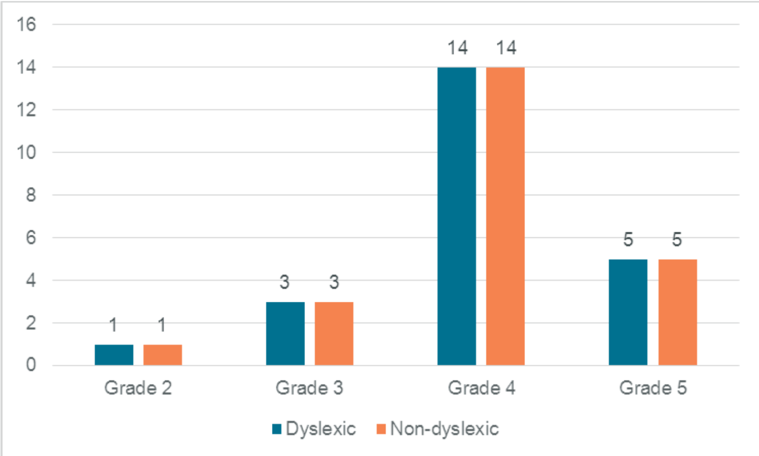


Chart 1. Distribution of Dyslexic and Non-Dyslexic Pupils Across Grade Groups

equal number of 23 pupils without dyslexia (refer to Figure 1). Regarding gender distribution, the sample consisted of 33 boys and 13 girls, with 16 boys and 7 girls in the non-dyslexic group, and 17 boys and 6 girls in the dyslexic group.

The research groups exhibited significant age differences, with an average gap of 11 months, as indicated by the Mann-Whitney U test ($U = 106.5$, $Z = -3.474$; $p = 0.001$). This discrepancy can be attributed to the following factors:

1. Varied testing times: The dyslexic pupil group, tested towards the end of the academic year, boasted an average age of 10 years and 6 months, approximately 11 months older than the non-dyslexic control group, which underwent testing at the start of the year and had an average age of 9 years and 7 months.
2. Higher prevalence of deferred school entry: The dyslexic group displayed a higher incidence of deferred school entry, with 9 pupils compared to the 6 pupils in the control group.

The decision not to test the grouped pupils at a single point in time was based on the primary focus of our research being centred on evaluating reading fluency in children with dyslexia, who are known to be particularly affected in this area. Therefore, we opted to provide pupils with dyslexia one full school year to consolidate their reading skills, ensuring that any observed performance

Table 1. Characteristics of Non-Dyslexic and Dyslexic Pupil Groups by Age

	N	Min	Max	Mean	Median	SD
Non-Dyslexic pupils	23	86	133	116,22	118	10,91
Dyslexic pupils	23	108	142	127,39	125	8,86

Note: The pupils' ages are expressed in months.

Table 2. Descriptive Statistics of Performance for the Group of Non-Dyslexic Pupils

	N	Min	Max	Mean	Median	SD	Normality
TSWR A (RS)	23	22	99	64,39	64	18,05	,29
TSWR A (E)	23	0	14	2,43	2	3,3	,00
TSWR A (C)	23	0	6	1,26	1	1,51	,00
TSWR A (%)	23	61,11	100	95,21	97,18	8,41	,00
TSWR B (RS)	23	30	108	74,17	73	18,73	,24
TSWR B (E)	23	0	20	2,83	0	4,78	,00
TSWR B (C)	23	0	6	1,83	1	1,59	,01
TSWR B (%)	23	71,43	100	95,92	100	7,21	,00
RTWC 1 (RS)	18	4	12	7,67	7,5	1,97	,91
RTWC 1 (%)	18	80	100	92,69	91,16	7,18	,00
RTWC 2 (RS)	5	17	29	21,80	22	4,76	,59
RTWC 2 (%)	5	90	95,65	92,54	92	2,43	,55
GWS (RS)	18	7	31	25,67	27,5	5,84	,00
ASTUP (RS)	5	31	46	40,4	41	5,77	,4
ASTUP (E)	5	0	4	1,8	1	1,64	,49

discrepancies were not influenced by external factors. For instance, we aimed to mitigate the potential impacts of reduced lesson allocations during the COVID-19 pandemic measures implemented from 2020 to 2021, which may have affected dyslexic pupils more acutely than their peers without reading difficulties.

Table 3. Descriptive Statistics of Performance for the Group of Dyslexic Pupils

	N	Min	Max	Mean	Median	SD	Normality
TSWR A (RS)	23	25	92	48,57	46	16,64	,1
TSWR A (E)	23	0	17	6,13	6	5,29	,04
TSWR A (C)	23	0	5	1,74	2	1,14	,01
TSWR A (%)	23	59,52	100	87,9	88,52	11,2	,01
TSWR B (RS)	23	33	105	60,48	60	17,13	,35
TSWR B (E)	23	0	13	5	4	4,22	,03
TSWR B (C)	23	0	7	2,52	2	1,95	,1
TSWR B (%)	23	80,77	100	92,37	92,96	5,74	,3
RTWC 1 (RS)	18	3	14	6,83	6	2,83	,17
RTWC 1 (%)	18	21,74	100	81,21	88,2	19,69	,00
RTWC 2 (RS)	5	4	20	14,2	16	6,02	,11
RTWC 2 (%)	5	44,4	88,89	75,39	83,33	18,73	,10
GWS (RS)	18	8	29	18,67	18,5	5,79	,67
ASTUP (RS)	5	23	37	28	27	5,39	,26
ASTUP (E)	5	2	29	18	24	12,19	,21

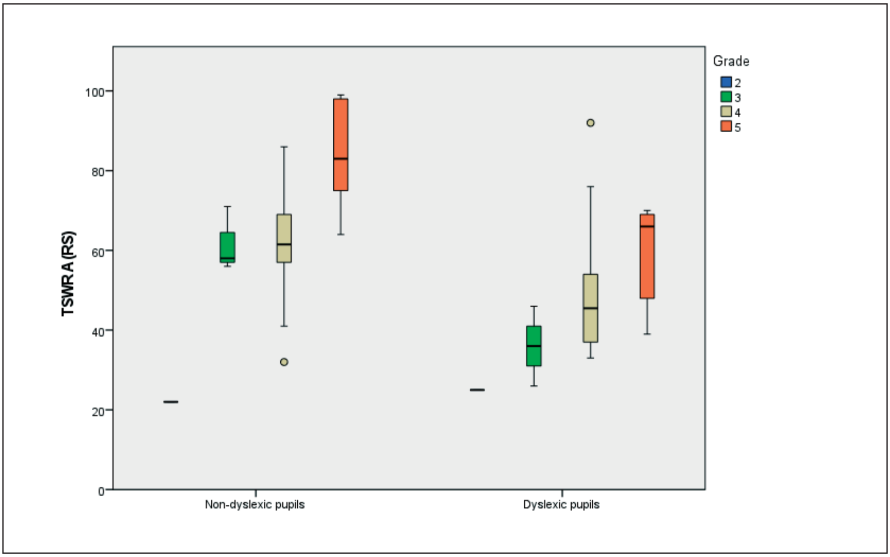
Note: TSWR A/B (RS) – raw score; TSWR A/B (E) – number of errors; TSWR A/B (C) – number of corrections; TSWR A/B (%) – percentage of correct responses; RTWC 1 (RS) – Reading Test Word Completion (raw score) – the number of words correctly completed for the single-word version administered to pupils in Grades 2 to 4; RTWC 1 (%) – Reading Test Word Completion (percentage) – percentage of reading accuracy for the single-word version administered to pupils in Grades 2 to 4; RTWC 2 (RS) – Reading Test Word Completion (raw score) – the number of words correctly completed for the two-word version administered to pupils in Grade 5; RTWC 2 (%) – Reading Test Word Completion (percentage) – percentage of reading accuracy for the two-word version administered to pupils in Grade 5; GWS (RS) – Graded Word Spelling (raw score) – number of correctly spelled words; ASTUP (RS) – Advanced Spelling Test for Upper-Level Pupils (raw score) – number of correctly spelled words; ASTUP (E) – Advanced Spelling Test for Upper-Level Pupils (number of non-specific errors); the Shapiro-Wilk test was utilized to evaluate the normality of the test data

Results

For the statistical analysis of the results, we utilized the statistical software SPSS 23. Before interpreting the results, we present tables containing descriptive statistics of the performances, including mean values, medians, standard deviations, minimum and maximum values, and the normality of distributions, for both research groups separately (Table 2 for pupils with dyslexia and Table 3 for pupils without dyslexia).

In Figures 2 and 3, the discrepancies

Figure 2. Comparison of Raw Scores Performance in TSWR A between Non-Dyslexic and Dyslexic Pupils by Grade Group

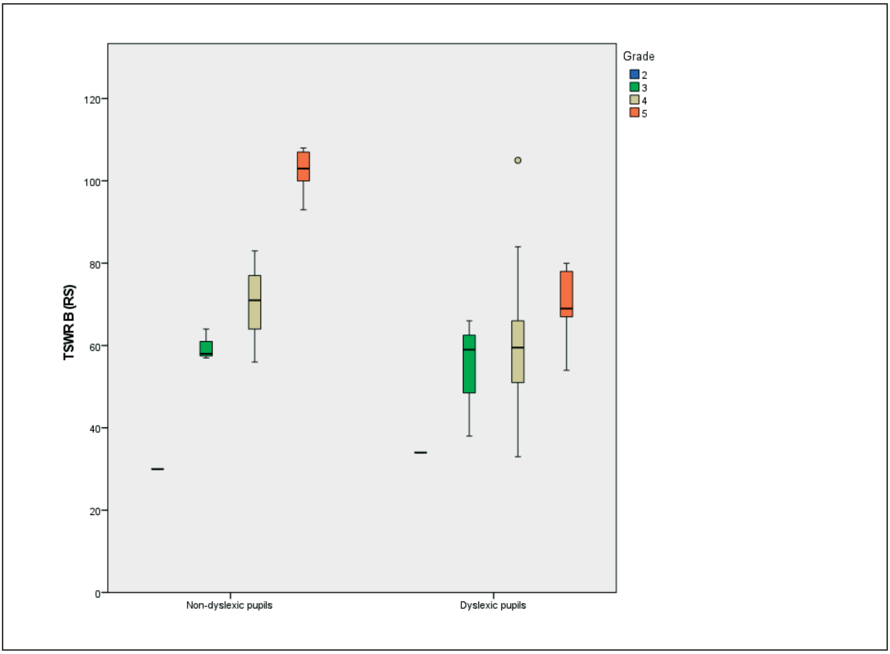


Note: The y-axis displays the raw score values, representing the number of correctly separated words.

in the raw scores of TSWR A and B between the groups of dyslexic and non-dyslexic pupils across grade levels are evident. Notably, in both groups, pupils attained higher raw scores on average in version B, which was administered second in order. Additionally, it is observable that performance gradually improves for both research groups throughout grades 2-5. As the grade level increased, pupils exhibited higher scores on the TSWR in both versions of the test.

Based on the literature reviewed, we hypothesized the presence of statistically significant differences in performance on the Test of Silent Word Reading (both A and B versions) for dyslexic and non-dyslexic pupils across all studied parameters (H1, H2, H3, H4). We employed the non-parametric Mann-Whitney U test to compare differences in the Test of Silent Word Reading (refer to Table 4). The statistical verification results confirmed the validity of the formulated hypotheses in H1, H2, and H4. Specifically, there are statistically significant differences be-

Figure 3. Comparison of Raw Scores Performance in TSWR B between Non-Dyslexic and Dyslexic Pupils by Grade Group



Note: The y-axis displays the raw score values, representing the number of correctly separated words.

tween the research groups in raw scores, error rates, and percentage correctness, all to the disadvantage of dyslexic pupils. However, our research did not confirm H3, indicating no statistically significant differences between the groups in the area of corrections. Additionally, when differences were observed, we further investigated the effect size(r) calculated using the formula $r = \frac{z}{\sqrt{n}}$. The results revealed a medium effect size between the groups across the parameters of raw scores, errors, and percentage correctness in both versions A and B.

Discussion

Our research aimed to compare the performance of two research groups, namely dyslexic and non-dyslexic pupils, in the

Table 4. Comparison of Performance on the Test of Silent Word Reading Between Dyslexic and Non-Dyslexic Pupils

	TSWR A (RS)	TSWR	TSWR A (corrections)	TSWR A (%)	TSWR B (RS)	TSWR B (errors)	TSWR B (corrections)	TSWR B (%)
Mann-Whitney U	131,000	147,000	185,500	148,000	153,000	165,000	209,000	144,500
Z	-2,935	-2,622	-1,797	-2,589	-2,451	-2,237	-1,242	-2,693
p	,003	,009	,072	,010	,014	,025	,214	,007
r	**0.43**	**0,39**		**0,38**	**0.36**	**0,33**		**0,4**

new Test of Silent Word Reading. We utilized a sample of 46 Slovak-speaking pupils from grades 2 to 5 in primary school and assessed their performance on the Test of Silent Word Reading in terms of raw scores, errors, corrections, and percentage correct. Our formulated hypothesis posited that there would be statistically significant differences in all parameters to the disadvantage of pupils with dyslexia.

The research population consisted of mainstream primary school pupils, who were matched according to their year group, with non-dyslexic pupils being tested at the beginning of the school year and dyslexic pupils at the end of the school year. Dynamic changes in literacy development occur during the early years of formal education, as confirmed by Mikulajová, Vencelová & Caravolas (2012, p. 162), who assert that grades 1 to 4 represent *"the stage of reading development from its origins to its automation"*. Given that our research primarily focused on children at the primary level of education, we opted to test dyslexic pupils only at the end of the school year to allow them time to consolidate their reading skills, for at least two reasons.

One reason was that we tested silent reading fluency, which is considered a scientifically validated neurobiological indicator (Christodoulou et al., 2014) and a behavioural marker of dyslexia (van den Boer et al., 2022), across typologically different languages (Carioti et al., 2021). Since children with dyslexia are known to exhibit lower reading fluency compared to their peers (van den Boer et al., 2022), we aimed to ensure that the validated test could effectively differentiate between them within the same grade level, even with nearly a 10-month disparity over the school year. This is particularly important if standardized tests establish norms based on assessing a standardized sample at a single point in time for an entire grade.

The second, crucial reason was that all children were tested during the COVID-19 pandemic, a period when the pandemic's impact had not yet been scientifically examined. However, there was an increase in negative feedback from families, schools, and clinical settings, particularly in relation to the children with neurodevelopmental disorders. Hence, we scheduled the assessment of the dyslexic children at the end of the school year to provide time for academic skill consolidation and mitigate the potential effects of the COVID-19 pandemic. This pandemic, which occurred from 2020 to 2021, resulted in reduced instructional hours and in social isolation due to anti-pandemic measures, factors to which dyslexic pupils might have been more susceptible compared to their neurotypical peers with regard to literacy. This assertion is supported by an Italian study conducted by Baschenis et al. (2021), which examined the effects of the pandemic lockdown on 65 dyslexic children in grades 3 to 8 (mean age 10.64 years, SD = 1.60). The study revealed that up to 63% of dyslexic children did not achieve the expected average progress in reading skills, underscoring the vulnerability of dyslexic children as a specific at-risk group for whom school closures may carry greater consequences than the neurotypical population.

We were interested in comparing the performance of dyslexic and non-dyslexic pupils in the Test of Silent Word Reading across both versions. We found that performance improved for both research groups throughout Years 2-5, a trend consistent with findings from pilot studies conducted at both primary level (Zubáková & Bekečová, 2022) and lower secondary level (Zubáková et al., 2023). Additionally, we noted differences in performance between versions A and B for both groups, with version B consistently yielding better results. This improvement can be attributed to the learning effect, a phenomenon confirmed by previous research (Mather et al., 2014; Zubáková & Bekečová, 2022). In another investigation (Zubáková et al., 2023) focusing on the new TSWR, we verified whether versions A and B were comparable in difficulty and if the observed learning effect contributed to the enhanced performance in the second administered test. Through paired sampling of 50 pupils in grades 5 to 9 of primary school, we confirmed no statistically significant differences between versions A and B in either type of score.

When comparing the two research groups, the most notable difference between them was evident in the average raw scores in both test versions - dyslexic pupils correctly identified a lower number of words on average compared to their non-dyslexic counterparts. This outcome could be attributed to the slow and non-fluent reading commonly observed in individuals with reading difficulties (Mikulajová, Vencelová & Caravolas, 2012), which has been confirmed in both reading modes (van den Boer et al., 2022). Another contributing factor may lie in the distinct reading strategies employed by individuals with dyslexia, as suggested by Vagge and colleagues (2015) in their research. They argued that dyslexic individuals engage in a more complex and effortful visual scanning process when reading written information compared to those without dyslexia. Additionally, Rayner et al. (2016) proposed that language processing, particularly word identification, serves as the primary driving force behind reading. According to the authors (Reichle, Pollatsek & Rayner, 2006), the speed of reading relies on the linguistic processing of the written material. Another factor that may contribute to the lower number of words identified by dyslexic students is vocabulary knowledge. This has been supported by research (Wise et al., 2007) conducted on primary school dyslexic pupils in Grades 2 and 3. The findings revealed that a good level of expressive vocabulary significantly enhances the ability to read words aloud. Since performance on the TSWR encompasses reading accuracy as well as speed, we can refer to the research of Šelingerová (2018), concerning the influence of vocabulary on pupils' performance. Based on her findings, she identified vocabulary as one of the predictors of reading fluency, alongside RAN (rapid automatized naming) ability, phonemic awareness speed (phoneme transposition), and working memory. Ouellette (2006) explains that individuals with larger vocabularies tend to be more attuned to sublexical details, which impacts reading fluency. These results align with the lexical quality hypothesis (Perfetti, 2007), which posits significant associations between lexical ability and reading comprehension.

The two research groups were also distinguished by the parameter of the number of errors. The higher error rate in the dyslexic group may stem from less developed language abilities (Adlof et al., 2017), weaker vocabulary (Adlof & Hogan, 2018), deficiencies in reading technique (van den Boer et al., 2022), deficits in executive function (Brosnan et al., 2002), as well as a consequence of possible comorbidity with ADHD, predominantly relating to attention (Boada, Willcutt & Pennington, 2012).

Within the framework of the formulated hypothesis, we hypothesized that statistically significant differences would be present in the performance of pupils with and without dyslexia in the TSWR. This was confirmed, based on the results of the Mann-Whitney U test, in all observed parameters in both versions A and B, except for the parameter of corrections. There was no statistically significant difference in the correction parameter; the research groups did not differ significantly from each other in terms of the number of corrections made. The lack of significant differences in corrections between dyslexic and non-dyslexic pupils can be attributed to the primary difficulties in reading fluency experienced by individuals with dyslexia (e.g., Carioti et al., 2021). Despite being slow, individuals with dyslexia tend to be accurate when reading, especially in transparent languages (Mikulajová, Vencelová & Caravolas, 2012). Since the test sheet is perceptually present throughout testing, students were not shown to make a statistically higher number of corrections than the general population. Although the differences in this parameter did not prove to be significant, there were more corrections in the group of pupils with dyslexia. For instance, in Test Form A, pupils without dyslexia scored between 0 and 6 corrections (M = 1.25), while pupils with dyslexia had scores ranging from 0 to 13 (M = 1.74). A higher number of corrections in the test may indicate impairments in attention and executive functions, which are typical features of ADHD (Shiels & Hawk, 2010). Although children with dyslexia may experience difficulties in executive functions (Barbosa et al., 2019), these challenges are more likely related to deficits in phonological working memory, which is directly associated with the core deficit in dyslexia. Alternatively, it could be ADHD with a predominance in the attentional domain, a comorbidity that frequently occurs with dyslexia (DuPaul & Volpe, 2009). However, research findings suggest that an increased number of corrections in silent reading is not a typical diagnostic marker for dyslexia.

In addition to our aim of determining whether there were statistically significant differences in TSWR between the groups, we were also interested in the magnitude of the demonstrated effect. As noted by Hajdúk (2020), simply stating that a difference is statistically significant is not sufficient; it is crucial to quantify the demonstrated finding to indicate the level of evidence. The effect size in the parameters - raw scores, errors, and percentage correct - indicated an effect size (r) ranging from 0.33 to 0.43, which can be considered a moderate difference.

We also compared the results of our research with the outcomes of the TOSWRF (Mather et al., 2014), which was standardized on a cohort of 2,429 individuals aged 6 to 24 years. In the manuscript, the authors reported the mean scores of the entire normative set (M = 100 words, SD = 15), as well as the performances of different clinical subgroups with neurodevelopmental differences that were part of the normative set. Among the clinical group of developmental learning disorders, those with combined deficits (dyslexia, dysorthographia, and dyscalculia, M = 80 words, SD = 13) performed the poorest, while those with dyslexia alone performed slightly better (M = 87 words, SD = 13). In our research set, non-dyslexic pupils separated an average of 16 more words in Version A than those with dyslexia, which aligns with the findings of the authors of the TOSWRF test, who showed a 13-point difference for those diagnosed solely with dyslexia.

The Test of Silent Word Reading is a quick, brief, and easily administered assessment that is timed. The utilization of time-limited tests in the diagnostic process is also advocated by Carioti et al. (2021). This recommendation is particularly pertinent because reading can be arduous for individuals with dyslexia and overburdening them with lengthy and challenging tasks during the diagnostic process may yield subjective results. Identifying dyslexia early is crucial, as highlighted by Denton et al. (2011), as delayed intervention can severely limit effective remediation options, especially if a child's reading skills lag behind their peers by several years. After undergoing the standardization process, the silent word reading test can serve as an essential diagnostic tool in assessing reading ability comprehensively.

Research limitations, future directions, and conclusion

The research study possesses several limitations that necessitate consideration when interpreting the findings. One limitation stems from the absence of uniform criteria for diagnosing dyslexia in Slovakia for many years. Furthermore, the lack of standardized diagnostic tools capable of comprehensively assessing all areas poses another limitation. Consequently, children officially diagnosed with dyslexia had to be excluded from the research sample based on inclusion criteria. Conversely, control pupils matched to those with dyslexia were also excluded from the research set due to poor performance in reading and/or spelling skills, despite their parents reporting no neurodevelopmental difficulties. While the Minimum Diagnostic Standards for the Diagnosis of Developmental Learning Disorders (National Institute for Education, 2019) now exist, the absence of diagnostic tools for comprehensive, objective diagnosis persists. Specifically, there is a dearth of tools for assessing language abilities during school age, tests to evaluate diagnostic markers of dyslexia, tests of reading and spelling skills beyond the word level, and reading tests that assess both modes of reading at various levels.

Another limitation of the research is that intellectual ability was not assessed when selecting participants for the groups. In the sample of dyslexic pupils, we received information from the Counselling and Prevention Centres indicating that the intellectual abilities of the selected pupils were within the average range. However, in the future, it would be necessary to evaluate the intellectual abilities of the pupils as well.

A third limitation of the research is that in the study population of dyslexic pupils, there were also children with comorbid disorders who were not specifically identified. We believe that in the case of comorbidity with a developmental language disorder (an older term for developmental dysphasia) or ADHD, these individuals may have performed below expectations, as language abilities and attentional processes are crucial components in the reading process. Therefore, we recommend that future research explores performance on the TSWR with a larger sample of dyslexic pupils, while also identifying and controlling for comorbid disorders.

In conclusion, the present research demonstrates that the new Test of Silent Word Reading has the potential to be utilized by speech therapists, special educators, and psychologists in the future as an assessment tool for evaluating silent reading fluency during the diagnosis of developmental learning disorders, in counselling, clinical, and school settings. A comprehensive assessment of reading skills should encompass both reading modes—silent and oral—at various levels (word, sentence, and text). The new Test of Silent Word Reading fills a gap in the absence of diagnostic tools in Slovakia and is the only tool that, following the standardization process, can be employed to evaluate silent reading fluency at word level. Our objective is to gather normative data in the future not only from elementary school pupils but also from secondary and university students, thereby enabling its use as supplementary diagnostic material not only for school-age children but also for adolescent and adult populations. Considering the availability of two forms of this test, we recognize its potential in the therapeutic domain, as it allows for the assessment of reading progress in individuals due to the comparability of the two test forms. Due to its potential for short and group administration, this test could be employed in the future not only for diagnostic purposes but also for screening or research endeavors.

References

Adlof, S. M., Scoggins, J., Brazendale, A., Babb, S., & Petscher, Y. (2017). Identifying children at risk for language impairment or dyslexia with group-administered measures. *Journal of Speech, Language, and Hearing Research, 60*(12), 3507–3522.

Adlof, S. M., & Hogan, T. P. (2018). Understanding dyslexia in the context of developmental language disorders. *Language, Speech, and Hearing Services in Schools, 49*(4), 762–773.

Bar-Kochva, I. (2013). What are the underlying skills of silent reading acquisition? A developmental study from kindergarten to the 2nd grade. *Reading and Writing, 26,* 1417–1436.

Barbosa, T., Rodrigues, C. C., Mello, C. B., Silva, M. C. S. E., & Bueno, O., F., A. (2019). Executive functions in children with dyslexia. *Arquivos de Neuro-Psiquiatria, 77*(4), 254–259.

Baschenis, I. M. C., Farinotti, L., Zavani, E., Grumi, S., Bernasconi, P., Rosso, E., … Chiappedi, M. (2021). Reading skills of children with dyslexia improved less than expected during the COVID-19 lockdown in Italy. *Children, 8*(7).

Berninger, V. W., Abbott, R. D., Trivedi, P., Olson, E., Gould, L., Hiramatsu, S., ... York Westhaggen, S. (2010). Applying the Multiple Dimensions of Reading Fluency to Assessment and Instruction. *Journal of Psychoeducational Assessment, 28*(1), 3–18.

Boada, R., Willcutt, E. G. & Pennington, B. F. (2012). Understanding the comorbidity between dyslexia and attention-deficit/hyperactivity disorder. *Topics in Language Disorders, 32*(3), 264–284.

Brosnan, M., Demetre, J., Hamill, S., Robson, K., Shepherd, H., & Cody, G. (2002). Executive functioning in adults and children with developmental dyslexia. *Neuropsychologia, 40* (12), 2144–2155.

Burns, M. K., Kwoka, H., Lim, B., Crone, M., Haegele, K., Parker, D. C., ... Scholin, S. E. (2011). Minimum reading fluency necessary for comprehension among second-grade students. *Psychology in the Schools, 48*(2), 124–132.

Caravolas, M., LervÍg, A., Mousikou, P., Efrim, C., Litavsky, M., Onochie-Quintanilla, E., … Hulme, C. (2012). Common patterns of prediction of literacy development in different alphabetic orthographies. *Psychological Science, 23*(6), 678–686.

Caravolas, M., Mikulajová, M., Defior, S., & Seidlová Málková, G. (2018). *Test písania zložitejších slov. Multilanguage Assessment Battery of Early Literacy. MABEL.* Available on: https://www.eldel-mabel.net/sk/test/

Carioti, D., Masia, M. F., Travellini, S., & Berlingeri M. (2021). Orthographic depth and developmental dyslexia: a meta-analytic study. *Annals of Dyslexia, 71*(3), 399–438.

Ciuffo, M., Myers, J., Ingrassia, M., Milanese, A., Venuti, M., Alquino, A., … Gagliano, A. (2017). How fast can we read in the mind? Developmental trajectories of silent reading fluency. *Reading and Writing, 30,* 1667-1686.

Denton, C. A., Barth, A. E., Fletcher, J. M., Wexler, J. M., Vaughn, S., Cirino, P. T., ... Francis, D. J. (2011). The relations among oral and silent reading fluency and comprehension in middle school: Implications for identification and instruction of students with reading difficulties. *Scientific Studies of Reading, 15*(2), 109–135.

DuPaul, G. J., & Volpe, R. J. (2009). ADHD and learning disabilities: Research findings and clinical implications. *Current Attention Disorders Reports, 1,* 152–155

European Dyslexia Association. (2020). *What is dyslexia?* Available on: https://eda-info.eu/what-is-dyslexia/

Gagliano, A., Ciuffo, M., Ingrassia, M., Ghidoni, E., Angeli, D., Benedetto, L., ... Stella, G. (2015). Silent reading fluency: implications for the assessment of adults with developmental dyslexia. *Journal of Clinical and Experimental Neuropsychology, 37*(9), 972–980.

Grigorenko, E. L., Compton, D. L, Fuchs, L. S., Wagner, R. K., Willcutt, E. G, & Fletcher, J. M. (2020). Understanding, educating, and supporting children with specific learning disabilities: 50 years of science and practice. *American Psychologist, 75*(1), 37–51.

Hajdúk, M. (2020). Metodológia a dizajny výskumu v klinickej psychológii. Bratislava: Univerzita Komenského v Bratislave.

Hall, R. et al. (2014). The relationship between expressive vocabulary knowledge and reading skills for adult struggling readers. *Journal of Research in Reading, 37*(1), 87–100.

Hammill, D. D., Wiederholt, J. L., & Allen, E. A. (2014). *TOSCRF: Test of silent contextual reading fluency.* Austin, Texas: Pro-Ed.

Handler, S. M. & Fierson, W. M. (2011). Learning disabilities, dyslexia, and vision. *Pediatrics, 127*(3), 818–856.

Christodoulou, J. A., Del Tufo, S. N., Lymberis, J., Saxler, P. K., Ghosh, S. S., Triantafyllou, C., … Gabrieli, J. D. (2014). Brain bases of reading fluency in typical reading and impaired fluency in dyslexia. *PLoS One, 9*(7).

Kim, Y. S. G., Petscher, Y., & Vortius, Ch. (2019). Unpacking eye movements during oral and silent reading and their relations to reading proficiency in beginning readers. *Contemporary Educational Psychology, 58,* 102–120.

Krieber, M. et al. (2016). The relation between reading skills and eye movement patterns in adolescent readers: evidence from a regular orthography. *PLoS ONE*, 2016*, 11*(1), 1–15.

Krieber, M. et al. (2017). Eye movements during silent and oral reading in a regular orthography: basic characteristics and correlations with childhood cognitive abilities and adolescent reading skills. *PloS ONE, 12*(2), 1-15.

Kuhn, M. R., & Stahl, S. A. (2003). Fluency: A review of developmental and remedial practices. *Journal of Educational Psychology, 95*(1), 3–21.

Laubrock, J., & Kliegl, R. (2015). The eye-voice span during reading aloud. *Frontiers in Psychology, 6*(1432), 1–19.

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). Defining dyslexia, comorbidity, teachers' knowledge of language and reading: A definition of dyslexia. *Annals of Dyslexia, 53,* 1–14.

Lou, C., Duan, X., Altarelli, I., Sweeney, J. A., Ramus, F., & Zhao J. (2019). White matter network connectivity deficits in developmental dyslexia. *Human Brain Mapping, 40*(2), 505–516.

Matějček, Z. (1974). *Vývojové poruchy čtení.* Praha: Státní pedagogické nakladatelství.

Mather, N., Hammill, D. D., Allen, A., & Roberts, R. (2014). *Test of Silent Word Reading Fluency. Examiner's manual.* Austin, Texas: Pro-Ed.

Mikulajová, M., Vencelová, L. & Caravolas, M. (2012). Test čítania s doplňovaním slov. In M. Mikulajová, M. (Ed.), *Čítanie, písanie a dyslexia (p. 160-176).* Bratislava: Slovenská asociácia logopédov.

Morris, D., & Turnbull, P. (2007). A survey-based exploration of the impact of dyslexia on career progression of UK registered nurses. *Journal of Nursing Management, 15* (1), 97–106.

National Institute for Education (2019). *Návrh minimálnych diagnostických štandardov pre špecifické poruchy učenia, poruchu aktivity a pozornosti a narušenú komunikačnú schopnosť.* Bratislava: Štátny pedagogický ústav. Available on: https://www.statpedu.sk/files/sk/vyskum/publikacna-cinnost/publikacie/navrh-minimalnych-diagnostickych-standardov-specificke-poruchy-ucenia-poruchu-aktivity-pozornosti-narusenu-komunikacnu-schopnost.pdf

Norton, E. S. & Wolf, M. (2012). Rapid automatized naming (RAN) and reading fluency: implications for understanding and treatment of reading disabilities. *Annual Review of Psychology, 63,* 427–452.

O'Connor, R. E. (2018). Reading fluency and students with reading disabilities: How fast is fast enough to promote reading comprehension? *Journal of Learning Disabilities*, *51*(2), 124–136.

Ouellette, G. P. (2006). What's meaning got to do with it: The role of vocabulary in word reading and reading comprehension. *Journal of Educational Psychology, 98*(3), 554–566.

Perfetti, Ch. (2007). Reading ability: Lexical quality to comprehension. *Scientific studies of reading, 11*(4), 357–383.

Prior, S. M., Fenwick, K. D., Saunders, K. S., Ouellette, R., O'Quinn, Ch., & Harvey, S.

(2011). Comprehension after oral and silent reading: Does grade level matter? *Literacy Research and Instruction, 50*(3), 183–194.

Psyridou, M., Tolvanen, A., Niemi, P., Lerkkanen, M.-K., Poikkeus, A.-M., & Torppa, M. (2023). Development of silent reading fluency and reading comprehension across grades 1 to 9: Unidirectional or bidirectional effects between the two skills? *Reading and Writing, 36,* 1969–1996.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372–422.

Rayner, K., Schotter, E. R., Masson, M. E. J., Potter, M. C., & Treimanm R. (2016). So much to read, so little time: How do we read, and can speed reading help? *Psychological Science, 17*(1), 4–34.

Reichle, E. D., Pollatsek, A., & Rayner, K. (2006). E–Z Reader: A cognitive-control, serial-attention model of eye-movement behavior during reading. *Cognitive Systems Research, 7*(1), 4–22.

Reis, A., Araújo, S., Morais, I. S., & Faísca, L. (2020). Reading and reading-related skills in adults with dyslexia from different orthographic systems: A review and meta-analysis. *Annals of Dyslexia, 70,* 339–368.

Robinson, M. F. (2019). *The relation among phonological processing, oral and silent reading fluency, and reading comprehension for students with dyslexia: A longitudinal investigation* (Dissertation). Memphis, Tennessee: University of Memphis.

Robinson, M. F., Meisinger, E. B., & Joyner, R. E. (2019). The influence of oral versus silent reading on reading comprehension in students with reading disabilities. *Learning Disability Quarterly, 42*(2), 105–116.

Share, D. L. (2008). On the Anglocentricities of current reading research and practice: The perils of overreliance on an "outlier" orthography. *Psychological Bulletin, 134*(4), 584–615.

Shaywitz, S. E., & Shaywitz, B. A. (2005). Dyslexia (specific reading disability). *Biological Psychiatry, 57*(11), 1301-1309.

Shiels, K., & Hawk, L. W. (2010). Self-regulation in ADHD: The role of error processing. *Clinical Psychology Review, 30*(8), 951–961.

Schöffelová, M., Mikulajová, M. (2012). Vývoj různých aspektu čtění ve slovenštine. *Pedagogika, 62*(1–2), 111–125.

Schulte-Körne, G. (2010). The prevention, diagnosis, and treatment of dyslexia. *Deutsches Ärzteblatt International, 107*(41), 718–727.

Slovak Centre of Scientific and Technical Information (2020). Štatistická ročenka CVTI SR 2020. Available on: https://www.cvtisr.sk/cvti-sr-vedecka-kniznica/informacie-o-skolstve/statistiky/statisticka-rocenka-publikacia/statisticka-rocenka-zakladne-skoly.html?page_id=9601

Smyrnakis, I., Andreadakis, V., Rina, A., Boufachrentin, N., & Aslanides, I. M. (2021). Silent versus Reading Out Loud modes: An eye-tracking study. *Journal of Eye Movement Research, 14*(2).

Šelingerová, A. (2018). *Kognitívne činitele vývinu gramotnosti u adolescentov* (Dizertačná práca). Bratislava: Paneurópska vysoká škola.

Vagge, A. et al. 2015. Evaluation of ocular movements in patients with dyslexia. *Annals of Dyslexia, 65*(1), 24–32.

van den Boer, M., van Bergen, E., & de Jong, P. F. (2014). Underlying skills of oral and silent reading. *Journal of Experimental Child Psychology, 128,* 138–151.

van den Boer, M., Bazen, L., & de Bree, E. (2022). The same yet different: Oral and silent reading in children and adolescents with dyslexia. *Journal of Psycholinguistic Research, 51,* 803–817.

Varvara, P., Varuzza, C., Sorrentino, A. C., Vicari, S., & Menghini, D. (2014). Executive functions in developmental dyslexia. *Frontiers in Human Neuroscience, 8.*

Váryová, B. (2012). Skúšky čítania pre mladší školský vek. In M. Mikulajová (Ed.), *Čítanie, písanie a dyslexia* (s. 126–159). Bratislava: Slovenská asociácia logopédov.

Vencelová, L., Mikulajová, M., & Caravolas, M. (2012). Hodnotenie pravopisných schopností u starších žiakov. In M. Mikulajová (Ed.), *Čítanie, písanie a dyslexia* (s. 223–241). Bratislava: Slovenská asociácia logopédov.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45*(1), 2–40.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (2010). *TOSREC: Test of silent reading Efficiency and comprehension.* Austin, Texas: Pro-Ed.

Wiederholt, J. L., & Blalock, G. (2000). *GSRT: Gray Silent Reading Tests.* Austin, Texas: Pro-Ed.

Wise, J. C., Sevcik, R. A., Morris, R. D., Lovett, M. W., & Wolf, M. (2007). The relationship among receptive and expressive vocabulary, listening comprehension, prereading skills, word identification skills, and reading comprehension by children with reading disabilities. *Journal of Speech Language and Hearing Research* Speech, *50*(4), 1093–109.

Wissinger, D. R., Truckenmiller, A. J., Konek, A. E., & Ciullo, S. (2023). The validity of two tests of silent reading fluency: A meta-analytic. *Review, Reading & Writing Quarterly.*

World Health Organization. (2019). *International statistical classification of diseases and related health problems* (11th ed.). https://icd.who.int/

Xia Z., Zhang, L., Hoeft, F., Gu, B., Gong, G., & Shu, H. (2018). Neural correlates of oral word reading, silent reading comprehension, and cognitive subcomponents. *International Journal of Behavioral Development, 42*(3), 342–356.

Yildiz, M. & Çetinkaya, E. (2017). The relationship between good readers' attention, reading fluency and reading comprehension. *Universal Journal of Educational Research*, 5(3), 366–371.

Zubáková, M., & Mikulajová, M. (2021). Silné prekurzory ranej gramotnosti v slovenčine. *Psychológia a patopsychológia dieťaťa, 55*(1), 3–25.

Zubáková, M., & Bekečová, M. (2022). Test tichého čítania slov ako diagnostický nástroj na hodnotenie plynulosti čítania. *Štúdie zo špeciálnej pedagogiky, 11*(1), 73–88.

Zubáková, M., Harvanová, S., Kapalková, S., & Kevická, V. (2023). Výkony žiakov v Teste tichého čítania slov na nižšom stupni sekundárneho vzdelávania. *Logopaedica XXV, 25*(1), 13–20.

Žovinec, E. & Dufeková, A. (2014). *ČÍ(s)TA. Čítanie starších: Príručka k diagnostickej batérii.* Nitra: Univerzita Konštantína Filozofa

Link to the grant scheme:
This work was supported by the grant project VEGA 1/0509/21 and by the Agency for Research and Development under Contract No. APVV-20-0126.

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GRAMOTNOST, PREGRAMOTNOST A VZDĚLÁVÁNÍ, 7 , 3, 35—53

VÝZKUMNÁ STUDIE

Comparison of Screening Questionnaire Results Focusing on Environmental Influences when Monitoring the Development of Reading Literacy among Pupils in the 1st Grade of Primary School

Hana Sotáková

Abstract: The paper focuses on environmental influences in the development of reading literacy among primary school pupils. We build on data obtained through screening questionnaires for family and teachers, which were created and verified during the standardisation of the PorTex test battery (Porozumění textu/Reading Comprehension, Kucharská et al., 2021) aimed at reading and reading comprehension assessment in Grade 1 - Grade 5 pupils. We believe that environmental factors can have an impact on the development of reading literacy and it is possible to use these environmental factors during interventions for pupils with specific learning difficulties; they should therefore be included in diagnostics. In the following text, we will present the results of the experimental questionnaires created for the above-mentioned test battery, we will show the potential for using their outputs and how they relate to the pupils' results in tests of reading, reading comprehension and language awareness. We will also discuss the potential of these questionnaires in diagnostic and counselling practice.

Key words: Reading; Reading comprehension; Environmental factors; Parent questionnaire; Teacher questionnaire; Reading assessment; Intervention

DOI: 10.14712/25337890.4525

Environmental Factors in the Development of Reading Literacy in Pupils

According to Thor (2015), reading is a developmental task based on the demands of society, and although it is not yet an essential skill for a successful life within a society in many countries around the world, it is just the opposite in our culture. In view of this, reading and its development with the support of educational institutions is given considerable attention. Based on domestic and international empirical studies, it is evident that factors related to the attitude of family and school are also important factors for the development of reading literacy. In fact, a child learns to read mainly in two basic environments: within the family and at school. In the family, the child is introduced to books and activities related to reading while at school, they work on the targeted development of reading and writing. It turns out that even the teacher's approach as well as the chosen method can play a crucial role, especially for beginning readers and children with specific difficulties (cf. Gabal & Václavíková Helšová, 2003; Kucharská, 2014; Sénéchal & LeFevre, 2014).

When creating a test battery for reading diagnostics, we therefore decided to include screening tools for monitoring environmental factors, namely a questionnaire for parents and a questionnaire for teachers. Our motivation was a comprehensive diagnosis based on the prevention-intervention model – hence a diagnosis serving as a basis for determining possible interventions in case a pupil shows deficits in reading or reading comprehension or simply needs support to develop their maximum potential in the given area. It was also about identifying whether the pupil's problems in reading and reading comprehension might be related to an unstimulating environment or a teacher's approach that does not meet the pupil's needs. When diagnostics are carried out by school counselling staff for children with reading difficulties, whatever their nature may be, we consider it important to assess the influence of the environment, which can be stimulating but can also have a negative effect on the development of the skills mentioned (Kucharská et al., 2021).

We first present the two experimental tools, their design process, administration, and then the results of the standardisation study. As mentioned above, given that they are complementary to diagnostic information, the questionnaires are conceived as **screening tools** to determine the level of risk in the family or the teacher's approach and to allow us to use them to collaborate in intervention or to look for new ways to support the pupil in compensating for reading comprehension problems. Thus, we assess the risk level of the family and school environments, and consider whether their outcomes are complementary and whether one environment has the potential to compensate for the risk level of the other (Kucharská et al, 2021).

Parent Questionnaire – Screening Method

The family is undoubtedly one of the most important factors that influence the development of a child. It contributes to the formation of a child's attitudes and values, which of course also applies to the field of education. The family is also the setting for the development of so-called pre-literacy skills, i.e. the skills necessary for the satisfactory development of reading, writing and arithmetic. As repeatedly found in research studies, the number of books in the household is one of the important criteria for assessing the socio-economic status of the family (Kucharská, 2014). Thus, the family can facilitate the child's start in the early years of schooling and, in the long term, guide the child's reading behaviour. That is why theories dealing with the influence of the family environment on a child's success in school appeared as early as in the 1970s, referring to the socio-cultural capital or socio-cultural handicap that a child carries with them from their family (Štech, 2000; Havlík & Koťa, 2011; Greger, Simonová, & Straková, 2015).

As Kucharská (2014) points out, the family has a significant influence on the development of pre-reading skills and abilities through activities such as introducing the child to books and reading, making books available from an early age, by the child observing the parents reading, telling stories and discussing the stories they have read. The family may be one of the protective factors for literacy development but we can also find risk factors here in terms of disposition (e.g. the presence of specific learning disabilities in the family) or those stemming from an unstimulating environment. This is the basis for monitoring family influence in the context of screening family reading environments. The family reading environment, or Home Literacy Environment (HLE) in international literature, is to some extent related to the socio-economic status of the family but there is no direct causality; in addition, the value system of the family, especially their attitude towards education, enters into the picture. For our purposes, we consider this to be an umbrella term for all notions of family environment and family activities related to reading. We can divide it into two basic areas: conditions for reading (availability of books, parents' reading pattern, shared reading as a leisure activity); the second area is reading practices in the family, where we focus on targeted parental activity for reading development (e.g. learning letters, connecting pictures with letters or words). Sénéchal and LeFevre (2002, 2014) bring a similar approach, distinguishing factors that support the development of a child's reading literacy and identifying the key factors to be related to the child's personality and cognitive abilities as well as environmental factors, where the family plays a crucial role, especially in the preschool period. Based on their longitudinal research, they developed a model of the family literacy environment comprising formal and informal family literacy development activities. They consider all activities where parents purposefully develop their child's literacy skills to be formal. On the other hand, informal activities are based on the frequency of spontaneous activities where reading or just book-related activities (looking at pictures, talking about stories, etc.) are involved. According to them, the frequency and proportion of these activities in the family plays a crucial role in literacy development of beginning readers, i.e. children from preschool age to the third year of compulsory schooling, when the child becomes an independent reader.

Korat and her colleagues reach similar conclusions with Arabic-speaking children. Using a study of 109 children, they show that family background is a significant factor in a child's reading performance in 1st grade. Again, the socio-economic status of the family is reflected here (see above), but surprisingly, the research in question did not show a significant relationship between the child's performance and the mother's efforts to interpret the meanings of the text verbally (Korat et al., 2013). Thus, the results of the selected research suggest both the importance of the family reading environment and the possible intervention potential for developing reading development and literacy skills in general. The importance of the family reading environment is also underlined especially by intervention studies targeting the prevention of literacy development difficulties. Niklas and Schneider (2013) conducted research with 921 children and their families. Their results highlight the fact that children from families applying literacy development activities (a researcher-led intervention) showed better language competence and phonological skills. Intervention in literacy development also significantly helped them in overcoming socio-cultural handicaps.

It follows from the above that the family reading environment is one of the important factors in the development of a child's reading abilities and greatly influences the child's relationship with reading and their achievement in it. Nevertheless, it must be understood as one component of a comprehensive view of the child's reading development; as Carreteiro points out (Carreteiro et al., 2015), some authors consider the importance of the family to be overestimated – it cannot be removed from the context of other influences such as the child's cognitive and personality characteristics. The importance of the family environment is greatest in the early stages of literacy development, which is also why most of the research cited above focuses on the period before and at the beginning of compulsory schooling.

Description, Administration and Evaluation of the Questionnaire

The questionnaire for parents included in the PorTex test battery (Porozumění textu/Reading Comprehension, Kucharská et al., 2021) was constructed on the basis of analyses of the above-mentioned research on the family reading environment, the experience from the empirical study conducted by the Czech Science Foundation (GACR), No.13-20678 S: Reading Comprehension – Typical Development and its Risks (2013-2015), and last but not least, by screening tools used abroad, such as the Home Literacy Environment Checklist (Burgess, Hecht, & Lonigan, 2002). The questionnaire comes in two versions, the first one is designed for first graders (version A), as we assumed that in the first year of primary school, family activities are focused on the development of early reading and differ from higher grades. The second is designed for parents of pupils in Grades 2-5 (version B). Both versions of the questionnaire contain 20 items divided into two parts that target the conditions for reading and reading practices in the family (see above). In the preliminary version, the questionnaire also included items on demographic data (education, parents' occupation) but since these questions are normally included in anamnestic questionnaires used in school counselling centres and school counselling offices, we did not consider it necessary to include them in the questionnaire.

The questionnaire is designed so that parents can fill it in independently before or during the child's examination, and it can be sent electronically. It is of course possible for more than one family member to complete the questionnaire (e.g. alternating custody). After receiving brief information, parents follow the instructions on the answer sheet: "*DEAR PARENTS, WE WOULD LIKE YOU TO COMPLETE A QUESTIONNAIRE FOCUSING ON THE ROLE READING PLAYS IN YOUR FAMILY. PLEASE SELECT ONLY ONE ANSWER PER QUESTION, THANK YOU!*"

Scores are recorded on an answer sheet where the total score determines the degree of potential or risk of the family environment for further development of the pupil's reading abilities and skills. In the case of a high-risk family environment, we consider whether the teacher's approach can compensate to some extent for areas of concern, considering recommendations for both the school and the family.

Teacher Questionnaire – Screening Method

In the Czech Republic as well as abroad, researchers emphasise the significant role of teaching quality, the teacher's didactic practices and their ability to reflect the needs of individual pupils, particularly at the outset of the educational journey. Currently, the choice of teaching methods or didactic material is the responsibility of each teacher (or potentially subject committees or school management). However, while there are many positives to this practice (possibility of an individualised approach, freedom and flexibility in the choice of textbooks, worksheets), this also sometimes places too many demands on the teacher, who may lack methodological or material support in everyday situations at school. Although there is a visible effort of state and non-state institutions to provide such support (see, for example, the Methodological Portal rvp.cz; the National Pedagogical Institute; the National Pedagogical Museum and Library of J. A. Komenský or CT Edu), as pointed out by Wildová and Vykoukalová (2013) or Klapwijk (2012), it is not systematically addressed and depends on the activity and personality of the teacher. It may seem that a teacher questionnaire is superfluous given that it is common practice in the Czech guidance system for schools to provide a school questionnaire as a basis for diagnosing reading or specific learning disabilities. However, if we analyse standard school questionnaires, we find that they mainly focus on describing the difficulties of the pupil. This is perfectly fine but it does not cover cases where the pupil's reading difficulties are related to the fact that the method of teaching reading is not suitable for the pupil or the approaches and strategies chosen by the teacher do not correspond to the pupil's needs.

International studies analysing reading development and reading comprehension support have attempted to show specific reading strategies that can be used in a school or family setting to facilitate reading development (Block & Duffy, 2008; Connor et al., 2005). Guthrie and colleagues also point out that certain strategies can increase pupils' engagement with reading, motivation to understand texts and activate them in the learning process (Guthrie et al., 2006; Guthrie, Wigfield & You in Christenson et al. 2012). Tonnessen and Uppstad (2015) then show that the emphasis on specific methods of early reading instruction and their application in schools is probably greatest in the United States. In Scandinavia (where the authors come from), as in the Czech Republic, early reading instruction is typically categorised into two basic methods: the analytic-synthetic method (phonics) and the global reading method (referred to in our context as the genetic method). While these approaches entail their own didactic procedures, teachers have the autonomy to choose specific instructional approaches within these frameworks. In their view, it is often not the method of teaching reading that is decisive but rather what exactly the teacher does with the children, as the methods are interpreted and practiced differently. Thus, in their view, it is the specific techniques and strategies that are decisive. They even believe that methods and practices in reading instruction should be chosen according to the needs of the pupil (especially for pupils showing difficulties in reading development).

It follows from the above that the teacher's approach, their ways of working and their solutions to a pupil's learning problems can be an environmental factor influencing the development of reading, reading comprehension and the pupil's attitude towards reading. Therefore, when creating the PorTex diagnostic battery (Porozumění textu/ Reading Comprehension, Kucharská et al., 2021), we found it necessary to include a questionnaire for teachers reflecting their approach and specific strategies used in teaching reading and developing reading comprehension. We drew on the findings of the Czech Science Foundation research, No. 13-20678S: Reading Comprehension – Typical Development and its Risks (2013–2015), where we asked teachers what specific strategies, methods and techniques they use most often when teaching and advancing reading and reading comprehension (Kucharská, 2015). We then selected the most frequent strategies and compared them with empirical findings targeting strategies and methods that enhance the development of reading and reading comprehension (e.g., Reynolds & Symons, 2001). This then resulted in a 20-item questionnaire where teachers expressed their attitudes towards statements regarding approaches and methods in reading instruction based on a 4-point Likert scale (Porozumění textu/ Reading Comprehension, Kucharská et al., 2021). All the items were subjected to statistical analysis, the interrelationship of the items was reflected and the scoring method of each item was revised according to the results.

Description, Administration and Evaluation of the Questionnaire

The aim was to design the questionnaire in such a way that teachers could fill it in independently before or after the child's examination, according to the needs of the specialist, and it can also be sent electronically. The administration is therefore simple; after reading the introductory information the respondent ticks their answer based on the instruction: *"PLEASE CHOOSE TO WHAT EXTENT DOES EACH OF THE FOLLOWING STATEMENTS REFLECT THE REALITY OF YOUR TEACHING PRACTICE, TO WHAT EXTENT DO YOU AGREE WITH THEM.*

PLEASE TRY TO CHOOSE ONE ANSWER AT A TIME AND ANSWER ALL QUESTIONS, EVEN IF YOU FEEL THAT ONE FOLLOWS FROM ANOTHER (INDICATE WITH A CROSS IN THE TABLE). THANK YOU!" The administrator evaluates the questionnaire on the basis of the record sheet template, the total score is obtained by adding up the points obtained in each item. Based on the total score, we can determine whether the teacher's approach is more or less supportive of reading development (Kucharska et al., 2021). Another option available to the diagnostician is a qualitative evaluation of the questionnaire**. For this reason, the statements have been arranged into groups where we can observe the following aspects:**

- Approaches that support reading activities at school and at home (items 3, 4, 6, 7, 8,9,10)
- Approaches to developing reading comprehension (items 11, 12, 14, 15, 16)
- Teacher's approaches if reading difficulties are present in the pupil (items 18,19,20)
- Approaches that do not support reading development and do not address reading difficulties (items 5, 13, 17)

For pupils in the early stages of reading development (Grades 1-3), we also include the method of reading instruction in the analysis to ensure that the pupil's difficulties are not the result of an inappropriate method (which can be very individual). After the evaluation, we also look at the results of the questionnaire filled in by the parents, and consider whether we can use any of the environmental influences (school, family) in the intervention in the case of the pupil, which we reflect again in the conclusions of the examination and recommendations.

Research Sample

Parent Questionnaire

In the standardisation research, parent questionnaires were distributed to the families of all pupils included in the research. Parents received the questionnaire from the researcher with an envelope to be used to return the completed questionnaire. Table 1 shows the number of parent questionnaires analysed. Thus, overall, questionnaires were obtained from approximately 83% of parent respondents, with the highest return rate in 3rd Grade and the lowest in the 2nd Grade.

Teacher Questionnaire

In the standardisation research, 127 teachers in the participating primary schools completed the *Teacher Questionnaire* (see below for detailed characteristics of the sample). Although this does not seem like a large number, it should

Table 1. The numbers of parent questionnaires whose results were reflected in the development of the questionnaire evaluation documents. Their proportion of the total number of pupils surveyed in a given year is in brackets

Grade	T1	T3	*TOTAL**
1st Grade	153	39	192 (78 %)
2nd Grade	156	-	156 (73 %)
3rd Grade	198	-	198 (89 %)
4th Grade	173	-	173 (88 %)
5th Grade	134	-	134 (86 %)
TOTAL			853 (83 %)

* *The Parent Questionnaire was administered only in the first stage and in the third stage when the sample of 1st Grade pupils was completed*

Table 2. Sample distribution by education

Highest education attained	N
Other	1
Secondary Vocational School	6
Higher Vocational School	2
University – Bachelor‘s degree	9
University – Mgr. and higher	108
no data	1
Total	127

be noted that a total of 46 schools were involved in the standardisation study. Only 4 schools did not return the teacher questionnaires. The total number therefore reflects the fact that the corresponding teacher taught in several of the participating classes, for example. There were also some schools where questionnaires were returned by teachers who were not currently teaching the children involved in the study. Their questionnaires were used for descriptive statistical analyses, and only the questionnaires of the participating pupils were used for correlational analyses, which were consistently paired with specific

Table 3. Sample description by length of experience

Length of experience	N
< 2 years	4
2–5 years	20
5–10 years	22
> 10 years	80
no data	1
Total	127

Table 4. Reliability Parent Questionnaire – Overall Score

Grade	T1 Cronbach's Alpha (Total score)
1	0.534
2	0.755
3	0.713
4	0.724
5	0.800

respondents (Kucharská et al., 2021). The research sample included a total of 108 females, 3 males, 16 respondents did not indicate a gender.

Results of the Questionnaires in the Standardisation Study

As part of the standardisation study, the results of the two questionnaires were subjected to statistical analyses, item analysis was performed and the items were either revised or the item scores (reverse Likert scale scores) were adjusted to ensure correct item placement. Reliability of both questionnaires reached a satisfactory level. For the *Teacher Questionnaire*, reliability was determined based on a total score of 0.946 (Cronbach's alpha), and for the *Parent Questionnaire*, reliability of the test for each grade ranged from 0.534 to 0.800 (see Table 4).

Descriptive analyses of the *Parent Questionnaire* showed that there were no significant differences between grades (see Table 5), so we decided to proceed with further analyses in aggregate. We were intrigued by the fact that all grade groups (except Grade 5) contained questionnaires with a score of 0 in the first

Table 5. Descriptive statistics of the Parent Questionnaire (total score, score of Part A – reading environment in the family, score of Part B – family reading-related activities)

		Total score	S1 – Part A	S2 – Part B
1st Grade	Average	28.50	7.73	20.77
	SD	4.187	1.575	3.378
	Minimum	15	0	10
	Maximum	37	10	27
2nd Grade	Average	27.96	7.63	20.33
	SD	5.531	1.570	4.695
	Minimum	7	0	4
	Maximum	39	10	30
3rd Grade	Average	28.39	7.89	20.51
	SD	5.065	1.560	4.311
	Minimum	15	0	9
	Maximum	38	10	29
4th Grade	Average	28.34	7.83	20.51
	SD	5.556	1.541	4.512
	Minimum	6	0	0
	Maximum	39	10	30
5th Grade	Average	27.18	7.66	19.52
	SD	6.108	5.045	1.650
	Minimum	6	3	3
	Maximum	39	10	30

section, which focused on the family's reading environment, and this occurred more than once in each of the grade groups. Based on the results of the standardisation study, critical values were established to determine the risk in reading development on the part of the family. The maximum score on the *Parent Questionnaire* was 40, and the critical value was 24.

In Table 6, we present descriptive statistics of the results of the *Teacher Qu-*

Table 6. Descriptive statistics of the Teacher Questionnaire with regard to teaching methods

	N	Average of total score	Standard deviation
Phonics method	32	41.06	12.313
Genetic method	85	36.58	14.960

estionnaire, where we reflect the results according to the two most represented teaching methods. Teachers applying the genetic method appear to have scored higher on average on the questionnaire but this is not a statistically significant difference and, moreover, as can be seen from the value of the standard deviations for the two methods, the teachers' results were very heterogeneous. Based on the evaluation, the critical threshold for judging a teacher's approach to be unsatisfactory for a pupil was set at 30 points, while the maximum score that teachers could reach was 60 points. It should be noted that the fact that a teacher's approach may increase the risk of difficulties in developing reading and reading comprehension does not mean that it cannot be satisfactory for other pupils. We recommend looking at the qualitative analysis to see in which area the teacher scored lowest to determine how this corresponds to the pupil's difficulties.

Comparison of Questionnaire Results with Pupils' Results in Reading and Language Competency Tests

In analysing the results of the questionnaires, we focused on observing the relationship between the questionnaires and the individual battery tests. We were particularly interested in whether its results were related to the reading and comprehension tests that form the basis of the battery.

Statistical analyses showed that in 1st Grade, it was not possible to detect a relationship between the *Parent Questionnaire* and some reading comprehension tests. No statistically significant relationship was found for the listening comprehension tests and no association was found for the reading aloud and silent reading tests because one of the variables was held constant. Then, from the 2nd Grade onwards, a statistically significant relationship was confirmed using Pearson's correlation coefficient between the total questionnaire score

Table 7. Relationship between the Parent/Teacher Questionnaire (total score) and comprehension tests (listening, reading aloud, silent reading (r)

	Total score Parent Questionnaire	**Total score Teacher Questionnaire**
Reading comprehension		
The Forest Elves	0.012	0.056
The Fidgety Little Star	0.166**	0.060
How to Mushroom	0.157**	-0.096*
Comprehension when reading aloud		
Preparing for the Journey	-	0.037
Feeding Rabbits	0.143**	0.002
Ice-skating	0.157**	-0.106**
Comprehension when silent reading		
The Snowman	-	0.167
Big Friends	0.263**	-0.020
A Trip to Kořenov	0.190**	-0.072
Decoding		
Reading pseudowords	-0.052	0.219**
Reading words	-0.053	0.308**

Statistically significant values at level: * $p < 0.05$; ** $p < 0.01$

and all the reading comprehension tests except for the *Word Reading and Nonword Reading* Tests (see Table 5). As can be seen from the table, the situation was more or less reversed for the *Teacher Questionnaire*. There was a correlation detected between the *Teacher Questionnaire* and the decoding tests (*word reading and nonword reading*); contrary to the *Parent Questionnaire*, no significant relationship was found between the Teacher Questionnaire and the comprehension tests and for some tests, such as *How to Mushroom, Ice-skating*, there was even a negative correlation detected. Nevertheless, it can be concluded that for both questionnaires a correlation was found between their results and selected reading comprehension tests, although for the *Teacher Questionnaire,* the relationship was found to be stronger with the decoding tests while for the *Parent*

Table 8. Relationship between Parent/Teacher Questionnaire (total score) and language competency tests (r)

	Total score Parent Questionnaire	Total score Teacher Questionnaire
Repearting Nonwords	0.111**	0.070**
Language Awareness	0.137**	0.235**
Phonemic Awareness	0.060	0.272**

Statistically significant values at level: ** $p < 0.01$

Questionnaire, it was with the reading comprehension tests. We can therefore conclude that the family environment, the richness of stimuli in it, develops in children abilities important for reading comprehension, which is also supported by other studies (e.g. Sénéchal and LeFevre, 2002; 2014).

We also looked at the relationship between the questionnaires and the language competency tests. Here it is evident that the significance of the correlations is greater. As we can see with the *Parent Questionnaire,* we did not find a statistically significant relationship with phonemic awareness but in the tests of nonword repetition and language awareness the correlation is clear. The language competency tests showed a stronger correlation with the *Teacher Questionnaire,* with both the *Phonemic Awareness* and *nonword Repetition* tests showing statistically significant values. An even stronger correlation is then observed with the *Language Awareness Test* in all its parts. Thus, the teacher's approach is related to the development of the pupil's morpho-syntactic skills, which also affect their reading comprehension, although a direct relationship between the results of the questionnaires and comprehension has not been demonstrated.

There was no statistically significant correlation between the *Parent Questionnaire* and the *Teacher Questionnaire* (-0.034), as suggested by the above results of the relationships with the individual reading and language competency tests. We believe that this can be explained, for example, by the fact that parent and teacher attitudes may differ significantly, meaning there may be two independent settings present if there is no regular communication between teacher and parents and if the teacher does not guide the parents on how to proceed in developing their child's reading. During the standardisation study, there was also an interesting finding that more than 50%

of parents were unable to aptly identify the method of reading instruction being applied with their child. This supports our conclusion of relatively independent environments that, while both influence the child, are often not sufficiently connected.

Discussion

The subject of the research study concerns screening questionnaires focusing on environmental factors affecting reading development and reading comprehension in the 1st Grade of primary school. Our aim was to show how the results of the *Parent Questionnaire* and *Teacher Questionnaire* related to pupils' performance on tests of reading, reading comprehension and language competence and how this can be used to set up intervention procedures and recommendations for the school targeting the compensation of pupils' problems.

We are drawing on the results of studies showing that family socio-economic status is indeed one factor to be taken into account (Chiu and McBride-Chang, 2010 or Korat et al., 2013) since children from low socio-economic status families perform lower in reading on benchmark tests (see PISA, 2000, 2003 and 2006). On the other hand, we have recently encountered more and more studies emphasising the necessity of identifying the child's needs and guiding the family in the development of reading and reading comprehension. Empirical studies have highlighted approaches and strategies that parents can adopt to effectively support their child in developing reading. Sénéchal and LeFevre (2002) stress the importance of the family environment from preschool to approximately Grade 3 in primary school. Baker (2014) points out that the frequency and type of reading activities are important and have a significant impact on a child's performance. This is supported by Saint-Laurent and Giasson (2005) who additionally report that when parents are purposefully guided and adhere to a reading development intervention program, children's performance is significantly better than that of children in the experimental group where the program was not included.

For the time being, our standardisation study has been interested in distinguishing between a supportive reading environment and family reading activities so that we are able to determine whether the family is more of a protective factor or risk factor. We then correlated the questionnaire results reflecting the family reading environment with pupils' performance on reading and language competency tests, and found that this environment showed a significant relationship with the reading comprehension tests and the *Language Awareness Test* in particular. It therefore seems that family activities such as reading together, talking and asking questions about the text read seem to promote the development of reading comprehension. Our results therefore support the findings that there is a relationship between a child's reading level and their family environment, although a statistically significant relationship was not detected with the decoding tests. Thus, the findings of the *Parent Questionnaire* can be used for an overall assessment of the pupil's situation and for the development of support measures for the school and, in case of severe problems, a family support plan.

For the *Teacher Questionnaire*, it is important to note that we can see a significant relationship with the decoding and language competency tests. If we go by what Špačková (2016) summarises, this conclusion supports the so-called "phonological pathway of decoding". In the *Language Awareness Test*, we can further observe the impact of the teacher's approach on the development of morphosyntactic skills, which also affect reading comprehension long term, although a direct relationship between the questionnaire results and comprehension has not been demonstrated. Our study's contribution also lies in the fact that it focuses on specific approaches and strategies employed by the teacher in teaching reading, which is not often reflected in our setting where only the method used by the teacher is usually considered. Our results, on the other hand, support the findings of Tonnessen and Uppstad (2015), who show that the method per se is not that important (moreover, not every method suits every pupil); it is the specific activities and strategies represented in the teacher's approach that they consider more important.

The results of the study show that the findings of environmental screening questionnaires are related to pupil performance on tests of reading and language competency. While it cannot be concluded that the results are unambiguous and statistically significant for all tests, they support our hypothesis that they are complementary to comprehensive diagnostic tests and should be interpreted together. If we include them in a reading comprehension diagnostic assessment, it may help us not only to explain a pupil's difficulties but also to seek effective procedures to compensate for those difficulties. Both environments can function as a protective or risk factor in the development of a pupil's reading skills.

Finally, we would like to mention that the next step in our research on environmental factors is the focus on intervention. By working with professionals using our PorTex test battery, we would like to identify effective compensatory and intervention strategies in the family and at school based on the approaches validated by our questionnaires.

References

Carreteiro, R. M., Justo, J. M., & Figueira, A. P. (2016). Reading Processes and Parenting Styles. *Journal Of Psycholinguistic Research*, 45, 901–914.

Baker, C. E. (2014). Mexican mothers' English proficiency and children's school readiness: Mediation through home literacy involvement. *Early Education And Development*, *25*(3), 338–355. DOI:10.1080/10409289.2013.807721

Block, C. C., & Duffy, G. G. (2008). Research on teaching comprehension: Where we've been and where we're going. In C. C. Block & S. R. Parris (Eds.), *Comprehension instruction: Research-based best practices* (2nd ed., pp. 19–37). The Guilford Press.

Burgess, S. R., Hecht, S. A., & Lonigan, C. J. (2002). *Relations of the home literacy environment (HLE) to the development of reading-related abilities: A one-year longitudinal study* [Online]. *Reading Research Quarterly*, *37*, 408–426. https://doi.org/10.1598/RRQ.37.4.4

Connor, C. M., Son, S., Hindman, A. H., & Morrison, F. J. (2005). Teacher qualifications, classroom practices, family characteristics, and preschool experience: Complex effects on first graders' vocabulary and early reading outcomes. *Journal Of School Psychology*, *43*(4), 343–375.

Gabal, I. & Václavíková Helšusová, L. (2003). *Jak čtou české děti?* Dostupné z http://www.gac.cz/files/igac/rep_cz.html

Greger, D., Simonová, J., & Straková, J. (2015). *Spravedlivý start?: nerovné šance v předškolním vzdělávání a při přechodu na základní školu*. Praha: Univerzita Karlova, Pedagogická fakulta.

Guthrie, J. T., Wigfield, A., Humenick, N. M., Perencevich, K. C., Taboada, A., & Barbosa, P. (2006). Influences of Stimulating Tasks on Reading Motivation and Comprehension. *Journal of Educational Research*, Vol 99(4), 232–245.

Guthrie, J. T., Wigfield, A., & You, W. (2012). Instructional Contexts for Engagement and Achievement in Reading. In S. Christensen, A. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 601–634). New York, NY: Springer Science.

Havlík, R., & Koťa, J. (2011). *Sociologie výchovy a školy*. Praha: Portál.

Chiu, M. M., & McBride-Chang, C. (2010). Family and reading in 41 countries: Differences across cultures and students. *Scientific Studies of Reading, 14*(6), 514–543.

Klapwijk, N. M. (2012). Reading strategy instruction and teacher change: implications for teacher training. *South African Journal Of Education*, 32, 191–204.

Korat, O., Arafat, S. H., Aram, D., & Klein, P. (2013). *Book reading mediation, SES, home* *literacy environment, and children's literacy: Evidence from Arabic-speaking families. First Language*, *33*(2), 132–154.

Kucharská, A. (2014). *Riziko dyslexie.* Praha: Univerzita Karlova v Praze, Pedagogická fakulta.

Kucharská, A. (2015). *Porozumění čtenému. III., Typický vývoj porozumění čtenému – metodologie, výsledky a interpretace výzkumu*. Praha: Univerzita Karlova, Pedagogická fakulta.

Kucharská, A., Málková, G., Sotáková, H., Špačková, K., Presslerová, P., & Richterová, E. (2016). *Porozumění čtenému.* (1. vydání, 194 stran). Praha: Univerzita Karlova v Praze, Pedagogická fakulta.

Kucharská, A., Špačková, K., Málková, G., Sotáková, H., Presslerová, P., Kučerová, O., & Chvál, M. (2021). *Klíčové gramotnostní dovednosti u žáků základních škol: manuál diagnostické testové baterie pro žáky 1. stupně ZŠ*. Praha: Univerzita Karlova, Pedagogická fakulta.

Niklas, F., & Schneider, W. (2013). Home literacy environment and the beginning of reading and spelling. *Contemporary Educational Psychology*, *38*(1), 40–50.

Reynolds, P. L., & Symons, S. (2001). Motivational variables and children's text search. *Journal of Educational Psychology, 93*(1), 14–22.

Saint-Laurent, L., & Giasson, J. (2005). Effects of a family literacy program adapting parental intervention to first graders' evolution of reading and writing abilities. *Journal of Early Childhood Literacy, 5*(3), 253–278.

Sénéchal, M., & LeFevre, J. (2002). Parental involvement in the development of children's reading skill: A five-year longitudinal study. *Child Development*, *73*(2), 445–460.

Sénéchal, M., & LeFevre, J. (2014). Continuity and change in the home literacy environment as predictors of growth in vocabulary and reading. *Child Development*, *85*(4), 1552–1568.

Špačková, K. (2016). Dyslexie: narušení čtenářských dovedností v oblasti dekódování i porozumění textu? *Psychologie Pro Praxi*, *2016*, 95–107.

Štech, S. (2000). Sociálně-kulturní pojetí handicapu. In Vágnerová, M., Hadj-Moussová, Z., & Štech, S. *Psychologie handicapu*. Praha: Karolinum.

Thorová, K. (2015). *Vývojová psychologie: proměny lidské psychiky od početí po smrt.* Praha: Portál.

Tonnessen, F. E., & Uppstad, P. H. (2015). *Can We Read Letters?* Rotterdam: Sense Publishers.

Vykoukalová, V., & Wildová, R. (2013). *Čtenářská gramotnost žáků 1. stupně a možnosti jejího rozvoje.* Praha: Univerzita Karlova, Pedagogická fakulta.

Wildová, R. (2005). *Rozvíjení počáteční čtenářské gramotnosti.* Praha: Univerzita Karlova, Pedagogická fakulta.

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Predictors for the Development of Arithmetic Skills in Pupils of Younger School Age

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Abstract: This study aims to map the predictors for the development of arithmetic skills in young school-age pupils. Specifically, the research investigation focused on comparing differences in performance between pupils with mathematical learning difficulties and a control group of pupils. The respondents performed tasks focusing on executive functions, spatial abilities, as well as estimation and symbolisation of quantities.
The performance of pupils with MLD (mathematical learning difficulties) differed from that of children without identified difficulties, particularly on tests focusing on matching number symbols and on numeracy skills alone. Significant, albeit smaller, differences between groups were also evident in non-symbolic quantity comparison and spatial skills (mental rotation). In terms of accuracy, we did not find statistically significant differences between the groups in any of the areas studied. The results indicate a close correlation between the speed of quantity symbolisation and the level of arithmetic skills.

Key words: mathematics, mathematical skills, arithmetic skills, younger school age, dyscalculia, mathematical learning difficulties

Introduction

The aim of the present study is to identify the risk factors for difficulties in the acquisition of numeracy skills among primary school pupils. We focus mainly on those indicators of difficulties in arithmetic that cannot be explained solely by the low intelligence of the individual, inappropriate teaching methods at school, or inadequate home preparation. Initially, we intended to deal with a specific numeracy disorder, i.e. **Developmental Dyscalculia (DD)**. However, due to inconsistencies in the way it is defined by different authors, we have decided not to adhere to this term strictly. Instead, we have started to use the more general

DOI: 10.14712/25337890.4532

term ***mathematical learning difficulties* (MLD)**. Nevertheless, in selecting the respondents for our study, we have tried to at least approximate the common criteria for diagnosing dyscalculia and have focused only on pupils with intellectual abilities within the norm. Despite their preference for the MLD designation, authors Bartelet, Ansari, Vaessen, and Blomert (2014) also followed a similar approach, suggesting that the terms be treated as synonyms in their study. This study is also inspired by, among other things, research on dyscalculia. We consider it likely that some of the respondents with MLD from our study would meet the criteria for a DD diagnosis with a more detailed diagnostic procedure. We chose the MLD designation because we did not conduct a more detailed diagnosis for the purposes of this study.

Learning disabilities in mathematics (or dyscalculia), as reported by some authors (Butterworth, Varma, & Laurillard, 2011; Hannell, 2013; Kuhn, 2015; Pražáková & Špačková, 2018), have generally received less attention than, for example, difficulties in language areas and thus remain neglected in terms of research and funding. At the same time, some (Butterworth et al., 2011; Kuhn, 2015) point out that improving the level of an individual's mathematical skills would help to improve not only their quality of life but also their country's GDP. Thus, our aim is to look for ways to identify potential risks of numeracy skills acquisition problems as early as possible and to address them in a timely manner.

We believe that identifying the causes of difficulties in mathematics in individual children will help us recognise whether they are due to a lack of aptitude on the part of the pupil, or to other causes, such as inadequate teaching methods. In particular, the results of studies (Locuniak & Jordan, 2008; Stock, Desoete, & Roeyers, 2009; Presentación, Siegenthaler, Pinto, Mercader, & Miranda, 2015) conducted with preschool children before the respondents encountered formal mathematics instruction, or at the beginning of the first year of primary school (Passolunghi, Vercelloni, & Schadee, 2007), and which were later compared with their mathematics skill levels, suggest to us that the relationship between some skills and subsequent mathematics achievement may be largely causal and therefore not likely to be a simple association. Nevertheless, even in studies focusing on primary school pupils, the authors sought to compare the mathematical skills of respondents with their performance on tasks in which performance was to be least affected by school instruction. In these tasks, children were asked, for example, to compare groups of objects (e.g. dots) based on their number (numerosity) or two numbers based on their numerical value. **It is assumed that even children with specific numeracy impairments can**

manage most of these tasks correctly, but they need more time to complete them compared to children without difficulties in mathematics (e.g., Butterworth, 2003; Landerl, Bevan, & Butterworth, 2004; Landerl, Fussenegger, Moll, & Willburger, 2009; Szucs, Devine, Nobes, Gabriel, & Soltesz, 2013; Pražáková, 2017; Šamajová & Cígler, 2020). Other domains receiving attention in this context include working memory (Landerl et al., 2004, 2009; Passolunghi et al., 2007; Presentación et al., 2015), spatial ability (Locuniak & Jordan, 2008; Vágnerová & Klégrová, 2008; Stock et al, 2009; McCaskey, von Aster, O'Gorman Tuura, & Kucian, 2017) inhibition (Presentación et al., 2015; Wang, Tasi, & Yang, 2012) and logic (Stock et al., 2009; Presentación et al., 2015; Morsanyi, Devine, Nobes, & Szűcs, 2013).

In some studies (Landerl et al., 2004, 2009; Bartelet et al., 2014; Szucs, Devine, Nobes, Gabriel, & Soltesz, 2013; Pražáková, 2017; Šamajová & Cígler, 2020), computer-administered tools were used to help pupils perform the tasks. Their advantage lies in the possibility of measuring the reaction time for each item separately, in addition to the number of errors, with greater accuracy than if the administrator measured the time manually using a stopwatch. They also allow for group assignments and immediate evaluation of results.

In the following paragraphs, the research investigation into possible indicators of difficulties in mathematics will be presented in more detail. Our aim was to investigate the above-mentioned indicators of difficulties in mathematics in the Czech school environment. Furthermore, we decided to use **tablet-administered methods** for this purpose**.** In contrast to methods using computer administration, our respondents can choose an answer directly on the touch screen and do not have to divide their attention between the monitor and another part of the device (keyboard or mouse). Moreover, in contrast to research (e.g., Landerl et al., 2004, 2009; Bartelet et al., 2014; Szucs et al., 2013; Pražáková, 2017; Šamajová & Cígler, 2020) in which respondents had to choose an answer from two options when non-symbolically comparing quantities or when comparing numerical symbols, we designed some tasks so that they had to choose from three options. Our hypothesis was that this would increase the difficulty of the tasks and thus increase the differences in performance between children with and without mathematical difficulties. **In the future, we want to contribute to expanding the possibilities of diagnosing difficulties in mathematics**. Finally, potential further research is discussed.

Mathematical Abilities and Skills

The term ability can generally be understood as the potential or aptitude for a particular activity, be it sport, playing a musical instrument, etc. (Říčan, 2010). At the same time, however, it is also used to refer to the level of knowledge and skills that we have already attained and that enable us to perform various activities (Atkinson, 2003; Říčan, 2010).

Experts and researchers (cf. Landerl, Bevana, & Butterworth, 2004; Vágnerová & Klégrová, 2008; Zelinková, 2009; Jordan, 2010; Hannell, 2013; Bednářová & Šmardová, 2015) agree that multiple sub-skills are involved in solving mathematical problems and that there is no single holistic mathematical ability or skill. At the same time, we can encounter multiple ways to categorise these abilities. In the Czech Republic, the following categorisation is often used (Vágnerová & Klégrová, 2008), which also corresponds to the concept in the Diagnostic and Statistical *Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association, 2013):

- understanding the nature of numbers – understanding the symbolism of numbers, the meaning of number order and inclusion (the fact that a larger number includes a smaller one),
- memory for numbers and other numeric characters,
- numeracy skills - the ability to handle numbers and apply general rules to the relationships between them,
- mathematical reasoning - specific abstract thinking that no longer depends only on concrete numbers, including the manipulation of more general concepts such as algebraic signs.

By suggesting that a number of different predictors are involved in mathematical skills, Jordan (2010) suggests a possible explanation for why **some individuals may perform relatively well in certain areas of mathematics while performing less well in others.**

In addition to cognitive predictors, a number of other factors influence the mathematical results we achieve. These include motivation (Presentación et al., 2015; Mercader, Miranda, Presentación, Siegenthaler, & Rosel et al., 2018), the socio-emotional development of the individual (Novák, 2004; von Aster & Shalev, 2007) and the influence of the family environment, among others, but these can be difficult to control (Locuniak & Jordan, 2008; Presentación et al., 2015). In this article, we focus primarily on cognitive predictors for the development of numeracy skills.

Predictors for the Development of Mathematical Skills

Some studies have sought to identify predictors for the development of numeracy skills that cannot be fully explained by inappropriate teaching styles at school or inadequate home preparation.

An important study in this respect is the investigation conducted by Landerl et al. (2004), in which the authors looked for possible causes of difficulties in mathematics in pupils with dyscalculia, dyslexia and a combination of both learning disabilities. They examined skills such as executive function, visuomotor coordination, reading and writing numbers, and estimating quantities. For some tasks, a voice recording was made to determine the exact reaction time – the time it took pupils to complete the task. The authors concluded that the main cause of dyscalculia is impaired understanding of basic number concepts, especially the idea of numerosity. This was particularly evident in the set of tasks where pupils were presented with a group of dots and were asked to quickly determine their number, but also when comparing numbers according to their numerical value. That study contributed to the development of a standardised method, the *Dyscalculia Screener* (Butterworth, 2003), aimed at screening for dyscalculia (see below).

Not all experts, however, agree with this notion of dyscalculia. For example, Osmon et al. (2006) concluded, on the basis of cluster analysis, that dyscalculia can be classified according to the causes of the difficulties as deficits in executive functions, in spatial abilities, or dual (mixed) deficits in spatial and executive functions. Bartelet et al. (2014) also performed a factor analysis in children with MLD, which yielded several groups of different sizes, divided according to impairments in different domains. These included a subtype of MLD with the so-called weak mental number line subtype, which was manifested in the placement of digits on a number axis, a group with impairment in the approximate number system (weak ANS subtype), which was manifested, for example, in the area of numerosity, a spatial difficulties subtype, which also showed impairment in the approximate number system (ANS)[1], the access deficit subtype, with difficulties in, for example, comparing numbers according to numerical value, and finally, the no numerical cognitive deficit subtype, which showed no impairment in the areas studied and, on the contrary, children from this group showed good results in verbal working memory, as did the garden-variety subtype, which showed only relatively lower nonverbal IQ.

Research on early predictors of subsequent numeracy skills has also yielded important findings. For example, Stock et al. (2009) found seriation

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[1] ANS provides a fuzzy representation of numerosities. It resides in the intraparietal sulcus- IPS (Szucs et al., 2013; Plassová, Stuchlíková, & Vavrečka, M, 2017).

ability (see below) to be the strongest ever predictor in the preschool period, thereby highlighting another important area – that of logic.

It is evident that the researchers focused on a range of abilities that could be considered predictors for the development of numeracy skills. The following paragraphs provide a closer look at those areas that were most frequently encountered in our study of the available research. We have already addressed risk factors in the development of numeracy skills in preschool children in a review study (Pražáková & Kucharská, 2019). Here, we focus more on those predictors in the context of school years. Although the following predictors are divided into categories, **these categories may overlap** (e.g. spatial and memory abilities tend to be considered components of intelligence).

General Intelligence

Intelligence or intellectual ability can be defined as "*the ability to learn from experience, to reason in abstract terms, and to deal purposefully with one's environment*" (Atkinson, 2003, p. 692). According to some authors (Vágnerová & Klégrová, 2008; Zelinková, 2009), mathematical ability can also be understood as one of the components of the structure of intelligence. At the same time, however, the level of reasoning ability does not clearly predict how an individual will master mathematics (Zelinková, 2009). As for the predictive value of intelligence in relation to school performance, according to Vágnerová (2005), the correlation coefficient is between 0.5 and 0.7, so it is a relatively high value.

Each of the subcomponents of intelligence may have a different effect on the development of mathematical skills. For example, great importance is attributed to memory skills (Locuniak & Jordan, 2008; Vágnerová & Klégrová, 2008) and spatial skills (Vágnerová & Klégrová, 2008; Landerl et al., 2009). In contrast, the level of vocabulary or even the ability to solve Matrix-type[2] problems in relation to numeracy skills appears to be less important (Landerl et al., 2004; Locuniak & Jordan, 2008).

Numerosity

According to a number of authors (Butterworth, 2003; von Aster & Shalev, 2007; Iuculano, Tang, Hall, & Butterworth, 2008; Babite & Emerson, 2018), humans have an innate implicit understanding of quantity. This allows us, for example, to compare two groups of objects according to their quantity. The same ability has been observed in human infants and even

[2] Among other skills, these tasks test nonverbal fluid intelligence and the ability to understand the relationships between the parts and the whole of a pattern (Maccow, 2011).

in some species of animals (Butterworth, 2003; Furman & Rubinsten, 2012). We can also encounter the term ***number sense***, which includes the ability to understand and work with quantity (Babite & Emerson, 2018) or the ability to represent numerical magnitude nonverbally on a number axis (Aster & Shalev, 2007).

Numerosity has been investigated in relation to numeracy skills in a number of studies, but the results do not appear to be entirely consistent. This link seems to be increasingly less conclusive compared to the ability to symbolise quantity using numbers (Furman & Rubinsten, 2012), which is the focus of the next section of this chapter. This is confirmed by the results of a pilot study conducted in the Czech Republic (Pražáková, 2017; Pražáková & Špačková, 2018). Another study conducted in the Czech Republic (Šamajová, 2018; Šamajová & Cígler, 2020) also failed to reliably demonstrate a significant association of this ability with numeracy impairment. In another study (Stock et al., 2009) conducted with preschool children, non-symbolic quantity comparison was found to be a relatively significant predictor of subsequent difficulties in mathematics but was not among the strongest predictors.

Symbolic Number Processing

Research results show that both **accuracy and fluency** in working with number symbols play a very important role in numeracy skills. In tasks aimed at matching numbers according to their numerical value, as well as in tasks aimed at matching a numerical symbol to a group of the corresponding number of objects (e.g., dots), respondents with specific learning disabilities in mathematics repeatedly perform worse than respondents from control groups (Landerl et al., 2004, 2009; Szucs et al., 2013; Pražáková, 2017; Pražáková & Špačková, 2018).

Logic

In Czech (Novák, 2004; Traspe & Skalková, 2013) and international (Stock et al., 2009; Presentación et al., 2015) literature, one can find the classification of intellectual development stages according to Piaget's theory, which serve as fundamental predictors for the acquisition of primary mathematical skills. In this context, the following abilities – which are also referred to as logical abilities by some authors (Stock et al., 2009; Presentación et al., 2015) – are often mentioned:

- **Classification** – sorting elements according to a certain criterion or similarity. Children first learn to sort by physical properties, then by purpose and finally by quantity (Novák, 2004). Some authors (Stock et al., 2009; Presentación et al., 2015) also introduce the concept of inclusion, which they refer to as the highest form of classification and by which they mean the understanding that a number can contain other numbers.

- **Seriation** – perception of differences between elements and the ability to sort them according to size, number, etc. Stock et al. (2009) found this ability in preschool children to be the strongest predictor of later arithmetic skills (relative to already acquired numeracy, quantity comparison and other logical skills).
- **Conservation** - understanding the principle of preserving the quantity of elements even when changing their spatial arrangement (understanding that nothing is added or lost during this change).

Further insights into logic in relation to mathematics are provided by Morsanyi, Devine, Nobes and Szűcs (2013), who examined it in school-age children using syllogisms[3]. Compared to the control group, children with dyscalculia performed poorly on those tasks where implausible premises appeared. The authors thus concluded that children with dyscalculia have weaker reasoning skills. Yet they themselves discuss whether it may have been more of a failure of inhibition skills. The latter is usually classed with executive functions.

Executive Functions

Executive functions are used to control, manage and regulate cognitive processes. They are particularly important in new or more demanding situations requiring rapid and flexible adaptation, but also, for example, where it is necessary to resist distractions (Vágnerová 2012). Of the executive functions, **working memory and inhibition** in particular were investigated in relation to mathematical abilities and skills. They are discussed in more detail below.

Inhibition

Vágnerová (2012) describes inhibition as the ability to control and suppress what is not needed in a given situation or that which is disturbing. Several studies have confirmed the link between this ability and mathematics performance. Wang, Tasi, and Yang (2012) examined different types of inhibition in school-age children and found that children with specific difficulties in mathematics failed primarily in number inhibition, where they were asked to verbally indicate the number (quantity) of digits presented that did not correspond to their numerical value. They also performed poorly in graph inhi-

[3] The children solved problems like *„Insects are smaller than mice. Mice are smaller than rabbits. Are rabbits smaller than insects?“* In some of the problems presented, plausible statements were replaced with implausible ones, e.g., *„Mice are bigger than elephants.“* The children were instructed to imagine that the given premises were correct.

bition, where they had to label the less distinctive of two shapes. On the other hand, dyslexic children performed worse in the word inhibition, where they had to name the colour in which different words were printed and suppress the tendency to read the word.

Memory

Performance in mathematics can also be influenced by memory, which facilitates recall of mathematical facts (e.g., that 2 + 3 = 5), procedures, mnemonic devices, etc. (Mazzocco, 2007). One of the most frequently cited types of memory in relation to mathematical skills is verbal working memory. For example, Locuniak and Jordan (2008) administered digit span backward repetition tasks to preschool children and this skill emerged as a significant predictor of later numeracy fluency, whereas simple digit span forward repetition did not show significant predictive power. Presentación et al. (2015), who observed executive functions in preschool children, **found working memory to be the overwhelmingly strongest predictor of numeracy skills.** Similarly, Passolunghi et al. (2007) also tested children at the beginning and end of their first year of school, and in addition to numeracy skills, working memory was also found to be the strongest predictor of later mathematics performance. The authors **suggest both of these abilities be a part of a simple screening for later difficulties in mathematics.**

Visuospatial Ability

Mathematics is also associated with spatial or visuospatial abilities. According to some authors, they are important for the mastery of geometry (Locuniak & Jordan, 2008; Vágnerová & Klégrová, 2008; Stock et al., 2009). Other possible consequences of deficits in this area are losing the order of digits, difficulties in working with the decimal point, deflection of digits from columns, etc. (Stock et al., 2009).

At the same time, McCaskey et al. (2017) point out that individuals with dyscalculia do not have a general deficit in spatial abilities but in some subcomponents. According to their study, respondents with dyscalculia performed statistically significantly worse, for example, in the area of so-called mental rotation, where they were asked to identify a particular shape (e.g. a square) if it was rotated in a different way from the template. On the other hand, they did not differ from the control group in tasks where they had to compare objects according to size, which was also shown in our earlier study (Pražáková, 2017; Pražáková & Špačková, 2018).

Language Abilities

Some authors have also linked mathematics to language skills (e.g., Locuniak & Jordan, 2008; Mazzocco, 2007). As Mazzocco notes, words can describe, for example, quantity (e.g., one, two, or three), categories of quantities (many, few), relative quantities (more, less), or relationships between quantities (twice as many). Even the memorisation of mathematical facts (e.g., 2 + 3 = 5) can be considered a linguistic as well as mathematical matter in this respect.

Didactical Aspects of Success in Mathematics

Mathematical knowledge and skills can also be impaired by inappropriate or insufficient stimulation from the school or family, e.g. as a result of forms of teaching that do not match the child's personality type or cognitive learning styles, however appropriate his or her intellectual and mathematical predispositions may otherwise be (Novák, 2004).[4]

Dilemmas about what to pay more attention to in mathematics education include drill on the one hand and comprehension on the other (Resnick & Ford, 2008; Rendl & Páchová, 2013). Proponents of the drill approach stress the need for repetition, i.e., automation of acquired knowledge. It turns out that this approach is also supported by many Czech teachers, while according to its critics, it leads only to mechanical acquisition of the material (see Rendl & Páchová, 2013). Didacticians drawing on constructivism, for example, oppose the drill approach. Among the best-known proponents of didactic constructivism in the Czech Republic is Hejný (see, e.g., Hejný & Kuřina, 2015), and his methodology of teaching mathematics is already widespread in many Czech schools.

Research by McConnell (in Resnick & Ford, 2008) has shown that while strict drilling leads to greater accuracy and speed in solving examples, a comprehension-focused approach, in contrast, promotes greater success with less familiar types of numerical problems. With regard to the so-called Hejný method specifically, the results are not entirely clear-cut. For example, in research by Chytrý, Říčan and Živná (2019), pupils taught using the classical method performed significantly worse in a didactic mathematics test. However, the limitations of this study include a relatively small number of respondents. Conversely, the Czech School Inspectorate (2017) found a slight difference between schools in favour of teaching according to Hejný, although these results did not reach statistical significance.

Developmental Dyscalculia

Developmental dyscalculia (DD) is generally understood to be a specific learning

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4 Novák uses the term didactogenic calculastenia for this phenomenon.

disorder with deficits in calculation (or arithmetic) skills that is not primarily caused by low intellectual ability or inadequate education (Butterworth et al., 2011; Novák, 2004; Vágnerová, 2008; Kaufmann & von Aster, 2012). In ICD-11 for Mortality and Morbidity Statistics, it is defined as follows: „*Developmental learning disorder with impairment in mathematics is characterised by significant and persistent difficulties in learning academic skills related to mathematics or arithmetic, such as number sense, memorization of number facts, accurate calculation, fluent calculation, and accurate mathematical reasoning.*" It also states that it leads to a significant reduction in academic or vocational competences.

An earlier version (ICD-10) described DD primarily as a deficit manifesting itself in arithmetic skills rather than in more abstract calculation tasks, which include algebra, geometry and others. Thus, in the newer version, there has been some expansion of this definition. However, neither of these versions explicitly uses the term dyscalculia anymore. Butterworth et al. (2011), who suggest that dyscalculia manifests itself primarily in arithmetic, state that even individuals with severe dyscalculia can excel in geometry, use statistical files and master computer programming at a high level. The authors differ on how to define, limit and classify it.

In the literature, we can also encounter the term ***mathematical learning difficulties* (MLD)**. Although, according to some authors (Bartelet et al., 2014), it can be used as a synonym for dyscalculia in certain contexts, it is often used as a more general term for difficulties in mathematics. According to other authors (Kaufmann & von Aster, 2012), the term MLD, unlike the term dyscalculia, does not take intellectual ability into account. They see the importance of distinguishing these terms only for research purposes; the labels should not affect the planning of interventions in practice. According to Karagiannakis et al. (2014), MLD also encompasses a wide range of deficits in mathematical skills. They consider the concept of dyscalculia too one-dimensional and therefore propose a multidimensional classification model that takes into account several subtypes of MLD according to causes and possible manifestations. These authors, on the other hand, consider it important to distinguish between the different subtypes and to use them in interventions.

Diagnosing Difficulties in Mathematics

The assessment of an individual's mathematical abilities and skills is quite complex. As stated by Novák (2004), in addition to the recognition of mathematical skills, it includes the collection of anamnestic data, the diagnosis of general intellectual abilities, personality traits and possibly medical aspects.

In the Czech Republic, we still encounter the so-called discrepancy criterion, the purpose of which is to determine whether a specific learning disability or a more general cognitive deficit is present. Vágnerová and Klégrová (2008) consider a difference of at least 15-20 points, i.e. 1-1.25 standard deviations, between IQ and performance in didactic mathematical tests to be diagnostically necessary. However, inconsistency in the definition of dyscalculia is also evident in terms of diagnostic criteria based on the severity of difficulties in mathematics assessed by standardised tests, ranging from performance below the 3rd percentile to performance below the 25th percentile, i.e. 2 to 0.68 standard deviations below the mean (Devine, Soltesz, Nobes, Goswami & Szucs, 2013). Kaufmann and von Aster (2012) and Kuhn (2015) also note that in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association, 2013), the requirement for a discrepancy criterion is also not strictly stated, given the heterogeneity of these disorders and comorbidities with others. Rather, Kaufmann and von Aster recommend examining discrepancies within individual subtests of multidimensional intelligence tests.

One of the most common and multidimensional intelligence tests used in the Czech Republic is the third edition of the Wechsler Intelligence Scale for Children – WISC-III (Krejčířová, Boschek, & Dan, 2002). The Wechsler tests reflect, for example, verbal comprehension, perceptual-spatial abilities, memory, work rate, etc. Children with learning disabilities in mathematics can be expected to score lower on some of these subtests (especially the numeracy skills subtest) (cf. Landerl et al. 2004, 2009; von Aster & Shalev, 2007; Locuniak & Jordan, 2008; Vágnerová & Klégrová, 2008; Presentación et al. 2015; Peters et al. 2018). This may reduce the overall score.

Kaufmann and von Aster (2012) divide tests of mathematical abilities and skills into curricular (performance) tests, which cover the school curriculum and assessment of mathematical skills, and neuropsychological orientation tests, which focus more on the causes of possible difficulties in this area. The *Dyscalculia Screener* (Butterworth, 2003), aimed at screening for dyscalculia, is probably an example of the second type of test. The method screens not only for numeracy skills attained but also for numerosity and the ability to symbolise quantities, which Butterworth considers to be key predictors for the development of arithmetic skills. The author further assumes here that even **children with dyscalculia can solve most of the problems correctly and that they differ from others mainly in their speed of solution.** He also draws on the finding that **pupils with specific difficulties in mathematics perform worse than their neurotypi-**

cal peers only on time-limited tasks and, conversely, do not differ significantly from the control group on tasks without a time limit (e.g. Jordan & Montani, 1997). Thanks to computer administration, reaction time is measured in milliseconds. The method also includes a control subtest that focuses on reaction time when working with non-numerical stimuli.

To our knowledge, there is no standardised diagnostic tool currently available in the Czech Republic that uses computer administration and allows such sensitive measurement of reaction time. One of the most recent test methods used here is the *Diagnostic of Mathematical Abilities and Skills* (Bednářová et al., 2015). This battery is used to determine the current level of the sub-skills needed for mathematics as well as the achieved skills. It focuses on the area of numbering (e.g. reading and writing numbers), basic number operations and the application of basic number operations (e.g. adding the characters of operations).

Aim of the Study

The main aim of the research was to map the possible causes of difficulties in mathematics among younger pupils (1st stage) in Czech primary schools. We were looking for indicators that could not be explained only by low intelligence, insufficient home preparation or inappropriate teaching methods at school.

Methods

Respondents

The participants were pupils in the 3rd year of primary school in the Czech Republic. The data collection took place between 2020 and 2022; the data collection period was extended due to measures taken in the light of the COVID-19 pandemic. The experimental group (21 pupils with MLD) and the control group (35 pupils) were formed from an original sample of 150 pupils attending a total of 5 schools in or near Prague. Of these, 99 children were taught using the classical method, while the rest were taught using the constructivist method, namely the so-called Hejný method (see e.g. Hejný & Kuřina, 2015).

The **experimental group** consisted of students with MLD who scored a standard score of 85-115 on a test of nonverbal intellectual abilities, while their scores were at or below the 25th percentile on at least two subtests testing mathematical abilities and skills. According to the comparison by Devine et al. (2013), most studies use more stringent criteria (lower percentile scores) for inclusion in the MLD or DD groups. We opted for this step in order to increase the number of respondents. The group consisted of a total of 21 students, 7 boys and 14 girls. The average age was 109.73 months.

The **control group** consisted of pupils who achieved a standard score of 85-115 on a test of nonverbal intellectual abilities. At the same time, they had to meet the condition that their results on the mathematical abilities and skills test corresponded to at least the 40th percentile in at least two subtests. In total, there were 35 pupils, 24 boys and 11 girls. The average age was 108.29 months.

The groups were designed to be statistically significantly different in terms of mathematics performance but not in terms of nonverbal intellectual ability (see the Standardised Methods section for more details). Thus, as in some previous studies (Landerl et al., 2009; Bartelet et al., 2014; Szucs et al., 2013), all selected respondents had standard scores (IQ) on a nonverbal intelligence test in the average range. The selected students were then presented with the experimental tasks.

Comparisons of the research groups on the standardised tests are shown in Table 1. For most tasks, the data did not show a normal distribution, therefore a Mann Whitney U test was run to determine whether there were differences in achievement scores. The table shows that the groups were not statistically significantly different in terms of nonverbal intellectual ability ($p = 0.180$), and the effect size did not reach very high values. On the contrary, the results reached statistical significance ($p < 0.05$) in all the areas of mathematical abilities studied; moreover, the differences between the groups can be considered large. The method of statistical processing is described in more detail in the Results section.

There were no statistically significant differences between the groups in terms of age. However, the groups could not be aligned in terms of gender composition. While the experimental group is dominated by girls, the control group shows a predominance of boys.

In the course of administering the standardised methods, it was brought to our attention by some teachers who teach mathematics using a constructivist approach that their students were not used to working under a time limit as required by the chosen standardised tools. We therefore decided to check whether there would be differences in our sample between students taught in the classical manner and students taught in the constructivist manner within the standardised methods. No significant differences were found in most of the areas monitored by the standardised methods. Only in the *Basic Numerical Operations* test (Bednářová et al., 2015) did the respondents taught in a constructivist manner perform worse. Although this is inconsistent with previous research (Chytrý et al., 2019; Czech School Inspectorate, 2017), it may represent a limitation of the research, which is addressed in the final discussion.

Table 1. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in standard tasks

	Group	N	Mean	Median	SD	Statistic	P value	Effect Size
Cattel	C	35	102.6	104	9.08	288	0.180	0.216
	MLD	21	99.3	101	9.19			
No. missing	C	35	86.9	95.3	19.27	105.5	< 0.001	0.713
	MLD	21	40.2	33.9	32.30			
Operations	C	35	67.3	66.0	16.52	1.0	< 0.001	0.997
	MLD	21	16.8	14.0	10.01			
Characters		35	74.9	78.5	17.76	4.0	< 0.001	0.989
		21	14.6	14.2	12.81			

Note: MLD – mathematical learning difficulties, C – control, N – sample size, SD – standard deviation, p – p value

Standardised Methods

Standardised methods were used in this study to select appropriate respondents for the subsequent part of the research in which experimental methods were administered. The purpose of the standardised tests was thus to identify students with and without difficulties in mathematics.

Mathematical abilities and skills were assessed using three subtests selected from the *Diagnostic of Mathematical Abilities and Skills* test battery (Bednářová et al., 2015). The subtests were chosen to at least partially cover all areas of mathematics targeted by the method. Specifically, the subtests were *Filling in the missing numbers* (area of numeration), which contains ascending or descending number series in which some numbers are missing and the pupil is asked to fill them in; *Basic number operations,* which contains numerical examples focusing on addition, subtraction, multiplication and division, where the child is asked to write the result; *Completion of operations* (application of basic numerical operations), which contains the same types of examples as *Basic number operations*, but instead of a result, pupils are asked to complete the sign of the operation, i.e. plus, minus, times or divide. Pupils get one point for each correct answer. All subtests are timed and the raw scores of each subtest are converted to percentiles.

Nonverbal intellectual abilities were assessed using the first part of the *Cattel*

Fluid Intelligence Test – CFT 20 R (Fajmon, Hönigová, Urbánek, & Širůček, 2015). It is a nonverbal method; all subtests are figural in nature[5] and solved in pencil-and-paper form. All tasks are time-limited. The test also allows for group administration. Gross scores are converted to IQ scores.

Experimental Methods

In order to map possible cognitive predictors for the development of numeracy skills, we decided to use a non-standardised test battery administered via tablets. The administration was done in groups of up to 10 students. At the beginning of each subtest, pupils were instructed how to solve the task, while at the same time, the instructions were displayed to them via the app. This was followed by three test items. If a pupil made a mistake, the app automatically alerted them to the error and prompted them with the correct answer. The test items were not scored or timed. Before the actual subtest was given, pupils had the opportunity to ask the administrators questions. After completing all the subtest items, after the time limit had expired, or after a pupil had answered three consecutive items incorrectly, respondents were instructed to wait for further instructions from the administrator.

The test battery was created for the purposes of this study and was also partially used in a collaborative project (Stiernakova, 2022).

In composing the test items, we assumed, as did (Butterworth, 2003), that **most students can complete most items correctly** and that students with DD or MLD can usually correctly determine, for example, which of the two numbers presented represents the larger value. Based on the results of previous studies (e.g., Jordan & Montani, 1997; Landerl et al., 2004; Pražáková, 2017), we expected that students with MLD would differ from neurotypical students **mainly in the speed with which they solve these relatively easy tasks** (except for the control *Ordinary Reaction Time* subtest, where, on the contrary, we did not expect differences).

The following subtests were given.

Normal Reaction Time. This is a control subtest. Its purpose was to see if the groups differed in solving tasks that we assumed to be unrelated to mathematics. Respondents were sequentially presented with two, three or four boxes, one of which contained a picture and the others were blank. Students were asked

5 It includes 4 subtests: Series – determining which of the five images best completes the series; Classification – determining the image that does not belong with the others; Matrix – determining the image that best completes the matrix; Topology – selecting the image that most closely matches the rules in the template.

to click on the box containing the picture as quickly as possible. A total of 30 items were administered within a time limit of two minutes. The control subtest in the standardised *Dyscalculia Screener* (Butterworth, 2003) method works on a similar principle, where students are asked to press a computer button when a black dot appears on the monitor.

Classification. As mentioned above, classification is often considered a logical skill (Novák, 2004; Stock et al., 2009). This skill has been investigated, for example, by Stock et al. (2009) in preschool children, and in their research, the respondents were asked to work with numbers. In this task, students were instructed to choose the picture out of four that was least similar to the others. For example, three pictures showing fruit and one showing a pastry could be presented at the same time. In total, 15 items were administered within a time limit of three minutes.

Mental Rotation. This task was chosen to measure spatial ability. According to McCaskey et al. (2017), mental rotation is one of the spatial abilities where students with DD differ more from neurotypical students. Respondents were shown a picture of a cube with three sides at the top of the screen and two others at the bottom. Pupils were informed that one of the cubes at the bottom was the same as the one at the top, but was rotated differently. They were asked to identify which of the two cubes at the bottom corresponded to the one at the top. Thus, the task was designed to assess the level of spatial imagination and required a mental rotation for successful completion. Fifteen items were administered within a time limit of three minutes. A similar task from the standardised I-S-T 2000 R: Structure of Intelligence Test (Plháková, 2005), which is administered in a pencil-and-paper format, was also used in our earlier study (Pražáková, 2017) with adult respondents with DD, where they achieved slightly lower scores compared to the standardisation sample. However, that was a very small research sample.

Inhibition. At the top of the screen there was a box containing two shapes, one of which was always larger and more prominent. At the bottom were two more boxes, each containing one shape. Respondents were asked to indicate which of the shapes on the bottom corresponded in shape to the smaller of the shapes shown above. Twenty items were administered within a time limit of two minutes. This test was inspired by the *Graph Inhibition* task by Wang, Tasi, and Yang (2012), which also deals with geometric shapes. We chose this form of the task here because it can be easily measured using tablets.

Comparing Two Fields of Dots. Pupils were asked to compare two fields according to the number of dots and to mark the more numerous of the two, regardless of the size of the dots. Twenty items were

Table 2. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Normal Reaction Time subtest

	Group	N	Mean	Median	SD	Statistic	P value	Effect Size
Speed	C	35	27.281	24.865	10.905	342	0.672	0.0694
	MLD	21	26.700	24.698	5.835			
Correctness	C	35	29.286	30.000	2.926	346	0.578	0.0585
	MLD	21	27.952	30.000	5.277			
Median	C	35	0.725	0.707	0.147	300	0.257	0.1837
	MLD	21	0.760	0.724	0.138			

Note: MLD – mathematical learning difficulties, C – control, N – sample size, SD – standard deviation, p – p value

administered within a time limit of two minutes. As mentioned above, similar tasks have been administered in multiple studies (Landerl et al., 2004, 2009; Bartelet et al., 2014; Szucs et al., 2013; Pražáková, 2017; Pražáková & Špačková, 2018; Šamajová, 2018; Šamajová & Cígler, 2020; Stock et al., 2009), but without using tablets.

Comparing Three Fields of Dots. Unlike the previous task, here the students were asked to compare three fields containing dots. This time they had to mark the box that contained neither the most nor the least dots. Thus, if the simultaneously displayed fields contained, for example, 2, 4 and 7 dots, respondents should click on the field with 4 dots. There were 15 items administered within a time limit of three minutes.

Comparing Two Numbers. Students were asked to compare two boxes of numbers by clicking on the one that indicated the larger number, regardless of the size of each digit. Twenty items were administered within a time limit of two minutes. A similar type of task has been used in a number of previous studies (Landerl et al., 2004, 2009; Szucs et al., 2013; Pražáková, 2017; Pražáková & Špačková, 2018) as well as the standardised method, the Dyscalculia Screener (Butterworth, 2003), but none of them used tablets for administration.

Comparing Three Numbers. Students were asked to compare three boxes containing numbers. Again, the criterion was the quantity that the numbers denoted. Respondents were asked to click on the number that indicated neither the largest nor the smallest number. Thus, if they had to decide between the numbers 2, 4 and 7, they should click on the box containing the number 4 as instructed.

Table 3. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Classification subtest

	Group	N	Mean	Median	SD	Statistic (df)	p	Effect Size
Speed	C	35	78.82	80.45	36.86	-1.362 (54)	0.179	-0.3759
	MLD	21	93.95	88.33	45.42			
Correctness	C	35	8.83	10.00	3.66	348	0,738	0,0544
	MLD	21	9.52	10.00	2.42			
Median	C	35	4.07	3.90	1.28	0.357 (53)	0.723	0.0991
	MLD	21	3.94	3.73	1.36			

Note: MLD – mathematical learning difficulties, C – control, N – sample size, SD – standard deviation, p – p value

There were 15 items administered within a time limit of three minutes.

Arithmetic. Respondents were shown an arithmetic problem at the top of the screen. At the bottom, they were presented with two possible results. Students were instructed to mark the number corresponding to the correct result. Twenty problems were administered with a time limit of three minutes. In our earlier study (Pražáková, 2017; Pražáková & Špačková, 2018), respondents with DD differed more from the control group in a similar task than in the other areas studied. A similar subtest is also included in *Dyscalculia Screener* (Butterworth, 2003).

According to the original plan, we had also prepared a test for verbal **working memory,** namely the backward repetition of a series of numbers and letters. Based on previous research (Locuniak & Jordan, 2008; Presentación et al., 2015; Passolunghi et al., 2007), we considered it to be one of the most important predictors of the development of numeracy skills. However, this task was designed for individual administration. Due to the complex and rapidly changing pandemic situation, we finally decided to exclude it from the study areas.

Results

We first determined whether the individual test results reached a normal distribution. In order to assess if the differences between the compared groups reached statistical significance in each test method, we used the T-test for two independent sets in the case of a normal distribution and the non-parametric Mann-Whitney U-test if the data did not fit a normal distribution. We set a 5% significance level ($p<0.05$) as the criterion

Table 4. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Mental Rotation subtest

	Group	N	Mean	Median	SD	Statistic	p	Effect Size
Speed	C	35	79.62	74.20	53.50	306	0.302	0.167
	MLD	21	99.18	101.88	60.80			
Correctness	C	35	8.03	10.00	4.15	299	0.243	0.188
	MLD	21	7.19	9.00	4.09			
Median	C	34	4.60	3.99	2.70	209	0.035	0.353
	MLD	19	6.16	5.86	2.44			

Note: MLD - mathematical learning difficulties, C- control, N- sample size, SD – standard deviation, p – p value

for confirming statistically significant differences between groups.

Next, the effect size was calculated so that we could determine the differences between them more accurately. Thus, the results obtained using the T-test were supplemented with the *d* statistic (Cohen's d), where differences between sets are considered small for values of *d* around 0.2, medium for values around 0.5 and large for *d* around 0.8 (Cohen, 1988). Sawilowsky (2009) further describes the values as very large for *d* around 1.2 and huge for *d* around 2. The results of the U-test were complemented by calculations for the correlation coefficient r, where differences between sets are considered small for values of r = 0.1, medium for r = 0.3, and large for r = 0.5 (Cohen, 1988).

To look for differences between the groups, we analysed the total time taken to solve each problem (speed), the average number of correct answers (correctness) and the median time for each group (median).

Normal Reaction Time. In the control subtest monitoring reaction time when working with non-numerical stimuli, the differences between groups did not reach statistical significance, nor were they very large in terms of effect size (Table 2).

Classification. When classifying the images, the differences between the groups did not reach statistical significance. Also, the effect size reaches very low values (see Table 3).

Mental Rotation. In this test, children with MLD performed statistically worse than the control group in terms of median speed of correct responses (see Table 4). The effect size reached moderate values.

Table 5. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Inhibition subtest

	Group	N	Mean	Median	SD	Statistic (df)	p	Effect Size
Speed	C	35	41.21	41.49	20.430	-1,035 (54)	0.305	-0,286
	MLD	21	46.47	43.99	14.403			
Correctness	C	35	16.63	18.00	4.466	323	0.715	0.122
	MLD	21	17.10	19.00	4.836			
Median	C	35	1.98	1.96	0.815	291	0.195	0.210
	MLD	21	2.34	2.14	0.830			

Note: MLD – mathematical learning difficulties, C – control, N – sample size, SD – standard deviation, p – p value

Inhibition. Although the MLD students were slower than the control group, the differences between the groups did not reach statistical significance (see Table 5).

Comparing Two Fields of Dots. Here too, the MLD students achieved lower scores, both in terms of speed and accuracy. However, the differences between the groups did not prove to be statistically significant (see Table 6).

Comparing Three Fields of Dots. When comparing the three fields of dots, statistically significant differences in terms of the median correct response rate were found in favour of the control group, and the differences between the groups can be considered to be moderate (see Table 7).

Comparing Two Numbers. When determining the larger of the two numbers, the differences between the groups reached statistical significance in terms of both speed and median speed of correct answers in favour of pupils without identified difficulties in mathematics. The effect size also reached high values (see Table 8).

Comparing Three Numbers. When comparing three numbers, the students with MLD were statistically significantly worse in terms of speed of responses compared to the control group (see Table 9). The differences can be considered to be approximately moderately high.

Arithmetic. When solving the arithmetic problems, the differences between groups reached statistical significance in terms of both speed and median speed of correct answers in favour of pupils without identified difficulties in mathematics (see Table 10). Moreover, the effect size reaches very high values.

Table 6. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Comparing Two Fields of Dots subtest

	Group	N	Mean	Median	SD	Statistic	p	Effect Size
Speed	C	35	76.72	57.39	59.69	267	0.807	0,273
	MLD	21	106.98	116.27	67.34			
Correctness	C	35	5.77	5	4.65	253	0.052	0.312
	MLD	21	6.33	8	4.21			
Median	C	30	5.71	5.31	2.86	284	0.158	0.229
	MLD	19	7.84	8.12	3.48			

Note: MLD - mathematical learning difficulties, C- control, N- sample size, SD – standard deviation, p – p value

Conclusion and Discussion

In this study, we built on previous research examining possible causes of difficulties in mathematics. In contrast to those studies, we used tablets to administer the tasks, which, to our knowledge, have never been used for this purpose in the Czech Republic.

The experimental group of pupils with MLD and the control group were composed so that the pupils differed as much as possible in the mathematical areas of interest but not in their nonverbal intellectual abilities. We tried to follow similar, albeit simplified, criteria as in the diagnosis of dyscalculia, while no longer strictly adhering to this term. Apart from the lack of a clear definition, another reason was that both mathematical and intellectual abilities were assessed only tentatively, not comprehensively, with the inclusion of multiple components of both intellect and mathematics. The disparity criterion of at least one standard deviation difference between the results of the intelligence test and the test of mathematical abilities and skills, which is still commonly considered in the Czech Republic in diagnosing DD, was also not met. In order to recruit as many respondents as possible into the experimental group, we chose a relatively modest criterion, namely, scores below the 26th percentile in two of the three subtests administered in the standardised mathematics diagnostic tool. We believe that with a larger number of respondents, it would have been ideal to choose more stringent criteria, but it was important for us to achieve signifi-

Table 7. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Comparing Three Fields of Dots subtest

	Group	N	Mean	Median	SD	Statistic	p	Effect Size
Speed	C	35	67.67	60.83	32.48	267	0.088	0.274
	MLD	21	84.86	93.73	38.35			
Correctness	C	35	15.34	16.00	2.92	343	0.683	0.067
	MLD	21	14.05	14.00	2.84			
Median	C	35	2.69	2.16	1.38	171	0.019	0.402
	MLD	21	3.82	3.16	2.27			

Note: MLD – mathematical learning difficulties, C – control, N – sample size, SD – standard deviation, p – p value

cant differences between the comparison groups.

The results obtained using experimental methods are largely consistent with previous research (Butterworth, 2003; Landerl et al., 2004, 2009; Szucs et al., 2013; McCaskey et al., 2017; Pražáková, 2017; Šamajová & Cígler, 2020). **The performance of pupils with MLD differed from that of children without identified difficulties on the experimental tasks, particularly on tests focused on matching number symbols and on numeracy skills alone.** Significant, albeit smaller, differences between the groups were also evident in **non-symbolic quantity comparison and in spatial skills** (mental rotation). However, in terms of accuracy, we found no statistically significant differences between the groups in any of the areas examined. Where the groups did differ significantly from each other, it was invariably only in terms of task-solving speed. This means that MLD pupils were slower at solving some experimental tasks compared to children without identified difficulties, but this did not significantly affect the accuracy of the solutions. As mentioned above, such findings are not very surprising to us. A British standardised instrument, the *Dyscalculia Screener* (Butterworth, 2003), was constructed on the basis of a similar hypothesis. In this instrument, the test items were designed so that most pupils could solve most of the tasks correctly. Children with difficulties in mathematics (or DD) are to be identified mainly by their need for more time to solve items with numerical stimuli. The exception here is also a control subtest with non-numerical stimuli, focusing on simple reaction time, which is intended to distinguish whether pupils are slower

Table 8. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Comparing Two Numbers subtest

	Group	N	Mean	Median	SD	Statistic	p	**Effect Size**
Speed	C	35	32.33	31.67	9.402	170	<.001	0.537
	MLD	21	39.83	40.78	7.596			
Correctness	C	35	18.66	20.00	3.360	322	0.400	0.124
	MLD	21	19.14	19.00	0.910			
Median	C	35	1.53	1.44	0.297	170	<.001	0.537
	MLD	21	1.83	1.81	0.362			

Note: MLD - mathematical learning difficulties, C- control, N- sample size, SD – standard deviation, p – p value

to respond to all stimuli in general or specifically in tasks more closely related to mathematics. Butterworth also draws on findings (e.g., Jordan & Montani, 1997) indicating that **although students with DD tend to be slower than neurotypical students on numerical tasks, they might perform similarly on tasks without a time limit.**

It follows that because the research groups in this study were compared with each other in time-limited tasks, not only in the experimental but also in the standardised tasks, we cannot conclude that they would have differed in tests that had no time limit. Even so, it should be kept in mind that the MLD group was not significantly slower in all tasks -- not even in the standardised methods. The groups were designed to differ only on the maths skills test but not on the nonverbal intellectual ability test, which also has a set time limit. It therefore seems likely that, even within the non-standardised methods, pupils with MLD performed worse, particularly on those tasks that were genuinely related to mathematics rather than general work pace or intelligence. Thus, it also appears that, in the context of school-based support measures, increasing the time limit for pupils with MLD (or DD) serves a purpose.

The assumption that students with MLD perform significantly worse on inhibition was not supported in this study. Further research would be needed to determine whether this was due to the composition of the research population (grouping criteria, sample size, etc.) or the nature of the test material. Significant group differences did not show up in the control subtest focusing on simple reaction time, which we did not expect

Table 9. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Comparing Three Numbers Test

	Group	N	Mean	Median	SD	Statistic	p	Effect Size
Speed	C	35	68.63	63.86	33.61	-2.271(54)	0.031	-0.612
	MLD	21	89.47	84.03	34.80			
Correctness	C	35	10.34	12.00	4.36	363	0.939	0.014
	MLD	21	10.48	11.00	4.13			
Median	C	34	4.69	4.27	1.95	211	0.012	0.409
	MLD	21	5.76	5.25	1.54			

Note: MLD – mathematical learning difficulties, C – control, N – sample size, SD – standard deviation, p – p value

given its purpose, nor in the subtest on item classification (logic). In the latter subtest, we also did not anticipate large differences between the groups because, as we have already mentioned, the groups did not differ significantly in terms of nonverbal intellectual abilities. In some respects, this task resembles the CFT 20 R method, especially its *Classification* subtest, although in our experimental test, unlike the CFT 20 R, students worked with concrete patterns. This hypothesis would need to be confirmed or refuted by further research.

Compared to the studies (e.g., Landerl et al., 2004, 2009; Bartelet et al., 2014; Szucs et al., 2013; Pražáková, 2017; Šamajová & Cígler, 2020) that we drew on here, we also added tasks comparing three fields with objects or three fields with numbers. This was to test our hypothesis that this might increase the differences in performance between pupils with MLD and pupils without difficulties in mathematics, especially in the case of non-symbolic quantity comparisons, where differences between groups are usually not very large. We were only able to confirm this assumption partially here. Although the students with MLD performed worse, they were statistically significantly different from the control group only in terms of median speeds for the Compare Three Fields with Objects task. In contrast, when comparing numerical symbols, the groups differed less from each other when working with three fields than when comparing only two fields. Although the MLD pupils performed statistically significantly worse than the control group even when working with three fields, in terms of identifying possible difficulties in mathematics in the early years of schooling, compar-

Table 10. Descriptive statistics and results for the Comparison of the Experimental and Control Groups in the Arithmetic subtest

	Group	N	Mean	Median	SD	Statistic	p	Effect Size
Speed	C	35	94.33	90.89	29.572	136	<.001	0.630
	MLD	21	138.74	147.46	42.76			
Correctness	C	35	18.03	18.00	1.790	336	0.586	0.087
	MLD	21	18.33	18.00	3.07			
Median	C	35	3.32	3.43	0.949	135	<.001	0.633
	MLD	21	4.77	4.70	1.61			

Note: MLD – mathematical learning difficulties, C – control, N – sample size, SD – standard deviation, p – p value

ing two fields with numbers seems to be more effective thus far.

As also mentioned, the study involved not only schools that teach mathematics in the classical manner, but also schools that teach the so-called Hejný method, which is based on constructivism. In order to determine whether pupils taught according to different methods achieve comparable results in standardised tests, we compared the results in these tests according to the method of teaching. In one of the subtests of the standardised test of mathematical abilities and skills (Bednářová et al., 2015), pupils taught using constructivist methods achieved statistically significantly worse results in the part focusing on numerical operations than pupils taught in the classical way. This result may represent a limitation of this study, although it contrasts with, for example, the results of the Czech School Inspectorate (2017). A possible explanation for why pupils taught using this method performed worse is the time limit set in standardised methods, which, according to some teachers from the participating schools who teach in a constructivist manner, their pupils are not used to working with. Unfortunately, we did not have a standardised tool with standards specifically designed for the Hejný method, and therefore had no way of identifying possible difficulties in pupils taught in this manner. It should also be noted that we are dealing with a small research population sample here, and so any differences cannot yet be overgeneralised. In the future, we recommend that these findings be verified on a larger sample and that standards also be developed for the Hejný method. Similarly, we consider it worthwhile to check whether similar differences are also present in our experimental methods.

It is important to keep in mind that data collection was severely disrupted by the COVID-19 pandemic and did not proceed as planned due to relatively strict and prolonged measures, including repeated school closures. Although schools from other regions were included in the original sample, we only made this comparison for respondents from Prague or the surrounding area because none of the schools from other regions ultimately participated in data collection through experimental methods.

For the reasons mentioned above, we were forced to spread the data collection over a much longer period of time than anticipated, and even then fewer students took part. Due to the overall complexity of the situation following the pandemic outbreak, we also abandoned the intention to investigate verbal working memory, the importance of which might be interesting to explore alongside the other areas of interest. Based on previous research (Locuniak & Jordan, 2008; Presentación et al., 2015; Passolunghi et al., 2007), we considered this ability to be an important aspect for predictors of arithmetic skill development and originally intended to administer it individually, unlike the other experimental tasks, but we only managed to do so with 11 respondents. We were not able to prepare the option of assessing it using tablets in time, a solution conceived later, due to the rapidly deteriorating COVID-19 situation and the tightening of pandemic measures. In the end, we decided not to complicate an already difficult situation in schools with further testing. **In the future, however, it might still be interesting to add a working memory subtest to our battery,** or at least to test respondents' working memory orally in individual sessions. It would thus be useful to replicate the research on a larger research sample of children from more regions of the country, possibly including first or second grade students.

The Czech Republic currently **lacks a simple screening system** focused on mathematical skills that could identify pupils at risk of difficulties in the early years of education who deserve special attention. This could include, for example, a number matching test, given that these types of tasks appear to be highly relevant in relation to mathematics, as mentioned above. It should also be noted that this type of test is already used with computer administration in a standardised screening tool abroad (Butterworth, 2003). If the hypothesis that working memory is also a significant indicator of mathematics difficulties is confirmed, it could be included in a possible screening tool, as suggested by Passolunghi et al. (2007). However, as there are arguably multiple predictors for the development of numeracy skills, an overly simple screening with, e.g., only two skills (such as number matching and working memory) might not detect all children at risk of difficulties, such as children with impaired spatial skills.

Possible indicators of difficulties in mathematics **should also be investigated causally,** preferably already in preschool children (i.e. preschoolers' abilities in relation to later numeracy skills). As evidenced by international research conducted with kindergarten pupils, apart from the ability to solve certain types of arithmetical problems, the levels of which can vary from country to country (Locuniak & Jordan, 2008; Stock et al., 2009), it is precisely working memory (Locuniak & Jordan, 2008; Presentación et al., 2015) and the ability to serialise (Stock et al., 2009) that emerge as strong predictors of numeracy skills in the early years of school. These, or others, could thus become part of future screening for difficulties in mathematics as early as preschool age, as we also suggested in a previously published review study (Pražáková & Kucharská, 2019).

It should also be kept in mind that there are probably multiple subtypes of difficulties in mathematics, depending on the underlying causes but also in terms of how they manifest. Thus, because individuals with MLD may not have impairments in all predictors, not all areas of mathematics are affected.

These subtypes should also be examined more closely in the Czech context. At the same time, there is still no consensus among the professional community on how to classify the different types of difficulties in mathematics. Therefore, our proposal is to **approach** both the diagnosis and the remediation of possible difficulties in mathematics **individually**, regardless of the extent to which they fit specific diagnostic "labels."

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.).

Bartelet, D. Ansari, D. Vaessen, A. Blomert, L. (2014) Cognitive subtypes of mathematics learning difficulties in primary education. *Research in Developmental Disabilities*, 35, 657–670.

Bednářová, J. at al. (2015). *Diagnostika matematických schopností a dovedností: varianta pro školská poradenská zařízení 3. a 4. ročník*. Brno: Pedagogicko-psychologická poradna Brno.

Bednářová, J., & Šmardová, V. (2015). *Diagnostika školní připravenosti, varianta pro školská poradenská zařízení*. Brno: Pedagogicko psychologická poradna Brno.

Butterworth, B. (2003). *Dyscalculia Screener*. London: nferNelson.

Butterworth, B. Varma, S. Laurillard, D. (2011). Dyscalculia: From Brain to Education. *Science*, 332(6033), 1049–1053.

Cohen, J. *Statistical Power Analysis for the Social Sciences*. Hillsdale, NY: Lawrence Erlbaum, 1988.

Česká školní inspekce. (2017). Výběrová z jištění výsledků žáků na úrovni 5. a 9. ročníků základních škol ve školním roce 2016/2017 – závěrečná z práva. [online]. [cit. 2021-08-02]. Dostupné z: https://www.csicr.cz/getattachment/17f8e265-b04f-4459-a106-3aecbf735ca0/Vyberove-zjistovani-vysledku-zaku-na-urovni-5-a-9-rocniku-ZS-zaverecna-zprava.pdf.

Devine, A. Soltesz, F. Nobes, A. Goswami, U. Szucs, D. (2013). Gender differences in developmental dyscalculia depend on diagnostic criteria. *Learning and Instruction*, 27, 31–39.

Fajmonová, V., Hönigová, S., Urbánek, T., & Širůček, J. (2015). *CFT 20-R – Cattellův test fluidní inteligence*. Praha: Hogrefe – Testcentrum.

Furman, T., & Rubinsten, O. (2012). Symbolic and non symbolic numerical representation in adults with and without developmental dyscalculia. *Behavioral and Brain Functions*, 8, 55–69.

Hannel, G. (2013). *Dyscalculia. Action plans for successful learning in mathematics*. New York: Routledge.

Hejný, M., & Kuřina, F. (2015). *Dítě, škola a matematika: konstruktivistické přístupy k vyučování* (3. vydání). Praha: Portál.

Chytrý, V, Říčan, J, & Živná, D. (2019). Matematická výkonnost a metakognice žáků základních škol běžných, základních škol Montessori a žáků vyučovaných podle Hejného metody. *Studia paedagogica* 24(1), 107-133.

ICD-10 [online]. [cit. 2023-09-20]. Dostupné z: https://icd.who.int/browse10/2010/en#F81.2.

ICD-11 [online]. [cit. 2023-08-19]. Dostupné z: https://icd.who.int/browse11/l-m/en#/http://id.who.int/icd/entity/771231188 .

Iuculano, T., Tang, J., Hall, Ch. W., & B. Butterworth, B. (2008). Core information processing deficits in developmental dyscalculia and low numeracy. *Developmental Science* 11(5), 669–680.

Jordan (2010). Early Predictors of Mathematics Achievement and Mathematics Learning Difficulties. [online]. [cit. 2023-09-11]. Dostupné z: https://www.child-encyclopedia.com/numeracy/according-experts/early-predictors-mathematics-achievement-and-mathematics-learning.

Karagiannakis, G. Baccaglini-Frank, A. Papadatos, Y. (2014) Mathematical learning difficulties subtypes classification. *Frontiers in Human Neuroscience*, 8(57), 1–5.

Kaufmann, L., & von Aster, M. (2012). The diagnosis and management of dyscalculia. *Dtsch Arztebl Int*, 109(45), 767–78. DOI: 10.3238/arztebl.2012.0767.

Košč, L. (1972). *Psychológia matematických schopností*. Bratislava: Slovenské pedagogické nakladatel'stvo.

Krejčířová, D., Boschek, P., & Dan, J. (2002). *WISC-III: Wechslerova inteligenční škála pro děti*. Praha: Testcentrum.

Kuhn, J. Developmental Dyscalculia: Neurobiological, Cognitive, and Developmental Perspectives. (2015). *Zeitschrift für Psychologie*. 223(2), 69–82.

Landerl, K., Bevan, A., & Butterworth, B. (2004). Developmental dyscalculia and basic numerical capacities: a study of 8–9-year-old students. *Cognition* 93(2), 99–125.

Landerl, K. Fussenegger, B. Moll, & K. Willburger, E. (2009). Dyslexia and dyscalculia: Two learning disorders with different cognitive profiles. *Journal of Experimental Child Psychology*, 103(3), 309–324.

Locuniak, M. N., & Jordan, N. (2008). Using Kindergarten Number Sense to Predict Calculation Fluency in Second Grade. *Journal of Learning Disabilities,* 41(5), 451–459.

Mazzocco, M. M. (2007). Early predictors of mathematical learning difficulties: Variations in children's diffi culties with math. *Exchange*, 151, 51–54

Mercader, J., Miranda, A., Presentación, J. M., Siegenthaler, R., & Rosel, J. F. (2018). Contributions of Motivation, Early Numeracy Skills, and Executive Functioning to Mathematical Performance. A Longitudinal Study. *Frontiers in Psychology*. [online]. [cit. 2023-09-11]. Dostupné z: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5775518/.

McCaskey, U., von Aster, M., O'Gorman Tuura, R., & Kucian, K. (2017). Adolescents with Developmental Dyscalculia Do Not Have a Generalized Magnitude Deficit – Processing of Discrete and Continuous Magnitudes. *Frontiers in Human Neuroscience*, 11, 1–19.

Morsanyi, K., Devine, A., Nobes, A., & Szűcs, D. (2013). The link between logic, mathematics and imagination: Evidence from children with developmental dyscalculia and mathematically gifted children. *Developmental Science*, 16(4), 542–553.

Novák, J. (2004). *Dyskalkulie: specifické poruchy počítání: metodika rozvíjení základních početních dovedností*. Havlíčkův Brod: Tobiáš.

Osmon, D. C., Smerz, J. M., Braun, M. M., & Plambeck, E. (2006). Processing Abilities Associated with Math Skills in Adult Learning Disability. *Journal of Clinical and Experimental Neuropsychology*, 28(1), 84–95.

Passolunghi, M. Ch., Vercelloni, B., & Schadee, H. (2007). The precursors of mathematics learning: Working memory, phonological ability and numerical competence. *Cognitive Development*, 22, 165–184.

Peters, L., Bulthé, J., Daniels, N., Op de Beeck, H., & De Smedt, B. (2018). Dyscalculia and dyslexia: Different behavioral, yet similar brain activity profiles during arithmetic. *NeuroImage: Clinical* 18 (2018), 663–674.

Plassová, M., Stuchlíková, I., & Vavrečka, M. (2017). Úvod do aproximálního numerického systému. *Pedagogika*, 67(2), 161–176.

Plháková, A. (2005). *I-S-T 2000 R: Test struktury inteligence.* Hogrefe – Testcentrum.

Pražáková, K. (2017). *Přesnost a rychlost ve vnímání množství u jedinců s dyskalkulií* (Diplomová práce). Praha: PedF UK.

Pražáková, K., & Špačková, K. (2018). Přesnost a rychlost ve vnímání množství u jedinců s dyskalkulií. *Gramotnost, pregramotnost a vzdělávání*, 2 (2), 69–90.

Pražáková, K., & Kucharská, A. (2019). Riziko dyskalkulie a dalších obtíží v matematice u dětí předškolního věku. *Gramotnost, Pregramotnost A Vzdělávání*, 3(2), 143–165.

Presentación, M. J., Siegenthaler, R., Pinto, V., Mercader, J., & Miranda, A. (2015), Math Skills and Executive Functioning in Preschool: Clinical and Ecological Evaluation. *Revista de Psicodidáctica*, 20(1), 65–82.

Rendl, M., & Páchová, A. (2013). Procesy učení v diskurzu učitelů matematiky na 2. stupni základní školy. *Kritická místa matematiky na základní škole očima učitelů*. Praha: Univerzita Karlova v Praze. 127-182.

Resnick, L. B., & Ford, W. W. (2008). *Psychology of Mathematics for Instruction*. New York: Routledge.

Stieranková, M. (2022). *Vybrané kognitivní předpoklady a metakognice ve vztahu k obtížím v aritmetických dovednostech u žáků mladšího školního věku* (Diplomová práce). Praha: PedF UK.

Stock, P. Desoete, A., & Roeyers, H. (2009). Screening for mathematical disabilities in kindergarten. *Developmental Neurorehabilitation*, 12(6), 389–396.

Szucs, D., Devine, A., Nobes, A., Gabriel, F., & Soltesz, F. (2013). Developmental dyscalculia is related to visuo-spatial memory and inhibition impairment. *Cortex*, 49 (10), 2674-2688.

Traspe, P., & Skalková, I. (2013). *Dismas: Diagnostika struktury matematických schopností*. Praha: Národní ústav pro vzdělávání.

Vágnerová, M. (2005). *Školní poradenská psychologie pro pedagogy*. Praha: Karolinum.

Vágnerová, M., & Klégrová, J. (2008). *Poradenská psychologická diagnostika dětí a dospívajících*. Praha: Karolinum.

Von Aster, M. G., & Shalev, R. S. (2007). Number development and developmental dyscalculia. *Developmental Medicine & Child Neurology*, 49, 868–873.

Von Aster, M. G. (2000). Developmental cognitive neuropsychology of number processing and calculation: gervarieties of developmental dyscalculia. *European Child & Adolescent Psychiatry,* 9, 41–57.

Wang, L.–C., Tasi, H.–J., & Yang, H.–M. (2012). Cognitive inhibition in students with and without dyslexia and dyscalculia. *Research in Developmental Disabilities*, 33(5), 1453–1461.

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T-Conference

Monika Kadrnožková

On November 16, 2023, the first annual T-Conference for high school students took place, where students presented their professional contributions based on research conducted within their student research and professional activities (known as SVOČ). The T-Conference was organized by the Talnet organization, which has long been involved in supporting gifted and talented individuals in the Czech Republic, in collaboration with the Jaroslav Heyrovský Endowment Fund and the Institute of Physical Chemistry of the J. Heyrovský Academy of Sciences of the Czech Republic. The purpose of organizing this conference was to provide high school students with the opportunity to professionally present contributions from various scientific fields (natural sciences, technology, or social sciences). The motivation behind this event is primarily to support the utilization of the potential of the research results obtained from these student works and their presentation to a wider professional audience. The skill of being able to present research intentions and results comprehensibly, yet professionally, needs to be perfected and cannot be improved without real practice, namely presenting one's research to an audience. For these reasons, in addition to presenters, high school students who are just beginning to consider presenting their professional activities were also invited. The professional level of the contributions corresponded to scientific texts that encompassed both theoretical and empirical foundations. Students presented their often very inspiring topics in various scientific areas. The presented topics covered a wide range of scientific disciplines:

- Nearspace experiments on balloon probes, dosimetry, and cosmic radiation
- Calculation of celestial bodies' positions
- A didactic aid for teaching local history lessons in the village of Nové Sedlo
- Expositional experiments as a method of analyzing the limits of algae life
- The influence of canister therapy on fine motor skills and psychological states of seniors
- An experimental study of the La-Ni-Sn system
- The application of a virus and nicotine ligand to the mouse brain
- Electrolytic deposition of metals from solutions

 DOI: 10.14712/25337890.4527

- Self-tinting glass
- Zatlanka Active Citizens and People in Need
- The influence of the duration of hop planting on optimal root biomass formation

Authors had the opportunity not only to present their research findings but also to discuss the benefits of their work with other experts during the discussion period that followed each contribution. Participants also had the opportunity to establish new contacts and meet colleagues who are engaged in similar areas of research. The conference's guest was Daniel Brindžák, who presented the fruit of his professional work in the context of “what professional work gave me and what it took away,” thus creating a stimulating discussion on both the psychological and physical conditions within scientific activity.

Talnet is an organization that has been dedicated to the development and support of gifted and exceptionally talented students (especially high school students) since 2008. Its activities offer a comprehensive range of professional courses, excursions, expeditions, lectures, camps, and other interesting events with a crossover into different scientific fields. In addition to academic development, Talnet is also dedicated to nurturing the emotional and social development of these students and brings together exceptionally gifted talents in the community.

Název: Gramotnost, pregramotnost a vzdělávání
Odborný recenzovaný časopis zaměřený na problematiku čtenářské, matematické, informační a přírodovědecké gramotnosti a pregramotnosti
Číslo 3/2023, ročník VII, webová adresa: http://pages.pedf.cuni.cz/gramotnost/

Jazyková korektura: Simon Gill
Grafická úprava časopisu: MgA. Denisa Kokošková
Evidence periodického tisku: MK ČR E 22524, ISSN 2533-7882 (Print), ISSN 2533-7890 (Online)

Vydává: Univerzita Karlova, Pedagogická fakulta, M. Rettigové 4, Praha 1, 116 39
Adresa redakce: Gramotnost, pregramotnost a vzdělávání, Katedra psychologie PedF UK, Myslíkova 7, Praha 1, 116 39, e-mail redakce: gramotnost@pedf.cuni.cz
Návrh obálky a sazba: MgA. Denisa Kokošková, tiskárna a DTP: Nakladatelství Karolinum
Cena za 1 ks: 80 Kč, roční předplatné 200 Kč + poštovné a balné
Distribuce: ADISERVIS s.r.o., Na nivách 18, 141 00 Praha 4 – Michle, IČO: 28367499, tel.: 241 484 521, mobil: 603 215 568, e-mail: adiservis@seznam.cz

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9 772533 788007