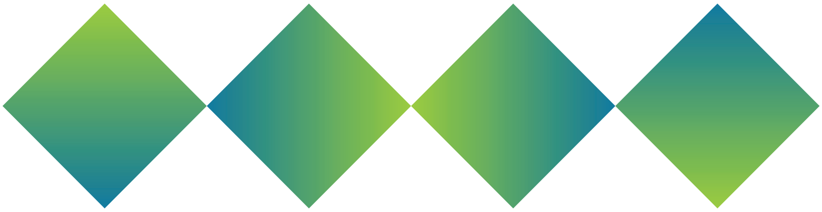
Cognitive training and dynamic testing in the school domains:

A glimpse on primary school children's potential for learning

Mirjam de Vreeze - Westgeest



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Mirjam de Vreeze-Westgeest

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Chapter 1

General introduction

Teachers and educational professionals are vital in facilitating and shaping children's learning experiences (Miller & Bernacki, 2019). Ideally, these learning experiences are carefully shaped to align with learning processes, tailoring instruction to the child's current capabilities while providing the necessary guidance to unfold their potential for learning (Kazemi et al., 2021). Evaluating the outcomes of these learning experiences should, in this case, be closely tied to assessment methods that can provide insight into these learning processes and potential for learning (Kazemi et al., 2021). Traditionally, however, assessment procedures in educational contexts primarily involve static tests, such as norm-referenced school aptitude or intelligence tests. These tests are standardised assessment instruments focused on the product of learning, typically conducted after a teaching period. Static tests require that children independently complete tasks following a brief standardised instruction. They aim to gauge the child's current skill level and identify potential knowledge gaps (Petersen et al., 2016; Resing et al., 2000).

Although static tests have several advantages, for example, they are often straightforward to interpret and administer, they also have some drawbacks. Due to their focus on past learning experiences (Caffrey et al., 2008), these tests might not fully grasp a child's educational needs (Touw et al., 2019), might not provide an accurate representation of children's cognitive development and might potentially underestimate general ability (Caffrey et al., 2008; Gellert & Elbro, 2017; Hill, 2015; Resing et al., 2020). This latter notion seems, in particular, valid for children with learning difficulties (Navarro & Lara, 2017; Swanson & Howard, 2005), language difficulties (Touw et al., 2019), children exhibiting test anxiety (Vogelaar et al., 2017) or children from ethnic minority backgrounds (Caffrey et al., 2008; Verpalen et al., 2018). Therefore, practitioners and researchers alike advocate for alternative testing approaches that are less prone to bias and provide insight into children's educational needs and potential for learning.

This dissertation centred on two alternative testing approaches: Cognitive training in mathematical problem-solving and dynamic testing of reading and writing. The main aims of this dissertation were to examine the utility of these approaches in online and on-site educational or clinical settings in three different groups of children: Potentially gifted students in the domain of mathematics, typically developing children, and those diagnosed with dyslexia in the domain of reading and writing. Children diagnosed with dyslexia are generally disadvantaged when static tests are administered (Dixon et al., 2022). In addition, research has shown that static tests might lead to over-identification of reading and writing difficulties, especially in young children (Dixon et al., 2022). On the other hand, potentially gifted children are regularly overlooked in classrooms, as it is generally expected that they can manage their schoolwork independently. However, research indicates that they can also profit from help and instruction and do not necessarily demonstrate their full capability on a static test (Vogelaar et al., 2017).

In this regard, the current dissertation aimed to investigate the use of cognitive training and (online) dynamic testing to gain insights into the learning processes of three groups of children: Potentially gifted children in mathematical problem-solving and typically developing children and children diagnosed with dyslexia in reading and writing. Specifically, the studies part of this dissertation aimed to analyse whether cognitive training in the domain of mathematical problem-solving could improve working memory and metacognitive abilities and whether a dynamic reading and writing test could improve skills such as Phonemic Awareness, Prosodic Awareness, Writing competence and Context-Dependent Words beyond the effect of static testing. In so doing, this dissertation, in particular, focused on factors known to affect the learning process negatively or known to be potential causes of bias on static test performance and investigated whether cognitive training in mathematical problem-solving and dynamic testing could compensate for intelligence, working memory, inhibition, cognitive flexibility, and lower reading self-concept. Moreover, this dissertation examined the predictive value of a dynamic reading and writing test on responsiveness to clinical dyslexia interventions.

This chapter briefly introduces the underlying theory of cognitive training and dynamic testing: Vygotsky's (1978) social constructivist theory. It then proceeds to explore cognitive training in the context of mathematics and giftedness, as well as dynamic testing in reading, writing and dyslexia. Subsequently, this chapter examines and concludes with an overview of the studies incorporated within this dissertation.

1.1. Unfolding potential for learning: Cognitive training and dynamic testing

Both cognitive training and dynamic testing have been heavily influenced by Vygotsky's social-constructivist theory of the zone of proximal development (Hill, 2015; Vygotsky, 1978). According to Vygotsky, learning occurs within this zone of proximal development. The zone of proximal development represents the gap between the child's ability to solve a task independently (the zone of actual development) and their ability to solve it with a more capable adult (the zone of potential development). Various testing procedures focus on this zone of proximal development by integrating training and feedback into the testing process, often structured in a three-phase format: the test-training-test procedure, also known as the sandwich format (Touw et al., 2019).

Such procedures yield valuable insights into children's cognitive potential for learning and learning processes, including how responsive a child is to instruction, the level of support they require during training, and their ability to retain newly acquired knowledge (Resing et al., 2020). The perspective on what is being learned within the zone of proximal development varies among researchers (Hill, 2015). While some lean towards more domain-general approaches like inductive reasoning, analogy problem-solving or play (Hakkarainen & Bredikyte, 2008; Vogelaar et al., 2017), others emphasise domain-specific approaches, particularly in subjects like reading and mathematics (Cornoldi et al., 2015; Mata & Serrano, 2019). Both approaches, however, can be unified under the same conceptual framework of the zone of proximal development (Hakkarainen & Bredikyte, 2008). As children develop in multiple areas simultaneously, it is necessary to map out the zone of proximal development for domain-general and domain-specific subjects, studies suggest, as distinct variations may exist within a child's zone of proximal development across domains, for example, depending on the developmental stage of a child (Eun, 2018; Suranata et al., 2018). In the current dissertation, two approaches, each aiming to tap into the zone of proximal development from either a domain-general or domain-specific perspective, are investigated: Cognitive training in mathematical problem-solving focusing on metacognitive knowledge and working memory and dynamic testing of reading and writing.

1.2. Cognitive training

First, cognitive training is a distinct training method encompassing multiple sessions to improve diverse intellectual and cognitive abilities through systematic and guided practice, employing a standardised set of tasks (Leung et al., 2017; Martin et al., 2011). Cognitive training can be presented in diverse formats, with variations in duration and the number of training sessions, in selected tasks, task modalities, settings, and the level of guidance offered. In the training phase, tasks that target various aspects of cognitive functioning, like memory, attention, and problem-solving, are employed (Leung et al., 2017; Sala et al., 2019). In cognitive training, improvement of the practised skills is often classified as near transfer, and improvement in other domains, such as academic achievement, as far transfer. Cognitive training can focus on facilitating both near and far transfer (Gobet & Sala, 2023). Although enhancing far transfer is known to be complicated (Melby-Lervåg et al., 2016), studies suggest that, for instance, emphasising executive functions during cognitive training can lead to improvement in problem-solving in complex cognitive tasks, such as mathematical problem-solving (Cornoldi et al., 2015; Desoete & Creane, 2019).

1.2.1. Cognitive training in mathematical problem-solving

This dissertation described a standardised cognitive training in mathematical problem-solving based on the cognitive training procedure initially developed by Cornoldi et al. (2015). This program centred on improving mathematical problem-solving skills by focusing on working memory and metacognition while also considering the potential impact of intelligence on the results of the cognitive training in mathematical problem-solving.

Primary mathematics education goes beyond teaching basic mathematical concepts and skills. It also cultivates reasoning, analytical skills and problem-solving, establishing a solid foundation for future learning (Zhang, 2023). Problem-solving is essential to mathematics, particularly when tackling mathematical word problems. Mathematical problem-solving processes consist of five subprocesses: Understanding the text, problem representation, problem categorisation, planning the solution, and self-evaluation of the process (Lucangeli et al., 1998; Passolunghi & Pazzaglia, 2004). Moreover, solving mathematical problems requires additional cognitive skills such as semantic long-term working memory, metacognition and processing speed (Traff, 2013).

Studies on mathematical problem-solving focused on interventions regarding the subprocesses of problem-solving and executive functions (Cornoldi et al., 2015). They showed that children exhibited different levels of problem-solving, which are also linked to intelligence and executive functioning, resulting in varied educational needs. It is generally believed that potentially gifted children exhibit superior problem-solving abilities (Gorodetsky & Klavir, 2003).

1.2.2. Giftedness

The definition of giftedness has evolved over recent decades, shifting from a one-dimensional focus on intelligence to a multi-dimensional understanding that considers, in addition to intelligence, other skills, such as excellence in arts, leadership, sports or specific academic skills (Crepeau-Hobson & Bianco, 2013; Plucker & Callahan, 2016). One of the first models of understanding giftedness and looking beyond intelligence was the model of Renzulli (2011), in which a three-ring model of giftedness was proposed. The model included three interlocking components: creativity, above-average ability and task commitment. Children with a high level of all three qualities are likelier to demonstrate exceptional achievement and performance than typically developing children. Barab and Plucker (2002) broadened the multidimensional view of giftedness by suggesting that giftedness is cultivated through the interplay of the individual, environment and socio-cultural setting. They view talent development as an ongoing spiral process in which successive interactions reinforce each other over time, increasing opportunities to nurture talent and achieve greater success (Plucker & Callahan, 2016).

As such, giftedness can be understood and identified in diverse ways and with various identification methods and criteria (Plucker & Callahan, 2016). What is essential in this respect, however, is that gifted children demonstrate significant individual differences (Crepeau-Hobson & Bianco, 2013). For example, large differences within groups were discovered in areas such as school grades, cognitive approaches, thinking strategies, intellectual capacity, motivation, executive functioning and metacognitive skills (de Boer et al., 2013; Crepeau-Hobson & Bianco, 2013; Snyder et al., 2011). Gifted children may follow a learning path that facilitates outstanding cognitive capacities and problem-solving, leading to potentially different educational needs in the classroom (Vogelaar et al., 2017; Ziegler et al., 2012).

In education, there is a common assumption that gifted children consistently outperform their non-gifted peers in various areas, such as executive functioning, that they are capable of handling their learning independently, and that they do not need additional help (de Boer et al., 2013; Vogelaar, 2017). However, research indicates this is not always true (Carr et al., 1996; Reis et al., 2014). For example, research into the zone of proximal development of gifted children suggested that similar to typically developing children; there appeared to be inter- and intra-individual variations in their learning rates, transfer abilities, and the degree of instruction needed (Vogelaar & Resing, 2018). Likewise, although it is often believed that these children outperform their peers in various domains, studies indicate that they can also face challenges in, for example, executive functions and mathematics (Crepeau-Hobson & Bianco, 2013; Reis et al., 2014).

In the Dutch educational system, gifted children may undergo part of their education in enrichment classes, often funded by the school. Enrolment in these classes is often based on school performance, with children scoring at least at the 80 percentile in mathematics and comprehensive reading being admitted to these classes. Formal intelligence testing is typically not conducted before enrolling in these classes (De Boer et al., 2013). Therefore, instead of the term gifted, the term potentially gifted is used in this dissertation and refers to children nominated by their teacher and parents as gifted and subsequently enrolled in enrichment classes.

1.3. Dynamic testing

The second alternative testing approach focused upon in the current dissertation concerns dynamic testing, an interactive evaluation method centred around the child's cognitive functions, emphasising learning potential and the learning process rather than the knowledge or skills a child has acquired due to their learning experiences (Hill, 2015). There are many types of dynamic tests, but they all have in common that they incorporate feedback, training or hints within the testing process, designed to facilitate their ability to demonstrate improvement in solving various tasks (Resing et al., 2020). The training phase can vary from more individually tailored mediation, also known as dynamic assessment, to more active scaffolding and standardised procedures, often termed dynamic testing (Resing et al., 2020). The methods for providing assistance can vary and can be divided into two formats: The 'cake format' and the 'sandwich format'. The cake format involves presenting a series of items with immediate assistance when difficulties arise without pre- and posttest structures. In contrast, a pretest is administered in the sandwich format, followed by tailored instruction and a posttest (Elliott, 2003). The latter format is described in this dissertation.

Dynamic tests can be administered through computer-based platforms, making them less time-consuming. This addresses criticism of dynamic testing, namely the time-intensive nature of the dynamic test. As a result, there has been a growing interest in computerised and online assessment methods. These assessments often utilise interactive software and adaptive algorithms to tailor the test experience based on the test takers' responses (Touw et al., 2019; Vogelaar et al., 2021). Studies suggest that computerised tests can improve specific abilities such as writing, reading or mathematics (Ebadi & Rahimi, 2019; Passig et al., 2016; Poehner & Lantolf, 2013; Puhan et al., 2007). However, studies on online dynamic testing of reading and writing are limited. Computers were used in one study in this dissertation as a medium to facilitate online interaction (Ebadi & Rahimi, 2019).

In educational research, the focus on dynamic testing was on domain-general approaches, for example, inductive reasoning (Stad et al., 2017; Vogelaar et al., 2020) or domain-specific approaches, particularly in domains of mathematics or reading and writing (Dixon et al., 2022; Jeltova et al., 2011; Mata & Serrano, 2019). Research into dynamic testing of reading and writing mainly focused on predicting or classifying reading difficulties, phonological awareness, and decoding skills (Dixon et al., 2022; Petersen et al., 2014). For example, studies mainly focusing on phonological awareness showed that dynamic tests could predict future academic success better than conventional static tests alone (Caffrey et al., 2008).

1.3.1. Dynamic testing of reading and writing

This dissertation described the potential effects of a dynamic reading and writing test, initially developed in Spanish by Mata and Serrano (2019), among typically developing children and those diagnosed with dyslexia.

Reading and writing are cognitively demanding psycholinguistic processes that rely on the interaction of various systems, including visual, orthographic and semantic systems (Serrano & Defior, 2008; Serrano et al., 2016 Serrano & Defior, 2008;). Moreover, executive functions such as verbal fluency, working memory, inhibition and affective factors such as reading self-concept may impact reading and writing abilities (Peng et al., 2019). These psycholinguistic processes, executive functions, and affective factors all contribute to acquiring alphabetical knowledge, understanding grapheme-phoneme correspondences, and acquiring orthographic knowledge (Ehri, 1995; Galuschka et al., 2020). Moreover, more fundamental skills like phonological and prosodic awareness play crucial roles in reading acquisition (Melby-Lervåg et al., 2012; Serrano et al., 2016). Phonological awareness involves recognising that sentences consist of words and words consist of syllables and letters, which, in turn, is essential for rhyming abilities (Jing et al., 2019). Phonemic awareness involves manipulating and processing the smallest units of spoken language, phonemes (Nithart et al., 2011). The latter has been the most significant for reading development (Wade-Woolley, 2016). Prosodic awareness, which involves perceiving rhythm or indicating emphasis while listening, reading, writing or speaking (Godde et al., 2020), is also crucial for verbal and written language development and, consequentially, reading acquisition (Serrano et al., 2016), as an emphasis in words gives meaning to words (Wade-Woolley, 2016).

Strong orthographic knowledge is essential for correct writing, as it requires understanding letter configurations within words (Perfetti & Hart, 2002). Foundational to this knowledge is understanding the relationships between phonemes and graphemes. An inadequate understanding of the relationship between phonemes and graphemes leads to difficulties in both writing and phonological awareness (Aravena et al., 2017). Additionally, difficulties in phonological awareness are commonly linked to specific learning disorders, such as dyslexia (Galuschka et al., 2020).

1.3.2. Dyslexia

Dyslexia is a distinct neurodevelopmental learning disorder associated with language, characterised by challenges in recognising words fluently and accurately and difficulties in decoding and spelling (Lyon et al., 2003). These difficulties persist despite proper instruction, appropriate education, targeted interventions, and intact sensory abilities (Lyon et al., 2003; Snowling, 2012). In addition, children diagnosed with dyslexia will most likely not develop reading and writing skills to the level of their typically developing peers (Lyon et al., 2003; Snowling, 2012). The prevalence of dyslexia worldwide is estimated at 7.10 per cent (Yang et al., 2022). However, the assessment, quantification and comprehension of dyslexia may vary among countries. In the Dutch educational system, children experiencing unexpected difficulties in reading and writing are deemed eligible for dyslexia research when they consistently score within the lowest 10 per cent on standard curricular reading tests over three consecutive curricular reading test assessments. Furthermore, they must have received adequate support for two twelve-week periods, with evaluations indicating insufficient progress. An intelligence test is always part of dyslexia research. If dyslexia is diagnosed, children are entitled to treatment in about 40 weekly sessions. Dyslexia research and treatment are reimbursed through the Youth Care systems.

Moreover, a dyslexia diagnosis might negatively impact self-perception, influence self-esteem and lead to low reading self-concept (Gibby-Leversuch et al., 2021; Zuppardo et al., 2020). Reading self-concept is defined as one's self-image as a reader (Katzir et al., 2018). Reading self-concept is primarily formed in early childhood through reading accuracy and speed. Having a positive reading self-concept contributes to feelings of success and motivation to read. Low reading self-concept can lead to decreased motivation, avoidance of reading tasks, and low reading skills (Grills et al., 2018).

Dyslexia might have various causes (Werth, 2018). However, the phonological deficit theory is often used to understand dyslexia, in which reading and writing challenges are linked to difficulties in language skills, especially problems with understanding sounds (Aravena et al., 2017; Peterson & Pennington, 2012; Snowling, 2012). Other possible explanations of dyslexia include weaknesses in auditory information processing (Berninger & Richards, 2020), processing speed (Werth, 2018) and vocabulary (Snowling, 2012). Furthermore, studies have indicated that children diagnosed with dyslexia exhibited variability in their challenges with executive functions, such as working memory, inhibitory control, and cognitive flexibility (Dadgar et al., 2022; Peng et al., 2019).

1.4. Executive functioning

Executive functions refer to cognitive processes and skills necessary for individuals to engage in goal-directed behaviour involving regulating and organising thoughts and behaviour (Titz & Karbach, 2014; Zhang et al., 2019). These processes integrate information from the world around them and facilitate the generation of novel ideas (Diamond, 2013; Ropovik, 2014), rendering them essential for success in academic subjects like reading, writing and mathematics, as well as for achieving goals and learning new skills in everyday life (Diamond, 2013). There is agreement on three fundamental executive functions: Working memory, inhibition and cognitive flexibility (also known as mental flexibility or mental set shifting). These core executive functions serve as building blocks for higher-order executive functions such as problem-solving, planning, reasoning and metacognition (Diamond, 2013).

Working memory refers to the ability to retain information while simultaneously dealing with data that is no longer visible or perceptible (Diamond, 2013; Titz & Karbach, 2014; Träff, 2013). Inhibition, or inhibitory control, can be described as the proficiency to regulate attention, actions and thoughts. It consists of two main components: Response inhibition, which involves suppressing a behavioural response, and cognitive inhibition, which directs attention toward pertinent information (Friso-van den Bos & Van de Weijer-Bergsma, 2019). Cognitive flexibility refers to adapting thinking or behaviour to changing circumstances or tasks. It allows one to adjust strategies, switch tasks, and consider multiple viewpoints. As such, cognitive flexibility improves problem-solving abilities and adaptability in various situations (Diamond, 2013).

Metacognition, a higher-order executive function, can be defined as a child's understanding of cognitive processes, tasks, and themselves as learners (Diamond, 2013). Metacognition encompasses the child's awareness of their information-processing abilities and understanding of the nature of cognitive tasks and strategies for managing one's cognitive processes (Schneider & Artelt, 2010). Metacognitive skills involve self-regulatory strategies such as self-instruction, self-monitoring and self-questioning (Lucangeli et al., 1998). In this light, it is no surprise that metacognition significantly predicts academic performance (Othani & Hisasaka, 2018; Taylor & Zaghi, 2021).

Moreover, metacognition is considered to be highly related to intelligence. Although this relationship seems complex and multifaceted and is not yet fully understood, it is assumed that intelligence and metacognition are related and contribute independently to a child's ability to learn (Veenman et al., 1997). This suggests that while a child's intelligence may influence their learning, their metacognitive skills will also significantly impact their learning.

1.5. Intelligence

Recent intelligence theories, such as the Cattell-Horn-Carroll model (CHC model), have highlighted the multifaceted nature of intelligence (Schneider & McGrew, 2012). In recent models, intelligence has been seen as a conglomeration of various cognitive abilities. The CHC model organises different cognitive abilities into a hierarchical structure and groups these abilities into three levels (McGrew, 2009). The first level represents general intelligence (g), a broad overarching factor encompassing all cognitive abilities. General intelligence encompasses acquiring knowledge, learning from experiences, adapting to surroundings, and comprehending and effectively employing reasoning and thought (Othani & Hisasaka, 2018). This concept involves various abilities such as reasoning, problem-solving, abstract thinking, quick learning and adaptability (Deary & Caryl, 1997), which are integral to the academic performance of primary school children, notably in areas like comprehensive reading, writing and mathematics (Motallebzadeh & Tabatabaee Yazdi, 2016; Peng et al., 2019; Zarić et al., 2020).

General intelligence can be subdivided into broad cognitive intelligence factors at the CHC model's second level. These broad factors include fluid intelligence, crystallised intelligence, visual and auditory processing, processing speed and memory. These broad factors represent a distinct aspect of cognitive functioning and are responsible for specific mental tasks. These broad cognitive factors, in turn, can be subdivided into narrow cognitive abilities, the third level in the CHC model. These narrow cognitive abilities include spatial orientation, algebraic reasoning, rhythm judgments, verbal comprehension, quantitative reasoning, and spatial visualisation (Schneider & McGrew, 2018). Specific subtests on an intelligence test are assumed to measure (aspects of) these narrow cognitive abilities.

In this dissertation, the Intelligence and Development 2 (Grob & Hagmann-von Arx, 2018) screener was used to measure intelligence. The screener consists of two broad factor subtests: One non-verbal fluid intelligence subtest and one verbal crystallised intelligence subtest. Fluid intelligence is the capacity to utilise controlled mental processes for solving novel problems, and it affects how well complex tasks like reading, mathematics, and reasoning are understood. On the other hand, crystallised intelligence refers to the knowledge acquired through education and experience (Taylor & Zaghi, 2021). Crystallised intelligence, measured by vocabulary tests, involves acquiring, retaining and structuring information (Djapo et al., 2011). Both fluid intelligence and crystallised intelligence are highly predictive of success in education (Au et al., 2014; Thorsén et al., 2014).

1.6. Outline of this dissertation

Chapter 1 briefly introduced the theoretical background of potential for learning, cognitive training and dynamic testing, described factors that influence learning and provided an overview of the studies incorporated within this dissertation.

Chapter 2 described cognitive training in mathematical problem-solving, focusing on its potential effects on working memory and metacognition. It explored the possibility of improving working memory and metacognition following the training regimen in potentially gifted children aged between eight and twelve. Furthermore, the chapter investigated the correlation between children's intelligence levels and their working memory and metacognition skills.

The studies described in Chapters 3 and 4 collectively addressed the effectiveness of dynamic testing of reading and writing for typically developing children and children diagnosed with dyslexia, aged between seven and nine (Chapter 3) and aged nine to twelve (Chapter 4) by focusing on children's levels of improvement from pretest to posttest on Phonemic Awareness, Prosodic Awareness, Writing Competence and Context-Dependent Words and comparing those who were with those who were not trained. Specifically, the study described in Chapter 3 investigated the external validity of the dynamic test by focusing on the relationship between dynamic reading and writing tests and more conventional reading and writing tests. Moreover, whether the dynamic reading and writing test could compensate for intelligence was investigated. The study in Chapter 4 additionally concentrated on the potential relationship between dynamic testing of reading and writing and executive functioning, specifically focusing on working memory, inhibition, and cognitive flexibility. In addition, this study focused on the relationship between reading self-concept and dynamic reading and writing test outcomes. Faced with the challenges of the COVID-19 pandemic, this study was conducted online.

The study in Chapter 5 addressed the effectiveness of dynamic testing of reading and writing of children diagnosed with dyslexia, aged between seven and eleven. The study examined children's progress from the pretest to posttest in Phonemic Awareness, Prosodic Awareness, Writing Competence and Context-Dependent Words. It compared the improvement levels of the children who received training with those who did not. In addition, the efficacy of the dynamic reading and writing test in predicting the response to clinical dyslexia interventions was investigated.

Chapter 6 concluded with an overview of the study results and discussed the implications of the main results for education and clinical dyslexia interventions. It also offered insights into potential directions for future research focusing on cognitive training in mathematical problem-solving and dynamic testing.

Chapter 2

Cognitive training in the domain of mathematics for potentially gifted children in primary school

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Bart Vogelaar

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Abstract: This study examined auditive and visual working memory and metacognitive knowledge in 92 gifted children (aged between eight and twelve), utilising a pre-test-training-post-test design known as cognitive training design. This approach was used to examine the working memory and metacognitive knowledge of gifted children concerning progression after a cognitive training program in arithmetical problem-solving, taking into account the role of intelligence. Children were allocated to one of two experimental conditions: children received training after the pre-test (cognitive training condition) or were provided with training after the post-test (control condition). The results show that all children gained improvements in working memory and metacognition. Intelligence significantly predicted verbal and visual working memory. However, we did not find a meaningful relationship between intelligence and metacognitive knowledge. The cognitive training in arithmetical problem-solving seems to bring additional measurable changes in metacognitive knowledge but not in working memory.

2.1. Introduction

In the Dutch educational system, gifted children may receive part of their education in enrichment classes. In the Netherlands, enrollment in these classes is often based on their school performance: Those who score at least at the 80th percentile in comprehensive reading and mathematics are admitted to enrichment classes. Formal intelligence testing is often not conducted in primary education in the Netherlands (De Boer et al., 2013). What it means to be gifted has changed tremendously over the past decades. In general, the definition changed from a unidimensional conceptualisation, incorporating only intelligence, to a multidimensional conceptualisation taking into account other characteristic abilities, such as excelling in arts, sports, leadership or specific academic skills (Crepeau-Hobson & Bianco, 2013). Gifted children are, however, not a homogeneous group; they differ in terms of intellectual capacity, school grades, executive functioning, motivation and metacognitive skills (De Boer et al., 2013; Crepeau-Hobson & Bianco, 2013). Consequently, gifted children also have different educational and instructional needs in the classroom. Often, interventions are administered focusing on enrichment and deepening of the curriculum, acceleration, social-emotional skills and metacognitive skills such as planning and organising (Crepeau-Hobson & Bianco, 2013).

In practice, giftedness is associated with the ability to excel academically in one or more subjects (Koshy & Pinheiro-Torres, 2012). As a result, it is often assumed that these children are autonomous learners and do not need instruction, guidance or training (De Boer et al., 2013). It is often assumed that their cognitive and intellectual capacities should enable them to reach excellence independently (Subotnik et al., 2011). However, recent studies have shown that these children's learning takes place within a zone of proximal development, and, just like the learning processes of typically developing children, they need help to unfold their potential (Vogelaar et al., 2017). Indeed, studies show that gifted children can also struggle with academic domains, specifically arithmetic and math (Crepeau-Hobson & Bianco, 2013; Brody et al., 1997; Reis et al., 2014).

In education, cognitive training is sometimes used to help children develop expertise and unfold their potential. Cognitive training can be defined as providing organised practice of tasks relevant to complex cognitive activity, such as language, executive functioning, attention and memory (Martin et al., 2011). It is as yet, however, not known whether cognitive training programs can be implemented to help potentially gifted children unfold their potential. Therefore, the current study aimed to investigate the potential usefulness of a cognitive training program in the field of arithmetical problem-solving designed specifically for gifted children.

Cognitive training

Cognitive training interventions have received much attention in the literature (Martin et al., 2011). Often, they employ a pre-test-training-post-test design. The training generally consists of several sessions designed to strengthen different cognitive and intellectual abilities. Cognitive training can be offered in various forms, varying in selected tasks and task modalities, settings, the duration of the training sessions, and the amount of guided practice provided (Leung et al., 2017; Martin et al., 2011). In general, research shows that training cognitive functions related explicitly to complex academic competencies can help improve academic abilities such as reading and arithmetic in primary school children (Carretti et al., 2013; Cornoldi et al., 2015). For example, researchers found that reading comprehension and performance can be improved by cognitive training (Cornoldi et al., 2015; Weissheimer et al., 2019; Christopher et al., 2012). In relation to arithmetic, it was found that a Kindergarten program incorporating embedded and explicit training on metacognition can have positive effects on arithmetic performance in young children (Baten et al., 2017). More specifically, in two studies by Cornoldi and colleagues (Schneider & Artelt, 2010; Cornoldi et al., 1995) investigating a cognitive training program focusing on metacognitive awareness and control processes among typically developing children, it was found that increases in metacognition could be related to problem-solving and logical reasoning skills. This study highlights the importance of activating and strengthening metacognitive beliefs in mathematical problem-solving (Baten et al., 2017).

Individual child factors known to influence the effectiveness of cognitive training programs include intellectual ability, metacognitive skillfulness and executive functioning (Titz & Karbach, 2014; Hohn & Frey, 2002; Fuchs et al., 2003). In general, those who have lower initial levels of cognitive ability improve more from training than those with higher initial levels of cognitive ability (Rueda et al., 2021). As for executive functioning, individual differences in baseline performance were found to compensate for training effects (Bürki et al., 2014).

Often, cognitive training programs target several cognitive skills and processes, combining general and specific underlying abilities, such as executive functioning and problem-solving (Weissheimer et al., 2019; Titz & Karbach, 2014; Foster et al., 2017; Swanson & Beebe-Frankenberger, 2004; Jaeggi et al., 2008; Zhang et al., 2018; Schubert et al., 2014).

Executive functioning

Executive functions can be described as essential skills for academic achievement, goal achievement, and everyday life (Diamond, 2013). There are three core executive functions: Inhibition, working memory, and cognitive flexibility, which combine into higher-order executive functions such as updating information, metacognition and problem-solving (Diamond, 2013). Effective use of executive functions, serving and controlling critical complex cognition processes, develops during preschool years. Good executive functioning in early childhood predicts lifelong achievement in various aspects of life (Diamond, 2013). A recent meta-analysis indicated that focusing on executive functioning in cognitive training can lead to improvements in executive functioning of preschoolers, especially for atypically developing children or those who come from families with lower socio-economic status (SES) (Diamond, 2013). However, in a second meta-analysis, it was found that improvements in executive functioning were found in preschoolers, but cognitive training did not transfer to learning behaviour (Scionti et al., 2020). These authors suggest that in preschoolers, training might be more effective for developmentally-at-risk children.

Research suggests that focusing on executive functioning in cognitive training in school children has led to transfer to and progression in complex cognitive tasks such as reading comprehension (Weissheimer et al., 2019; Diamond, 2013) and mathematical performance (Lucangeli et al., 1998; Desoete & De Craene, 2019).

Cognitive training programs often target working memory. Working memory can be defined as the capacity to store information in the mind while processing data which is no longer perceptually present (Titz & Karbach, 2014; Diamond, 2013; Träff, 2013). As such, it is essential in supporting learning (Passolunghi & Pazzaglia, 2004; Holmes et al., 2009) and is linked to various activities, ranging from reasoning tasks to verbal comprehension (Alloway & Alloway, 2010). In addition, it is crucial to high-level cognition tasks such as mathematics (Titz & Karbach, 2014; Passolunghi & Pazzaglia, 2004). Theories regarding working memory indicate that there are different modalities, including visual-spatial and auditory modalities (Diamond, 20130). Working memory can be trained, with improvements found within and across modalities. In a recent study by Nelwan, it was found that training auditory working memory led to gains in visual working memory (Nelwan et al., 2018).

A second executive function often targeted in cognitive training is metacognition. Metacognition consists of skills and knowledge. Metacognitive knowledge can be defined as one's knowledge about cognitive processes and tasks and knowledge about one's self as a learner. They depend on knowledge about cognitive procedures and the control and regulation over one's learning (Schneider & Artelt, 2010; Van der Stel & Veenman, 2013). Metacognitive skills concern self-regulatory strategies (self-instructing, self-questioning, and self-monitoring) (Lucangeli et al., 1998), which help structure the process of problem-solving (Desoete & Craene, 2019). Research has shown that metacognition is teachable; children need to explicitly learn about metacognitive skills because they do not develop spontaneously from implicit exposure (Schneider & Artelt, 2010). Assessment and training of metacognition within the framework of improving mathematical performance appear to be promising; both metacognitive knowledge and skills are seen as separated but interactive predictors of mathematics achievement (Desoete & De Craene, 1998).

Cognitive training in arithmetical problem-solving

In addition to focusing on executive functions, cognitive training programs aim to improve problem-solving (Fuchs et al., 2003; Cornoldi et al., 2015). Problem-solving refers to behaviour in which potential strategies for the solution of a problem are determined, and the most appropriate strategy is chosen and evaluated in relation to its usefulness in solving the problem (Yu et al., 2014). Solving problems is complex, consisting of several underlying problem-solving strategies (Yu et al., 2014). These processes can be divided into two cooperating subprocesses: "understanding" and "searching" (Lucangeli et al., 1998). "Understanding" refers to understanding a problem at hand or making an internal visualisation of a problem. "Searching" refers to searching for a solution to a problem. Problem-solving processes often alternate or occur together (Lucangeli et al., 1998). Understanding the process's meaning and function is essential to successfully solve real-life problems (Yu et al., 2014).

The ability to solve problems is essential in daily life (Yu et al., 2014). It is also related to performance in various academic domains. More specifically, it is a crucial component of mathematics (Cornoldi et al., 2015; Träff, 2013; Passolunghi & Pazzaglia, 2004), for example, concerning solving mathematical word problems (Passolunghi & Pazzaglia, 2004; Lai et al., 2015). Therefore, several studies have focused on the effect of cognitive training interventions in the domain of mathematical word problems (Cornoldi et al., 2015; Hohn & Frey, 2002). Such studies revealed that arithmetical problem-solving consists of the following five subprocesses: text comprehension, problem representation, problem categorisation, planning the solution and procedural self-evaluation (Lucangeli et al., 2020; Passolunghi & Pazzaglia, 2004).

In a recent study, Cornoldi and colleagues studied whether promoting working memory and metacognition in a cognitive group training program could positively affect mathematical problem-solving (Cornoldi et al., 2015). The authors found that their training led to growth in metacognitive and working memory tasks as well as gains in arithmetical problem-solving. Furthermore, concerning the effectiveness of training, it was found that those with initial lower performance levels and poor problem-solving skills benefitted most from the training. These findings indicate that in addition to repeated mathematical practice, mathematical training programs should rely on training cognitive abilities. In other recent studies, it was found that beneficial effects of cognitive training programs for mathematics performance were found using brain games (Wexler et al., 2016), as well as in programs focusing on real-life mathematics (Sobkow et al., 2019).

Aims of the current study

The majority of studies into cognitive training in the domain of mathematics focused on typically developing children or children at risk of learning problems or disorders. No study as yet has been conducted focusing on cognitive training for gifted children, which seems surprising as, just like other children, gifted children can also struggle with arithmetic and mathematics (Crepeau-Hobson, 2013; Brody & Mills, 1997; Reis et al., 2014), and can benefit from training programs in the domain of mathematics (Snyder et al., 2011). Moreover, although in practice, it is sometimes assumed that gifted children excel in executive functioning (Brody & Mills, 1997), research indicates that this is not necessarily the case. Just like typically developing children, gifted children show individual differences in their mastery of executive functions (Vogelaar et al., 2017; Brody & Mills, 1997; Reis et al., 2014; Carr et al., 1996; Rodriguez-Naveiras et al., 2019; Kontostavlou & Drigas, 2022). Recent studies, more importantly, suggest that training the executive functions of gifted learners not only leads to improvements in their executive functions themselves, but also benefits their academic performance (Berg & McDonald, 2018).

Therefore, the current study aimed to investigate whether a cognitive training program in the domain of arithmetical problem-solving incorporating executive functions could be used effectively to improve the executive functions of potentially gifted children. To measure the effectiveness of the cognitive training, children were divided into a cognitive training and a control group. The cognitive program utilised was based on the program developed by Cornoldi and colleagues (Cornoldi et al., 2015) and adapted to fit potentially gifted children's needs.

The first research question addressed children's potential improvement in working memory and metacognition from pre-test to post-test. Based on previous research (Cornoldi et al., 2015; Hohn & Frey, 2002; Desoete & De Craene, 2019; Holmes & Gathercole, 2009), we hypothesised that children who received training would improve more in auditory working memory and arithmetical metacognition from pre-test to post-test than those in the control condition. Considering that the cognitive training program incorporated auditory but not visual working memory, it was explored whether training in auditory working memory would be transferred to the domain of visual working memory. As such, it was expected that trained children would show more improvement from pre-test to post-test on visual working memory than children in the control condition, demonstrating a transfer from trained auditory working memory to non-trained visual working memory (Nelwan et al., 2018). As for metacognition, we investigated whether promoting metacognition would positively affect arithmetical metacognition (Cornoldi et al., 2015). More specifically, was expected that trained children would improve more in arithmetical metacognition from pre-test to post-test than their peers in the control condition (Hohn & Frey, 2002).

The second research question concerned the potential relationship between children's intelligence, on the one hand, and working memory and metacognition performance on pre-test and post-test, on the other hand. Based on previous research (Bürki et al., 2014; Foster et al., 2017), we hypothesised that initial cognitive-intellectual abilities would predict pre-test working memory and metacognition performance. Furthermore, it was hypothesised that at the post-test, intelligence could predict results on working memory and metacognition tasks for untrained children but not for trained children, indicating a learning effect during training.

2.2. Method

Participants

In the current study, 133 gifted children between eight and twelve participated. They were selected based on their enrolment in enrichment classes. Unfortunately, 41 children were excluded from the data analysis due to missing data due to the COVID-19 school closure. Of the three excluded participants, we did not collect any data. The other excluded participants (*N* = 38) did not differ from the remaining participants in either age (*p* = .724) or IQ scores (*p* = .493).

The final sample consisted of 92 participants, of whom 56 were boys and 36 were girls (M_{age} = 10.67, SD_{age} = 0.63). Per class, the participants were randomly allocated to either the cognitive training or the control condition. The children in the two conditions did not differ in age (p = .639), IQ scores (p = .691), initial digit span performance (p = .357), initial picture span performance (p = .124), or initial metacognition performance (p = .384).

Design and procedure

The study had a test-training-test design, also known as a cognitive training design, with two conditions: an experimental condition and a waitlist condition. Children in the experimental condition received the training after the pre-test, and children in the waitlist condition received the training after the post-test. Schools were randomly divided over the two conditions.

In the first session, the pre-test was administered, consisting of the Intelligence and Development Screener (Intelligentie en ontwikkelingsschalen, 2018), Digit Span, Picture Span from the Wechsler Intelligence Scale-V-NL (Hendriks & Ruiter, 2018), and a metacognitive questionnaire (Cornoldi et al., 1995). Then, those in the training condition received the group training at their school consisting of eight sessions administered twice a week. After the cognitive training program was finished, all children were administered the post-test, consisting of the same digit and picture span tests and the metacognitive questionnaire used in the pre-test. Finally, the children in the waitlist condition were administered the cognitive training program.

Instruments

Intelligence and Development 2 (IDS-2) IQ Screener. The IDS-2 intelligence screener was used to measure intelligence (Intelligentie en ontwikkelingsschalen, 2018). The Intelligence and Development screener provides an indication of intellectual ability and consists of two subtests: Matrix Reasoning and Category Naming. Matrix Reasoning is a non-verbal test of fluid intelligence. It consists of 35 multiple-choice items referring to children's inductive reasoning and problem-solving skills. Children were asked to choose one out of five possible solutions that fit best in an analogy of type A:B:C:?. Matrix Reasoning has a test-retest reliability of r = .86. (Grob & Hagmann-von Arx, 2018). Category naming is a verbal test of crystallised intelligence. It consists of 34 multiple-choice items (first pictures, later words) referring to children's verbal reasoning and prior knowledge of categories. The tester shows the pictures (and later says the name) of three different entities that can be categorised together. The child should name the category in which the three entities fit. Category naming has a test-retest reliability of *r* =. 93 ((Intelligentie en ontwikkelingsschalen, 2018).

Digit Span Wechsler Intelligence Scale for Children-V-NL. Digit Span was used to measure working memory. It provides an indication of auditory working memory and consists of three subtests: Digit Span Forward, Digit Span Backward, and Digit Span Sequencing. Each subtest consists of 9 items with an increasing difficulty level. The tester tells the children a sequence of numbers. The child was asked to repeat this verbally given sequence, forward, backwards or was asked to repeat in an increasing sequence. The Digit Span task has a test-retest reliability of *r*=. 79 (Hendriks & Ruiter, 2018). In the current sample, a test-retest reliability of $r = .63$ ($p < .001$) was found for the children in the cognitive training condition and of $r = .77$ ($p < .001$) for those in the control condition.

Picture Span Wechsler Intelligence Scale for Children-V-NL. The Picture Span was used to measure working memory. It provides an indication of visual working memory. It consists of one subtest containing 26 items with an increasing difficulty level. The tester shows a page with pictures of objects in a particular order. After five seconds, a new page is presented with the same and some new pictures. The child should point out the earlier presented pictures in the same order. The Picture Span task has a test-retest reliability of $r = .60$ (Hendriks & Ruiter, 2018). In the current sample, a test-retest reliability of $r = .56$ ($p < .001$) was found for the children in the cognitive training condition and of $r = .53$ ($p < .001$) for those in the control condition.

Metacognition questionnaire. Arithmetical metacognition was measured using a Dutch version of the metacognition questionnaire designed by Cornoldi and colleagues (Cornoldi et al., 1995). The questionnaire consists of 17 items, 13 items asses arithmetical metacognition, and 4 are filler items. All items are statements that can be answered with true or false. An example of a statement is "someone good in arithmetic is very smart". An incorrect answer was scored with a one, and a correct answer was scored a two. Since the filler items were not scored, it was possible to obtain a score between 13 and 26. The questionnaire has a test-retest reliability of $r= .69$ (Cornoldi et al., 1995). In the current sample, a test-retest reliability of $r = .009$ ($p = .95$) was found for the children in the cognitive training condition and of $r = .46$ ($p = .003$) for those in the control condition.

Cognitive training program. The training program consisted of eight sessions, administered twice a week, conducted by master students and under the supervision of the second author.

Every session followed a strict schedule containing five elements: introduction (5 min), arithmetic-related metacognitive activities (20 min), working memory activities (various versions of the listening-span task, 10 min) (Cornoldi et al., 2015), problem-solving in arithmetic tasks with the use of a problem-solving heuristic (20 min), and a summary of the session (5 min). Each session covered a different topic of arithmetical metacognition and a new step in the problem-solving heuristic strategy. The arithmetical metacognition topics and the steps in the problem-solving heuristic strategy were based on the model used by Cornoldi and colleagues (Cornoldi et al., 2015).

In addition, over the sessions, the number of sentences to be remembered on the listening span task increased to fit the difficulty level to the target groups' expected larger baseline capacity and learning potential. At the beginning of the training, all children received a workbook with the problem-solving heuristic strategy and assignments covering the main elements of each session. The arithmetic tasks consisted of five open-ended arithmetic word problems per week. Although the sessions were held in groups, the children had to work independently. When solving the arithmetic problems, children had to apply the steps of the problem-solving heuristic strategy that were covered so far in the sessions. The listening task consisted of three-word sentences that could be true or false. During the first session, only the last word of the sentence should be remembered and written down by the child. In the other sessions, the child needed to write down the last word and determine whether the sentence was true or false. See Table 1 for an overview of the cognitive training program and table A1 in the Appendix for an example of a specific training session. We adapted the program of Cornoldi and colleagues (Cornoldi et al., 2015) to be more suitable for potentially gifted children by making the tasks more challenging, based on input from teachers and educational advisers involved in teaching gifted children in the Netherlands. In a pilot study, prior to the current study taking place, these materials were tested and evaluated for their suitability.

Table 1

Overview of the Cognitive Training Program, Based on Cornoldi et al. (Cornoldi et al., 2015).

	Metacognitive beliefs	Working memory	Problem-solving components
Session 1	Discussion of the importance of attention for problem-solving	Listening span task without a secondary task	Understanding the wording of the problem: focus on relevant information
Session 2	Discussion of the role of self-efficacy in problem-solving	Listening span task with a secondary task (2-6 sentences)	Understanding the wording of the problem: focus on irrelevant information
Session 3	Discussion of the importance of working memory in problem-solving	See session 2	A mental representation of the problem: building up a visual representation of the problem to insert and connect new information
Session 4	Distinguishing between different math problems; identifying the	Listening span task with a secondary task (3-7 sentences)	Classify different math problems by their structure

	characteristics of a math problem		
Session 5	Discussion of that problems can be solved using different procedures	See session 4	Identifying the phases that lead to the solution
Session 6	Using mistakes to improve problem-solving performance	Listening span task with a secondary task (3-8 sentences)	Producing plans for solving a given problem
Session 7	The importance of intrinsic motivation	See session 6	Solving problems: the importance of choosing the proper operations and performing them in the right order
Session 8	The importance of factors that negatively affect school attainment, particularly in mathematics (e.g., anxiety)	See session 6	The importance of monitoring problem-solving activities

2.3. Results

Training effectiveness: Progression from pre-test to post-test

To examine the effectiveness of the cognitive training, we conducted a Repeated Measures MANOVA on the raw scores for digit span, picture span, and metacognition, with Condition (cognitive training/control) as the between-subjects factor and Test session (pre-test/post-test) as the within-subjects factor. The multivariate and univariate effects of the Repeated Measures ANOVA are reported in Table 2.

The multivariate effects indicated a significant effect of time for the variables investigated (Wilk's λ = .57, $F(1,88) = 21.73$, $p < .001$, $\eta_p^2 = .43$). The interaction effect between time and condition was bordering on significance (Wilk's λ = .93, $F(1,88) = 2.23$, $p < .090$, $\eta_p^2 = .07$)

Table 2

Multivariate and univariate Effects of the RM MANOVA for the scores of Digit Span, Picture Span, and Metacognition

	Wilk's λ	*F*	*p*	η_p^2
Multivariate effects				
Measurement	.57	21.73	<.001	.43
Measurement x Condition	.93	2.23	.090	.07
Univariate effects				
Digit Span				
Measurement		31.26	<.001	.26
Measurement x Condition		1.34	.251	.02
Picture Span				
Measurement		28.50	<.001	.25
Measurement x Condition		.38	.539	.004
Metacognition				
Measurement		7.51	.007	.08
Measurement x Condition		5.59	.020	.06

The univariate results indicated that with regard to working memory, scores were found to improve significantly from pre-test to post-test for both digit span (*F*(1,88) = 31.26, *p* <.001) and picture span (*F*(1,88) = 28.50, *p* <.001). The cognitive training did not affect this progression for either digit span (*F*(1,88) = 1.34, *p* = .251) or picture span (*F*(1,88) = 0.38, *p* = .539).

For metacognition, scores were found to improve significantly from pre-test to post-test (*F*(1,88) = 7.51, *p* = .007). Additionally, for the children administered the cognitive training, progression from pre-test to post-test was significantly larger than those in the control group (*F*(1,88) = 5.59, *p* = .020). Descriptive statistics of these measures per condition are displayed in Table 3 and Figure 1, respectively.

Table 3

Descriptive statistics for the scores of Digit Span, Picture Span, and Metacognition per condition and measurement.

		Cognitive Training		Control Group	
		Pre-test	Post-test	Pre-test	Post-test
Digit Span	*M*	28.00	30.32	27.05	28.58
	(SD)	(0.53)	(0.55)	(0.60)	(0.61)
Picture Span	*M*	34.18	36.40	33.28	36.08
	(SD)	(0.74)	(0.58)	(0.82)	(0.65)
Metacognition	*M*	22.64	23.32	22.73	22.78
	(SD)	(0.16)	(0.14)	(0.18)	(0.15)

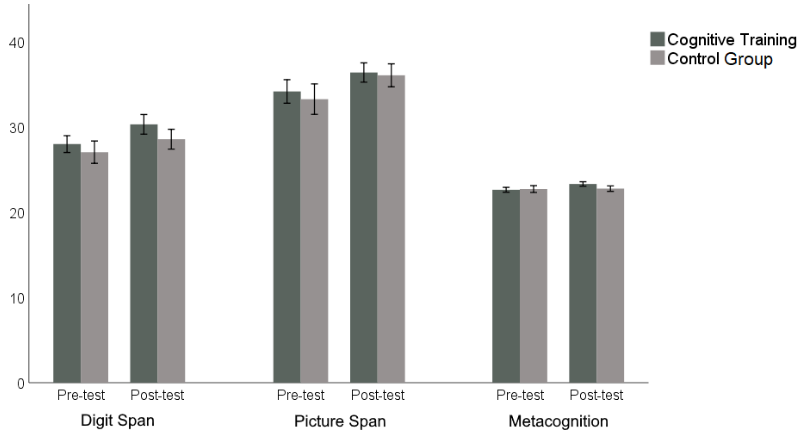

Figure 1

Progression in scores on pre-test and post-test per condition.

Role of IQ score in working memory and metacognition performance

The role of IQ in predicting working memory and metacognition performance was analysed through three separate linear regression analyses for the pre-test and three linear regression analyses for the post-test, including condition, cognitive training or control group as a predictor for the post-test scores.

The regression model with IQ score as a predictor for digit span pre-test scores was found to be significant, *F*(1,90) = 4.37, $p = .039$, $R^2 = .046$. IQ significantly predicted digit span pre-test scores ($b = 0.07$, $p = .039$). The regression model for the post-test scores, which also included condition as a predictor, was found to be significant, *F*(2,89) = 4.59, $p = .013$, $R^2 = .093$. IQ was found to be a significant positive predictor for digit span post-test scores ($b = 0.07$, $p = .029$), but condition was not.

The regression model with IQ score as a predictor for picture span pre-test scores was also found to be significant, *F*(1,90) = 11.07, $p = .001$, $R^2 = .109$. IQ was found to be a significant positive predictor for picture span pre-test scores ($b = 0.13$, $p = .001$).

The regression model for the post-test scores, which also included condition as a predictor, was found to be significant, *F*(2,89) = 8.34, $p < .001$, $R^2 = .158$. IQ was found to be a significant positive predictor for picture span post-test scores ($b = 0.14$, $p < .001$), but condition was not. The regression model with IQ score as a predictor for metacognition pre-test scores was not found to be significant, *F*(1,88) = 3.69, $p = .058$, $R^2 = .040$. IQ did not significantly predict metacognition pre-test scores. The regression model for the post-test scores, which also included condition as a predictor, was found to be significant, *F*(2,89) = 3.39, $p = .038$, $R^2 = .071$. IQ was not found to be a significant predictor for metacognition post-test scores, but condition was ($b = 0.54$, $p = .011$). See Table 4 for an overview of the regression models analysed.

Table 4

Regression models analyses.

	Pre-test						Post-test					
	Digit Span		Picture Span		Metacognition		Digit Span		Picture Span		Metacognition	
Variable	B *(SE)*	*β*	B*(SE)*	*β*	B *(SE)*	*β*	B *(SE)*	*β*	B *(SE)*	*β*	B *(SE)*	*β*
Constant	20.47 (3.34)		19.55 (4.28)		24.60 (1.01)		21.40 (3.28)		21.80 (3.56)		23.22 (0.86)	
IDS score	0.07 (0.03)	0.22*	0.13 (0.04)	0.33**	-0.02	-0.20	0.07 (0.03)	0.23*	0.14 (0.03)	0.40***	-0.004 (0.01)	-0.05
Condition							1.49 (0.80)	0.19	-0.31 (0.86)	-0.04	0.54 (0.21)	-0.27*
R^2	0.046		.109		0.040		0.093		.158		0.071	
F	4.37*		11.07**		3.69		4.59*		8.34***		3.39*	

Note: p <. 050*, *p* <.010**, *p* <.001***

2.4. Discussion

The current study sought to investigate the usefulness of a cognitive training program focusing on executive functions in the domain of arithmetical problem-solving. Building on Cornoldi et al. (2015), we took a different approach by adapting the training to fit potentially gifted children's needs. The study's main aim was to examine whether executive functions could be trained in a cognitive training program designed for potentially gifted children.

Firstly, results revealed that all groups of children showed significant improvements in auditory and visual working memory and metacognition from pre-test to post-test. However, concerning metacognition specifically, it was found that those in the cognitive training condition demonstrated more improvement than their peers in the control group. Discussing and guided instruction on various aspects of metacognitive knowledge seems effective in children with high abilities. It strengthens the belief that metacognition in gifted children does not develop automatically (Sihotang & Hutagalung, 2020), and training in metacognition can significantly contribute to this development.

In contrast to our expectations and Cornoldi et al.'s (2015) findings, it appears that training did not bring about any significant measurable changes in working memory (Oppong et al., 2018). A possible explanation for this finding is that the working memory tasks utilised in training differed too much from the pre-and post-test working memory measures.

Perhaps the working memory tasks utilised in training were too easy for the high-performing participants (Oppong et al., 2018). Therefore, further research should look into the difficulty and duration of the working memory tasks in cognitive training.

Secondly, this study investigated the relationship between intelligence and executive functioning. The results showed that intelligence significantly predicts verbal and non-verbal working memory, with higher intelligence levels predicting stronger working memory. This finding seems in line with previous meta-analytic research, which demonstrated that talented and gifted children excel in both visual and verbal working memory (Kornmann et al., 2015; Alloway & Elsworth, 2012).

However, we did not find a significant relationship between intelligence and metacognitive knowledge. The findings suggest that higher intelligence thus does not necessarily indicate better metacognitive knowledge. This outcome is supported by previous research, in which it was posited that a difference in metacognitive skills between average-ability and gifted children is less evident (Wexler et al., 2016). Individual differences in metacognition have been found in average-ability and gifted children (Kornmann et al., 2015; Veenman et al., 2005). The current study suggests that intelligence and metacognitive knowledge could be seen as independent concepts. The finding that intelligence predicts working memory skills but does predict metacognition underlines that metacognition and intelligence are not necessarily linearly related, as is sometimes assumed by teachers, and makes us mindful of the fact that all children, regardless of their cognitive abilities, can have deficits in their metacognition. Of course, it should be kept in mind that the children who participated in the current study were all potentially gifted and had relatively high IQ scores.

The following limitations of de study should be kept in mind when interpreting the results. Due to COVID-19, our sample size became smaller. Future research should aim to use a larger sample, as this will potentially improve statistical power. Furthermore, the results of the training should be compared to actual curricular mathematic achievements to measure far-transfer

Conclusions

In conclusion, it was found in the current study that potentially gifted children can benefit from cognitive training programs, specifically with regard to their metacognition. Although in practice, some teachers and other educational professionals assume that these children might excel in executive functions and, therefore, may not need additional help (Crepeau-Hobson & Bianco, 2013), the findings of the current study underline that gifted children also can benefit from particular interventions and explicit instruction. Moreover, teachers and practitioners in education should be aware that not every gifted child demonstrating above-average academic performance is already able to use metacognitive knowledge in the right way independently.

Appendix A

Table A1

Example of a specific training session (session 4).

Arithmetical metacognition	Distinguishing between different arithmetic problems; identifying the characteristics of an arithmetical problem	The trainer starts with a general explanation of categories and how problems can be categorised. Then, children discuss how arithmetic problems can be categorised. Children fill in a diagram with possible arithmetic categories and their characteristics. At last, children are guided on reflecting on how this diagram can help them with arithmetical problem-solving
Working memory	Listening span task with a secondary task (3-7 sentences)	Children listen to a series of short sentences. For each sentence, they have to recall the last word, write it down in the same order, and write down whether the sentences are true or false. The difficulty of the task increases from 3 to 7 words to recall.
Arithmetical problem-solving component		The trainer starts by explaining the fourth step in the problem-solving heuristic. Then, children are presented

	Categorising different arithmetic problems by their structure	with five arithmetic problems that they need to solve individually according to the first four steps of the problem-solving heuristic.

Chapter 3

Dynamic and conventional testing of reading and writing in typically developing children and children diagnosed with dyslexia.

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Abstract: This study aimed to evaluate the effectiveness of a dynamic reading and writing test in typically developing children and children diagnosed with dyslexia. In addition, this study analysed the patterns of relations between the dynamic reading and writing test and conventional tests of reading, writing and intelligence. A pretest-training-posttest design was employed with a control condition (*n* = 37) receiving training after the posttest and an experimental condition (*n* = 43) receiving training after the pretest. During training, children engaged in dynamic reading and writing tasks under the guidance of an adult. The training process involved visual materials and verbal explanations to enhance learning and comprehension. Generally, both typically developing children and children diagnosed with dyslexia showed equal levels of improvement from pretest to posttest. Specifically, the experimental group demonstrated a training effect in the Prosodic Awareness subtest. Moreover, the dynamic reading and writing measures were associated with the conventional reading and spelling measures and intelligence. Implications for education and clinical dyslexia interventions are discussed.

3.1. Introduction

In many countries, scholastic performance is assessed by means of static assessment tools. These tests often have a single-administration format and require that children solve tasks independently after a short standardised instruction. Although these tests have many advantages, such as straightforward administration and easily interpretable results, they often provide insight into what knowledge and skills a child has acquired through past learning experiences, which is not necessarily predictive of future learning experiences (Resing et al., 2020). Moreover, it has been debated that using a single-session static test might lead to misclassification of children when reading and writing problems are suspected, for example, due to false positive or ceiling effects (Bridges & Catts, 2011). Dynamic testing provides an alternative approach by measuring children's potential for learning (Dixon et al., 2022).

As part of dynamic testing, instruction or training is integrated into the assessment or testing procedure, which enables the measurement of a child's improvement on a task (Resing et al., 2020) and gives insights into a child's specific educational needs (Cho et al., 2012). Although there seems to be a growing interest in dynamic testing as an alternative to conventional assessment tools (Navarro & Lara, 2017; Resing & Elliott, 2010), applying dynamic testing principles to educational domains remains scarce (Navarro & Lara, 2017; Resing et al., 2020). Therefore, the current study aimed to gain insight into the use of a new dynamic reading and writing test in the Netherlands amongst typically developing children and those diagnosed with dyslexia.

Dynamic testing of reading and writing

Dynamic testing is an umbrella concept (Elliott & Resing, 2015; Resing et al., 2020) and contains various testing and assessment techniques, which find their origin in Vygotsky's theory of the zone of proximal development (ZPD; Navarro & Lara, 2017; Resing et al., 2020). The ZPD can be defined as the difference between the child's ability to solve a task independently and the ability to solve a task with the help of a more competent person (Vygotsky, 1980). By tapping into the ZPD, dynamic tests gain an insight into the learning process (Navarro & Lara, 2017; Vogelaar et al., 2017) and an indication of a child's potential for learning (Gellert & Elbro, 2017; Resing et al., 2020). A dynamic test often provides sample information about a child's learning process. Such information includes indications of the child's responsiveness to new information, training or instruction (Dixon et al., 2022), the type and amount of help needed during training, and how the child maintains this newly learned information (Resing et al., 2020).

Many dynamic tests utilise tasks from cognitive-intellectual domains (Mata et al., 2017; Navarro & Mora, 2011), such as inductive reasoning tasks (Resing et al., 2019; Tzuriel, 2011; Veerbeek et al., 2019). Despite growing interest in dynamic tests that focus more on academic domains such as reading and writing, research on dynamic tests in reading and writing after formal reading instruction in school has started is still scarce (Dixon et al., 2022). The existing studies focus on pre-reading or literacy skills and use dynamic screening instruments with little children as potential predictors of future reading and writing achievement (Cho et al., 2019; Gellert & Elbro, 2017). For example, Gellert and Elbro's (2017) longitudinal study into a dynamic test of children's decoding demonstrated that the results obtained during Kindergarten could significantly predict difficulties in reading words at the end of first grade. Moreover, Fuchs et al. (2011) found that dynamic testing results were more predictive in accurately identifying children at risk of reading difficulties than static measures. Support for using dynamic reading and writing testing can be found in a Dutch study by Aravena et al. (2017). In this study, the authors utilised a dynamic test in typically developing children and children with dyslexia aged between seven and 11. Past the early literacy stage, the children had to learn and apply artificial script-based letter-speech sound correspondences. The authors found moderate differences in the posttest results of the typically developing children and their age-related peers diagnosed with dyslexia. They concluded that dynamic tests have the potential to differentiate between children with dyslexia and typically developing children in learning letter-speech sound correspondences. More importantly, the new letter-speech sound correspondences learned were related to the static rapid automatised naming and phonological awareness tests and predicted variance in writing and reading abilities (Aravena et al., 2017).

Reading and writing

Reading is a complex psycholinguistic skill requiring interaction between several systems: visual, phonological, semantic and orthographic (Serrano et al., 2016). In addition, several cognitive and non-cognitive skills and processes are involved in reading fluently, including perception, attention, motivation and working memory (Peng et al., 2019). Furthermore, reading requires elementary skills like phonological and prosodic awareness (Melby-Lervåg et al., 2012; Serrano et al., 2016).

Phonological awareness can be defined as recognising and manipulating word sounds (phonemes). Teaching children to read implies learning the complex skill of discriminating between phonemes (Serrano, 2015). Research suggests that dynamic phonemic awareness interventions in young children contribute to increasing phonological skills (Bridges & Catts, 2011).

Prosodic awareness (rhythm perception) can be defined as the capability to hear an accent or indicate, manipulate, and recognise the emphasis in a word (Serrano et al., 2016). It is fundamentally relevant to the development of verbal language and, because of that, written language and learning to read (Serrano et al., 2016). Therefore, training prosodic awareness is connected to improvement in reading and writing (Serrano et al., 2016).

Learning to write is also a demanding task, requiring considerable cognitive effort (Galuschka et al., 2020). For example, keeping a mental graphic representation of the word is essential in writing homophones to spell the word adequately. After all, the child cannot rely on a writing rule to determine the correct writing of a context-dependent word. Moreover, it is necessary to retrieve the writing skills or knowledge of the word (stored in the lexicon) to write the word correctly (Serrano & Defior, 2008). Writing skills complement phonemic and prosodic skills (Galuschka et al., 2020).

Furthermore, excellent orthographic representations are needed for writing because the writer needs precise knowledge of all the letters in a word (Perfetti & Hart, 2002). Therefore, an insight into speech sound-letter correspondences is fundamental, demonstrating the nature of the relationship between writing difficulties and difficulties with phonological awareness (Aravena et al., 2017). Furthermore, poor phonological awareness (Aravena et al., 2017) is often associated with specific learning disabilities such as dyslexia (Galuschka et al., 2020).

Dyslexia

Developmental dyslexia is a specific, neurodevelopmental language-based learning disability characterised by difficulties with fluent and accurate word recognition, poor decoding and writing abilities, despite adequate instruction, appropriate education/targeted interventions and intact sensory abilities (Lyon et al., 2003; Snowling, 2012). Yang et al. (2022) recently estimated the worldwide prevalence of dyslexia in primary school children to be between 6.27 and 7.97 per cent, with a lower prevalence in girls.

Often, the phonological deficit theory is used to explain the occurrence of dyslexia (Aravena et al., 2017; Melby-Lervåg et al., 2012; Peterson & Pennington, 2012; Snowling, 2012). In this theory, reading and writing difficulties are explained by language skill problems, particularly deficits in poor phonological representations (Snowling et al., 2020). These deficits are already observed in young children. Other potential explanations for dyslexia include weaknesses in verbal short-term memory, processing speed, rapid serial naming (Aravena et al., 2017), and insufficient vocabulary knowledge (Peterson & Pennington, 2012; Snowling, 2012). In addition, it is increasingly accepted that dyslexia may have different aetiologies (Werth, 2018).

Although children diagnosed with dyslexia may improve phonological, reading and writing skills when different strategies are learned (Werth, 2018), being unable to read and write fluently remains an obstacle in education, as it affects children's well-being and school results (Dahlin, 2010). Therefore, careful assessment procedures for classifying dyslexia are essential. Dyslexia, unfortunately, cannot be diagnosed before formal literacy instruction starts (Peterson & Pennington, 2012). Furthermore, dyslexia might coincide with other developmental disabilities (Werth, 2018) but is unrelated to intelligence, as it seems to occur across the full intelligence range (Elliott & Resing, 2015; Snowling et al., 2020).

The relationship between intelligence and reading and writing skills

Often, intelligence is measured through static tests. These tests measure cognitive skills and abilities in fluid intelligence, verbal short-term memory, auditory short-term memory, long-term memory, verbal skills and processing speed, considered first-order domain-specific intelligence factors (Schneider & McGrew, 2018). Interestingly, these aspects of intelligence are also related to reading and writing development and, more specifically, the acquisition of literacy skills (Zarić et al., 2020). For example, Peng et al. (2019) highlight that reading skills require fluid intelligence, especially when children learn to read. Furthermore, when reading skills have been developed in older children, fluid intelligence becomes more related to reading comprehension, the ultimate goal of reading instruction (Motallebzadeh & Tabatabaee Yazdi, 2016).

Concerning the relationship between dyslexia and intelligence, the discrepancy theory has been in vogue for a long time. Following this theory, in dyslexia assessment procedures, reading and writing test results were compared to intelligence test results. When a discrepancy was found in favour of intelligence, dyslexia was classified (Stuebing et al., 2002). However, research increasingly showed that there are other plausible explanations for dyslexia in addition to the discrepancy theory, as children diagnosed with dyslexia tend to score lower on some first-order domain-specific factors in intelligence tests like auditory short-term memory (Ruiter et al., 2020), or processing speed (Werth, 2018) and auditory information processing (Berninger & Richards, 2010). Therefore, the usability of static intelligence tests in dyslexia assessments is being questioned, and the classification of dyslexia should be made regardless of intelligence (Werth, 2018), as children diagnosed with dyslexia may not be able to show their full potential in a static intelligence test (Giofrè & Cornoldi, 2015).

Aims of the current study

The current study aimed to investigate the potential effects of training on dynamic reading and writing test in typically developing children and children diagnosed with dyslexia. We aimed to analyse the potential relationships between the dynamic reading and writing test and more conventional reading and spelling tests used in the Netherlands for assessment purposes. Furthermore, we aimed to investigate whether children's accuracy scores on the dynamic test, before and after training, would be related to intelligence.

The first research question concerned the potential effect of training on reading and writing skills and focused on children's progression from the pretest to the posttest. Based on previous research (Aravena et al., 2017; Dixon et al., 2022; Mata & Serrano, 2019; Navarro & Lara, 2017), it was hypothesised that children in the experimental condition who received training between pretest and posttest would show more improvement in correct answers on the Phonemic Awareness, Prosodic Awareness, Writing Competence, and Context-Dependent Words subtests than children in the control condition who did not receive training. In addition, it was hypothesised explicitly that typically developing children would show more improvement than those with dyslexia, irrespective of whether they were trained. Research shows that children diagnosed with dyslexia experience difficulties performing on static and dynamic reading and writing tests (Aravena et al., 2017; Snowling et al., 2020) and have a lack of sensitivity to extra instruction or treatment (Aravena et al., 2017; Mata & Serrano, 2019).

The second research question concerned the relationship between the pretest and posttest scores of the dynamic reading and writing test, Phonemic Awareness, Prosodic Awareness, Writing Competence and Context-Dependent Words on the one hand and conventional (pseudo) word reading, phonological awareness and spelling tests on the other hand. Children's pretest accuracy scores considered static measures, were expected to correlate positively with static Word Reading Fluency, Pseudoword Reading, and Phonological Awareness accuracy scores. In contrast, children's pretest accuracy scores on Writing Competence and Context-Dependent Words were expected to correlate positively with the Spelling pretest accuracy scores (Navarro & Lara, 2017). Moreover, it was hypothesised that this positive relationship between subtests would be found in both typically developing children and children with dyslexia. Regarding children's accuracy scores at the posttest, it was expected that the accuracy scores of those in the control condition, which are also considered static measures, would also correlate with the conventional measures. However, the posttest accuracy scores of those in the experimental condition considered dynamic measures would not (Mata & Serrano, 2019).

The final research question considered the potential relationship between static and dynamic reading and writing scores and intelligence. Intelligence was expected to correlate positively with pretest static accuracy scores (Calero et al., 2011; Mata & Serrano, 2019). Concerning children's posttest accuracy scores on the dynamic reading and writing test, it was hypothesised that intelligence would also correlate to the static accuracy scores of untrained children in the control condition. Furthermore, considering the compensatory nature of dynamic testing, as the potential for learning does not always align with intelligence, no correlations were anticipated for the dynamic posttest measures of the trained children in the experimental condition (Bosma & Resing, 2006). Concerning the potential differences between the typically developing children and those diagnosed with dyslexia, no differences in both conditions were expected as dyslexia occurs across the entire intelligence range (Elliott & Resing, 2015; Snowling et al., 2020).

3.2. Method

Participants

Finally, eighty children between the ages of seven and nine and a half participated in the current study, of whom 41 were girls and 39 were boys (M_{Age} = 8.4 years, *SD* = 0.07). Children were categorised into two groups: typically developing children and children diagnosed with dyslexia. Those diagnosed with dyslexia were formally identified based on the definition used in the Dutch Protocol for Dyslexia Diagnostics and intervention (Tijms et al., 2021) and represented the 10% with the weakest reading or writing abilities. The remaining children were assigned to the typically developing children group.

Prior, eleven children were excluded, as they were not formally diagnosed with dyslexia but demonstrated reading scores falling within the 10% weakest range. Furthermore, seven children were excluded due to dropping out. The typically developing children (*n* = 39) were recruited from regular primary mainstream schools in Zuid-Holland. The children diagnosed with dyslexia (*n* = 41) were recruited from 1801, an educational service in the West of the Netherlands. The total distribution of children diagnosed with dyslexia and typically developing children over the two conditions is displayed in Table 1.

Furthermore, all children with dyslexia received clinical dyslexia intervention at the time of this research. Children were randomly allocated to the experimental or control condition as the result of a blocking procedure based on gender and intelligence. Written parental and school informed consent for participation was obtained prior to the study, and the corresponding author's institutional Committee of Ethics in Psychology (CEP) approved the study.

Design and procedure

This study had an experimental pretest-training-posttest design with two conditions: an experimental and a control condition, as seen in Table 1.

Table 1

Schematic Overview of the Design of the Study

		Session 1: 30 minutes	Session 2: 60-75 minutes			
		Preliminary Assessment[1]	The dynamic test of reading and writing:			
			Pretest	Training	Posttest	Training
Control Condition (*n* = 37)	Children diagnosed with dyslexia (*n* = 20)	X	X	-	X	X
	Typically developing children (*n* = 17)	X	X	-	X	X
Experimental Condition (*n* = 43)	Children diagnosed with dyslexia (*n* = 21)	X	X	X	X	-
	Typically developing children (*n* = 22)	X	X	X	X	-

Note 1. The following instruments were used as a preliminary investigation: IDS-2 Intelligence and Development Scales for Children: Intelligence Screener, Word Reading Fluency: [Brus], Pseudoword Reading [Klepel], Dyslexia Screenings Test: subtest Two-Minutes Writing, and Clinical Evaluation of Language Fundamentals: subtest Phonological Awareness.

Instruments

Intelligence Screener subtest of Intelligence and Development Scales for Children-2 (Grob & Hagmann-von Arx, 2018). The IDS-2 intelligence screener estimates children's intelligence. Administration of this test takes about 15 minutes. The screener consists of two subtests: Category Naming, a verbal test of crystallised intelligence, and Matrix Reasoning, a non-verbal measure of fluid intelligence. The subtest Category Naming consists of 34 multiple-choice items (first pictures, later words) referring to children's verbal reasoning and prior knowledge of categories. The diagnostician showed three categorised entities' pictures (and later said the names). The child is asked to name the type in which the three entities fit. Category naming has a test-retest reliability of *r* =. 93, and the correlation with general intelligence is *r* =. 64 (Grob & Hagmann-von Arx, 2018). The subtest Matrix Reasoning consists of 35 multiple-choice items referring to children's inductive reasoning and problem-solving skills. Children were asked to choose one of five possible solutions that fit best in an analogy of type A:B:C:? Matrix Reasoning has a test-retest reliability of r = .86. The correlation with general intelligence is r = .65 (Grob & Hagmann-von Arx, 2018).

Phonological Awareness Subtest of the Clinical Evaluation of Language Fundamentals CELF-4^{NL} (Kort et al., 2005). The phonological awareness subtest measures the ability to rhyme and manipulate sounds. In approximately 15 minutes, it aims to gain insight into the child's knowledge of the sound structure of Dutch and their ability to deal with speech sounds in various exercises. These exercises concern the representation of sentences, syllables and phonemes, the combination of syllables and phonemes, the indication of syllables in a word and the identification and processing of phonemes. These skills are required for learning to read and write. The phonological awareness test has a test-retest reliability of r = .80 (Kort et al., 2005).

Spelling [Dyslexia Screenings Test DST-NL] (Kort et al., 2005). The Spelling subtest measures the child's writing ability. The child had to write as many dictated Dutch words as possible in two minutes. The words listed by the tester have increasing difficulty, with a maximum of 36 words. The Spelling test has a test-retest reliability of r = .95 (Kort et al., 2005).

Word Reading Fluency *[Brus One-Minute-Test test form A]* (Brus et al., 2019). The Brus One-Minute-Test measures isolated Word Reading Fluency reading skills. The One-Minute-Test is a word recognition test. The child was given a piece of paper with 116 words of increasing difficulty. The words were arranged in four columns of equal length and presented in Universe typeface, font size 18. The child is asked to read as many words as correctly as possible in one minute. The One-Minute test has a test-retest reliability of r =. 96 (Brus et al., 2019).

Pseudoword Reading [Klepel-R$_{1\ min}$ *form A]* (Van den Bos et al., 2019). The Klepel-R$_{1\ \mathrm{min}}$ measures decoding skills. Alphabetical knowledge must be deployed to integrate the voiced letters into a word. The child was given a piece of paper with 116 pseudowords of increasing difficulty. The words were arranged in four columns of equal length and presented in Universe typeface, font size 18. The child was asked to read as many words as possible in one minute. The Klepel-R$_{1\mathrm{min}}$ has a test-retest reliability of r = .91 for seven and eight-year-olds and an r = .97 for nine and ten-year-old children (Van den Bos et al., 2019).

The dynamic reading and writing test (Mata & Serrano, 2019) assesses the potential for learning reading and writing skills and improving skills relevant to developing this expertise. The test was converted and cross-translated from Spanish into Dutch. The four subtests of the dynamic reading and writing test measure phonemic awareness, prosodic awareness, knowledge of writing rules and the spelling of homophonic words, all considered basic essential reading and writing skills (Mata & Serrano, 2019). The test takes 60 to 80 minutes, with 15 to 20 minutes for each subtest. Each subtest consisted of a pretest in which the child solved tasks independently. Next, a standardised and hierarchical training phase is included, commencing with hints at an abstract level and progressing to the task-specific level for hints in each subtest. Each child received all available hints. The training phase reflected performance, retelling the task, and various exercises with visually supported materials. See Table 2 for more information on the training principles. During the posttest, the child independently completed the pretest again.

Two scores were obtained per subtest. The first is the pretest score, which measures current knowledge of the required skill in the zone of actual development. This was considered a static test score. Secondly, a posttest score obtained after training reflecting the zone of proximal development is considered a dynamic test score.

Subtest 1: Phonemic Awareness: The Phonemic Awareness subtest measures children's ability to construct words by identifying smaller units (phonemes). The examiner covered her mouth with her hands while sounding out fourteen words, after which the child was tasked with identifying the spoken word. Mata and Serrano (2019) found an internal consistency of this subtest of α =.89.

Subtest 2: Prosodic Awareness: The subtest Prosodic Awareness evaluates whether children know the emphasis in a word. Eighteen audio-recorded words were played to the child, who had to determine which sound group contained the primary stress. Mata and Serrano (2019) found an internal consistency of this subtest of α = .87.

Subtest 3: Writing Competence: This subtest evaluates the ability to correctly write words and use phonological and writing rules in words and sentences. Twenty-five words were dictated to the child. Every word was said twice. Mata and Serrano (2019) found an internal consistency of this subtest of α = .83.

Subtest 4: Context-Dependent Words: This subtest measures the child's ability to determine the correct form of a homophonic word in the context of a sentence. Eighteen sentences containing a missing homophone were presented. The correct answer had to be selected from three words, two homophones and a word slightly similar to these homophones. Mata and Serrano (2019) found an internal consistency of this subtest of α = .62.

Table 2

Overview of the Dynamic Reading and Writing Test (based on Mata & Serrano, 2019).

Subtest	Task	Training			
		Hint 1	Hint 2	Hint 3	Hint 4
Phonemic Awareness	Make a word out of phonemes	Discussion and sentence-making with cards	Marking the phonemes on a card	Making (nonsense) words by throwing dice with syllables	Making words by rolling dice with vowels and consonants
Prosodic Awareness	Point out the syllable with an emphasis on nonsense words	Tapping the table, pointing out the loudest tap	Clapping words, thereby counting syllables	Pointing out the loudest syllable on a card	Practising with cards
Writing Competence	Write dictated words	Discussion of rules and working with cards, circling the same letter clusters	Completing words	Completing verbs	Practising with sentences
Context-Dependent Words (homophones)	Write the correct missing homophonic word in a sentence	Training the memory by seeing pictures matching with the homophones. In six steps, a part of these pictures is taken away, finally leading to a picture of the two letters associated with the homophone.			

3.3. Results

Before conducting our analyses, assumptions for normality for typically developing children and children diagnosed with dyslexia were checked through the Shapiro-Wilk test. The findings of the Shapiro-Wilks' test indicated that in the typically developing children, assumptions for normality were met for intelligence D (39) = .965, p >.05, Word Reading Fluency D (39) = .977, p >.05, Pseudoword Reading D (39) = .961, p >.05, and Spelling D (39) = .973, p >.05. In the children diagnosed with dyslexia assumptions for normality were met for intelligence D (41) = .973, p >.05, Word Reading Fluency D (41) = .987, p >.05 and Prosodic Awareness D (41) = .962, p >.05. Furthermore, assumptions for homogeneity typically developing children and children diagnosed with dyslexia were checked through Levene's test. The assumptions for homogeneity check indicated that assumptions were met for intelligence F(1,78) = .063, p >.05, age IQ F(1,78) = .024, p >.05, Word Reading Fluency F(1,78) = 2.22, p >.05, Pseudoword Reading F(1,78) = 3.34, p >.0), Spelling F(1,78) = .618, p >.05, Phonological Awareness F(1,78) = .035, p >.05, Phonemic Awareness F(1,78) = 1.900, p >.05, Prosodic Awareness F(1,78) = .338, p >.05, Writing Competence F(1,78) =3.838 , p >.05 and Context-Dependent Words F(1,79) = .959, p >.05.

Initial group comparisons

Prior to answering the research questions, a one-way MANOVA was conducted. The dependent variables in this analysis included age, intelligence, Technical Reading, Pseudoword Reading, Spelling and Phonological awareness. Furthermore, the pretest accuracy scores of the four dynamic reading and writing subtests were included. The independent variables were Condition (experimental versus control condition) and Subgroup (typically developing children versus children diagnosed with dyslexia).

An analysis of the multivariate effects revealed no significant differences in these variables between the children in the experimental and control condition (Wilks' λ = .91, F(10,67) = .64, p = .774, η_p^2 = .09). The multivariate Subgroup effect was, however, significant, (Wilks' λ = .33, F(10,67) = 13.70, p < .001, η_p^2 = .67).

The univariate between-subjects Subgroup effects, in combination with a visual examination of the mean scores, revealed that children diagnosed with dyslexia were, on average, older (F(1,76) = 13.30, p <. 001, η_p^2 = .149) and had lower accuracy scores on Word Reading Fluency (F(1,76) = 54.42 , p < .001 , η_p^2 = . 417), Prosodic Awareness (F(1,76) = 7.88, p = .006, η_p^2 = . 094), and Pseudoword Reading (F(1,76) = 87.78 , p <.001

, η_p^2 = . 536). No differences were found on intelligence ($F(1,76) = 0.091$, $p = .763$, η_p^2 = . 002), Phonological awareness ($F(1,76) = .554$, $p = .459$, η_p^2 = . 007), Spelling ($F(1,76) = .846$, $p = .361$, η_p^2 = . 011), Phonemic Awareness ($F(1,76) = .042$, $p = .839$, $\eta_p^2 = .001$), Context-Dependent Words ($F(1,76) = .027$, $p = .869$, $\eta_p^2 = .000$) and Writing Competence ($F(1,76) = 1,34$, $p < .716$, η_p^2 = . 002).

Means and standard deviations can be found in Table 3. Furthermore, a Chi-square analysis was conducted to explore the distribution of girls and boys between the two subgroups and conditions. Chi-square analysis unfolded a similar distribution of boys and girls across subgroups ($\chi^2(1) = 1.82$, $p = .18$) as well as conditions ($\chi^2(1) < .001$, $p = .99$).

Table 3

Means and Standard Deviations on Age, Preliminary Assessment Tests and Dynamic Reading and Writing Pretest accuracy scores Divided by Subgroup and Condition

		(1) Control Condition	(2) Experimental Condition	(3) Typically developing	(4) Diagnosed with dyslexia	(5) Total
n		37	43	39	41	80
Age in months	*M*	101.22	101.88	97.82	105.15	101.57
	SD	8.56	10.49	8.71	9.11	9.59
Intelligence	*M*	92.68	93.67	93.64	92.80	93.21
	SD	11.34	10.50	10.87	10.93	10.84
Word Reading Fluency	*M*	40.46	41.56	51.05	31.54	41.05
	SD	16.87	14.16	23.43	10.28	15.38
Pseudoword Reading	*M*	21.95	24.12	31.00	15.61	23.11
	SD	10.86	10.36	8.41	5.97	10.58
Spelling	*M*	11.16	11.12	11.69	10.61	11.14
	SD	2.39	4.69	4.88	5.36	5.13
Phonological Awareness	*M*	40.46	39.70	40.26	39.85	40.05
	SD	2.91	3.04	3.18	2.82	3.00
Phonemic Awareness	*M*	11.62	11.81	11.77	11.68	11.72
	SD	2.39	1.86	2.38	1.84	2.11
Prosodic Awareness	*M*	6.89	7.67	5.90	8.66	7.31
	SD	5.33	4.97	4.83	5.07	5.12

Writing Competence	*M*	13.89	14.58	14.38	14.15	14.26
	SD	5.72	5.70	6.31	5.09	5.68
Context-Dependent Words	*M*	11.95	11.35	11.72	11.54	11.63
	SD	4.52	4.68	4.89	4.34	4.58

Psychometric properties of the dynamic reading and writing test

Test-retest reliability of all reading and writing subtests was calculated by performing Pearson correlations separately for the experimental and control conditions. Positive, high correlations between pretest and posttest accuracy scores were found in the control condition for Phonemic Awareness ($r(37) = .92$, $p < .001$); Prosodic Awareness ($r(37) = .79$, $p < .001$), Writing Competence ($r(37) = .95$, $p <.001$ and Context-Dependent Words ($r(37) = .63$, $p < .001$), indicating sufficient test-retest reliability. In the experimental condition, high positive correlations between pretest and posttest accuracy scores were again found for all subtests (Phonemic Awareness: $r(43) = .61$, $p < .001$); Prosodic Awareness: $r(43) = .53$, $p < .001$; Writing Competence $r(43) = .91$, $p < .001$). A moderate correlation was found for the subtest Context-Dependent Words: $r(43) = .43$, $p = .004$). Overall, these findings indicate sufficient test-retest reliability.

Fisher's *r*-to-*z* transformations unfolded significant differences for the subtests Phonemic Awareness ($z = -3.77$, $p < .001$), Prosodic Awareness ($z = -2.06$, $p = .02$), a first potential manifestation of training effectiveness. However, no significant differences were found for the subtest Writing Competence ($z = -1.30$, $p = .10$) and Context-Dependent Words ($z = -1.21$, $p = .11$)

Cronbach's alpha coefficients were computed for the pretest scores to analyse the internal consistency of the subtests. They demonstrated coefficients ranging from $\alpha = .63$ for the subtest Phonemic Awareness, $\alpha = .81$ for the subtest Context-Dependent words, $\alpha = .89$ for the subtest Writing Competence and finally $\alpha = .90$ for the subtest Prosodic Awareness.

Table 4

Multivariate, Univariate and Between-Subject Effects RM MANOVA Outcomes

	Wilk's λ	*F*	*p*	η_p^2
Multivariate within-subjects effects				
Session	.75	6.05	< .001	.25
Session x Condition	.88	2.54	.047	.12
Session x Subgroup	.98	.308	.872	.02
Session x Condition x Subgroup	.87	2.77	.034	.13
Univariate within-subjects effects				
Phonemic Awareness				
Session		19.53	< .001	.20
Session x Condition		1.18	.280	.02
Session x Subgroup		.61	.436	.01
Session x Condition x Subgroup		.26	.610	.003
Prosodic Awareness				
Session		2.14	.148	.03
Session x Condition		9.43	.003	.11
Session x Subgroup		.20	.665	.003
Session x Condition x Subgroup		1.64	.204	.02
Writing Competence				
Session		1.33	.253	.02
Session x Condition		.07	.786	.001
Session x Subgroup		.53	.471	.01
Session x Condition x Subgroup		4.62	.035	.06
Context-Dependent Words				
Session		5.70	.019	.07
Session x Condition		2.02	.159	.03
Session x Subgroup		.02	.880	.000

Session x Condition x Subgroup		2.35	.129	.03
Multivariate Between-subjects effects				
Condition	.92	1.55	.198	.08
Subgroup	.88	2.40	.058	.12
Condition x Subgroup	.75	6.00	<.001	.25
Univariate between-subjects effects				
Phonemic Awareness				
Condition		.64	.426	.01
Subgroup		.25	.616	.003
Condition x Subgroup		.22	.638	.003
Prosodic Awareness				
Condition		6.35	.014	.08
Subgroup		8.08	.006	.10
Condition x Subgroup		4.71	.033	.06
Writing Competence				
Condition		.27	.604	.004
Subgroup		.27	.606	.004
Condition x Subgroup		9.40	.003	.11
Context-Dependent Words				
Condition		.02	.904	.000
Subgroup		.01	.910	.000
Condition x Subgroup		2.09	.152	.03

Significance $p < .05$, $p < .01$

Effect of training

The effect of training on reading and writing accuracy scores was examined through Repeated Measures of Multivariate Analysis of Variance (RM MANOVA). Session (pretest versus posttest) was included as a within-subjects factor, Condition (experimental versus control) and Subgroup (typically developing versus diagnosed with dyslexia) as between-subjects factors. In addition, the dependent variables were the dynamic reading and writing subtests of Phonemic Awareness, Prosodic Awareness, Writing Competence, and Context-Dependent Words.

All multivariate, univariate, within- and between-subject effects are displayed in Table 4. The multivariate within-subjects results indicated significant Session ($p < .001$, $\eta_p^2 = .25$) and Session x Condition effects ($p = .047$, $\eta_p^2 = .12$). These findings, combined with a visual examination of the mean scores, indicated that all children's accuracy scores improved from pre- to posttest. Furthermore, the significant Session x Condition effect indicated a significant difference in the two conditions' level of improvement. In addition, an insignificant Session x Subgroup effect ($p = .872$, $\eta_p^2 = .02$) revealed that typically developing children and children diagnosed with dyslexia demonstrated equal levels of improvement from the pretest to the posttest. An analysis of the multivariate between-subject effects revealed no significant condition ($p = .198$, $\eta_p^2 = .08$) or subgroup ($p = .058$, $\eta_p^2 = .12$) effects, indicating no differences at the condition or subgroup level. Univariate subgroup effects are described below.

Phonemic Awareness: The univariate effects unfolded a significant Session effect ($p < .001$, $\eta_p^2 = .20$), but no significant effect of Session x Condition ($p = .280$, $\eta_p^2 = .02$), Session x Subgroup ($p = .436$, $\eta_p^2 = .008$), or Session x Condition x Subgroup ($p = .610$, $\eta_p^2 = .003$). These results indicated that all groups of children performed better on this subtest from the pretest to the posttest. In contrast to our hypothesis, we observed no significant differences between the experimental and control conditions. Also, opposite to our hypothesis, no significant differences in accuracy scores were found between typically developing children and children diagnosed with dyslexia. In addition, the between-subjects effects for the Subgroup were insignificant (Phonemic Awareness, $p = .616$, $\eta_p^2 = .003$). This finding demonstrated that typically developing children did not outperform their peers diagnosed with dyslexia.

Prosodic Awareness: The univariate effects unfolded no significant effect of Session (p = .148, η_p^2 = .03), but a significant Session x Condition effect (p < .003, η_p^2 = .11). Furthermore, no significant Session x Subgroup (p = .665, η_p^2 = .003) or Session x Condition x Subgroup (p = .204, η_p^2 = .02) were unfolded. These results indicated that not all children performed better on this subtest from the pretest to the posttest. Consistent with our hypothesis, children in the experimental condition showed a significantly higher increase in accuracy scores from pretest to posttest than children in the control condition. Children in the control condition showed decreased accuracy scores from pre- to posttest. Contrary to our hypothesis, we did not observe any significant differences in the effects of training from pretests to posttest between typically developing children and children diagnosed with dyslexia. In addition, a significant between-subjects effect for the Subgroup (Prosodic Awareness, p = .006, η_p^2 = .10) indicated, in combination with a visual check of the mean scores, that the typically developing children had higher scores than the children diagnosed with dyslexia.

Writing Competence: The univariate effects unfolded no significant Session (p = .253. η_p^2 = .02), Session x Condition (p = .786, η_p^2 = .001), Session x Subgroup (p = .471,η_p^2 = .01). However, a significant Session x Condition x Subgroup (p = .035, η_p^2 = .06) was found. Contrary to the hypothesis, no significant improvements were observed from pretest to posttest, and no differences were found between experimental and control conditions. However, significant differences in improvement levels from pretest to posttest were found as a result of training and repeated practice between children diagnosed with dyslexia and typically developing children. Moreover, typically developing children did not outperform peers diagnosed with dyslexia, as indicated by the non-significant between-subjects effect for the Subgroup (Writing Competence, p =. 606, η_p^2 = .004).

Context-Dependent Words: The univariate effects unfolded a significant Session effect (p = .019, η_p^2 = .07), but no significant effect of Session x Condition (p = .159, η_p^2 = .03), Session x Subgroup (p = .880, η_p^2 =<.000), or Session x Condition x Subgroup (p = .129, η_p^2 = .03) effects. These results indicated that all groups of children performed better on this subtest from the pretest to the posttest. Contrary to the hypothesis, there was no significant improvement from pretest to posttest, no significant differences between experimental and control conditions., and no significant differences in accuracy scores between children with dyslexia and typically developing children. Typically developing children did not outperform peers with dyslexia, as indicated by the non-significant between-subjects effect for the Subgroup (Context-Dependent Words, p = .910, η_p^2 <. 001).

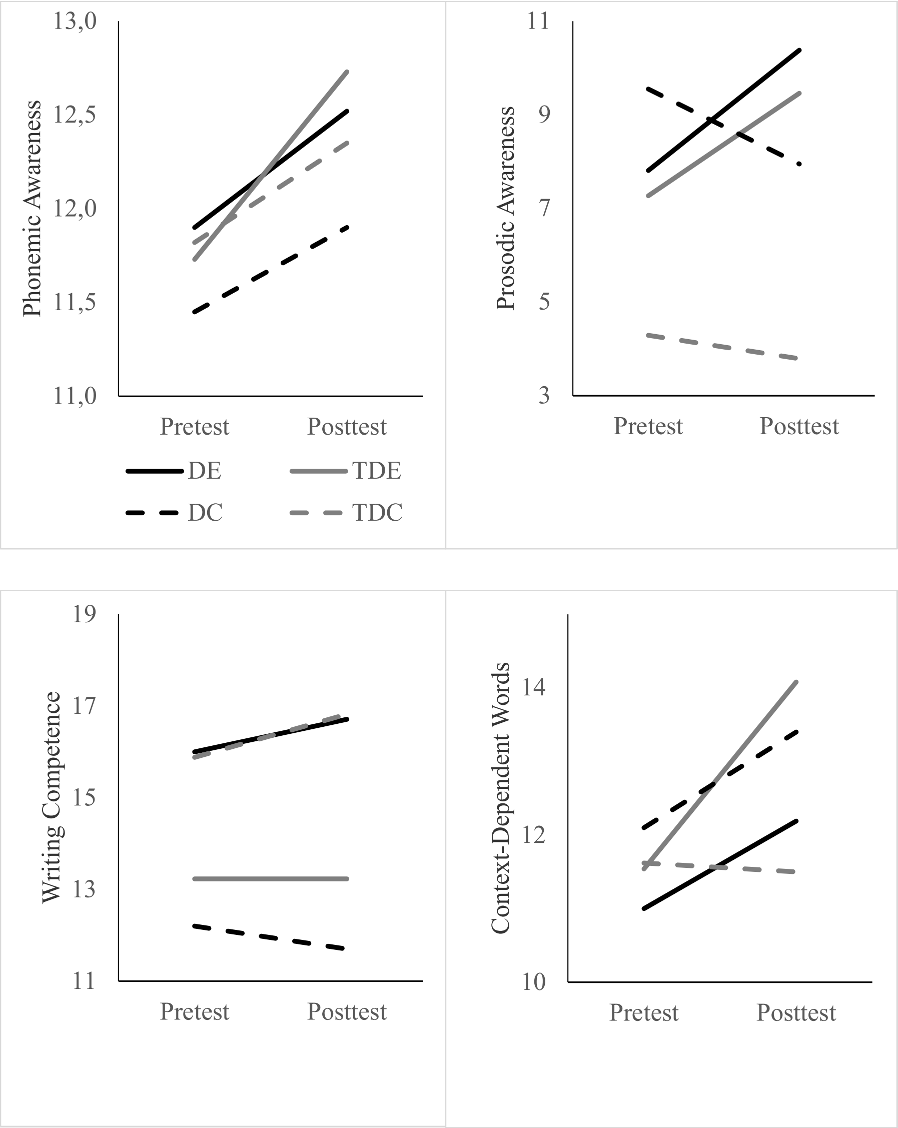
Table 5

Basic Statistics for Accuracy Scores on the Dynamic Reading and Writing Subtests at Pre- and Posttest

		Experimental Condition		Control Condition	
		Pretest	Posttest	Pretest	Posttest
Typically developing children					
Phonemic Awareness	*M (SD)*	11.73 (1.83)	12.73 (1.55)	11.82 (3.01)	12.35 (2.37)
Prosodic Awareness	*M (SD)*	7.55 (4.86)	9.32 (5.15)	3.76 (3.99)	3.82 (3.49)
Writing Competence	*M (SD)*	13.23 (5.74)	13.23 (5.86)	15.88 (6.86)	16.82 (7.14)
Context-Dependent Words	*M (SD)*	11.68 (4.99)	14.23 (3.68)	11.76 (4.88)	11.41 (5.01)
Children diagnosed with dyslexia					
Phonemic Awareness	*M (SD)*	11.90 (1.92)	12.52 (1.66)	11.45 (1.76)	11.90 (1.80)
Prosodic Awareness	*M (SD)*	7.81 (5.19)	10.38 (4.99)	9.55 (4.92)	7.95 (5.79)
Writing Competence	*M (SD)*	16.00 (5.42)	16.71 (5.66)	12.20 (3.98)	11.70 (3.44)
Context-Dependent Words	*M (SD)*	11.00 (4.42)	12.19 (4.63)	12.10 (4.30)	13.40 (3.63)

Figure 1

Mean Accuracy Scores of Dynamic Reading and Writing Subtests



Note. DE= children diagnosed with dyslexia in the experimental condition; DC= children diagnosed with dyslexia in the control condition; TDE= typically developing children in the experimental condition; and TDC= typically developing children in the control condition.

The relationship between static and dynamic reading and writing performance, conventional reading and spelling performance

The second research question was investigated through Pearson product-moment correlations. These analyses included correlations between the conventional and dynamic reading and writing subtests. Pretest scores of all children and posttest reading and writing scores of the untrained children were considered static scores. In addition, the posttest scores of the trained children were considered dynamic scores. Scores of the typically developing children and those diagnosed with dyslexia were analysed separately. Results are shown in Table 6.

Firstly, looking at pretest scores, correlations were found in the anticipated direction: Phonemic Awareness and Prosodic Awareness accuracy scores correlated positively with conventional reading scores, and Writing Competence and Context-Dependent Words accuracy scores correlated positively with the Spelling test in typically developing children and children diagnosed with dyslexia. In addition, unexpectedly, the subtests Writing Competence and Context-Dependent Words also correlated moderately to strongly with conventional reading tests. This pattern was also observed, though to a lesser degree, in children diagnosed with dyslexia. These findings suggest that the dynamic writing subtests might involve abilities similar to those needed in conventional reading tests.

Secondly, the posttest accuracy scores of the children in the control condition revealed strong positive correlations between Writing Competence and Context-Dependent Words on the one hand and Word Reading Fluency and Spelling on the other hand. These findings supported our hypothesis that the reading posttest accuracy scores of the untrained children correlated with conventional posttest reading scores, and the writing test scores correlated with spelling scores in both typically developing children and children diagnosed with dyslexia.

Again, unexpectedly, the subtest Writing Competence and Context-Dependent Words also correlated moderately to strongly with the scores of the conventional reading tests.

In addition, the posttest accuracy scores of the trained children revealed correlations with conventional reading and spelling subtests. Moderate to strong correlations were found between the subtest Writing Competence and Context-Dependent Words on the one hand and Word Reading Fluency, Pseudoword Reading and Spelling on the other. However, these correlations were generally stronger than the posttest measures of the untrained children in typically developing children and children diagnosed with dyslexia.

Table 6

Pearson Product-Moment Correlation Matrix between Dynamic Reading and Writing Measures (divided by Subgroup and Condition) and Conventional Static Test Measures

	Pretest				Posttest experimental condition				Posttest control condition			
	Phonemic Awareness	Prosodic Awareness	Writing Competence	Context-Dependent Words	Phonemic Awareness	Prosodic Awareness	Writing Competence	Context-Dependent Words	Phonemic Awareness	Prosodic Awareness	Writing Competence	Context-Dependent Words
Typically developing children												
Word Reading Fluency	.17	.26	.63**	.23	.12	.42	.69**	.02	.28	.03	.67**	.43
Pseudoword Reading	-.12	.26	.32*	.10	-.15	-.07	.49*	-.05	-.03	.14	.28	.28
Spelling	.50**	.24	.75**	.38*	.51*	.28	.55**	.30	.58*	.08	.84**	.66**
Phonological Awareness	.25	.00	.53**	.05	.39	.17	.57**	.10	.17	-.16	.36	.02
Intelligence	.21	.17	.18	.16	.64**	.20	.29	.15	.33	-.16	-.04	.11
Children diagnosed with dyslexia												
Word Reading Fluency	.12	-.06	.56**	.31	-.37	-.25	.53*	.10	.03	.14	.50*	.34
Pseudoword Reading	-.18	-.29	.31	-.03	-.65**	-.33	.14	-.15	-.21	-.05	.38	.13
Spelling	.12	.002	.34*	.01	.13	-.39	.35	-.16	-.12	.13	.52*	.24
Phonological Awareness	.06	.24	.34*	.05	.19	.07	.39	.29	-.11	.55*	.52*	.22
Intelligence	.34*	.13	.05	.05	.52*	.28	.04	-.02	.37	.11	.16	-.18

Significance * *p*< .05, ** *p*< .01

The relationship between dynamic reading and writing pretest and posttest accuracy and intelligence

Pearson product-moment correlations were computed to analyse the relationships between the pretest and posttest accuracy scores of the dynamic reading and writing subtests and intelligence. Similar to above, the pretest scores of all children and the posttest scores of the untrained children were considered static scores, and the trained children's posttest scores were considered dynamic scores, and the scores of the children, typically developing children and those diagnosed with dyslexia, were analyzed separately. Results are shown in Table 6.

At pretest, the results revealed modest correlations between intelligence and the subtests of Phonemic Awareness, Prosodic Awareness, Writing Competence and Context-Dependent Words for the typically developing children. However, a significant moderate correlation was observed between intelligence and Phonemic Awareness in children diagnosed with dyslexia, supporting the expected relationship between the subtest and intelligence.

Next, at the posttest, the accuracy scores of the untrained children revealed, as expected, generally moderate to small positive correlations between intelligence and Phonemic Awareness, Prosodic Awareness, Writing Competence and Context-Dependent Words in typically developing children and children diagnosed with dyslexia. In contrast, posttest scores of the children in the experimental condition unexpectedly revealed robust, significant correlations between Phonemic Awareness and intelligence in both typically developing children and children diagnosed with dyslexia. Unlike our hypothesis, dynamic measures generally revealed stronger correlations with intelligence than static measures.

3.4. Discussion

The current study aimed to investigate whether a dynamic reading and writing test would offer information on the potential for learning reading and writing for primary school typically developing children and children diagnosed with dyslexia. Furthermore, we aimed to gain more insight into the relationship between dynamic reading and writing test accuracy scores and more conventional reading and spelling tests. In addition, we investigated the relationship between intelligence and the accuracy scores on the dynamic and static reading and writing pre- and posttests.

This study offers preliminary support for using a dynamic reading and writing test. The study revealed that short, standardised training in Phonemic Awareness, Prosodic Awareness, Writing Competence and Context-Dependent Words could improve accuracy scores of typically developing children and children diagnosed with dyslexia. However, only a significant level of improvement beyond the influence of practice from the pretest to the posttest was found for the subtest Prosodic Awareness. These findings align with previous research (Mata & Serrano, 2019). Moreover, this finding advocates that the hints used in training in Prosodic Awareness might have unfolded children's potential for learning in Prosodic Awareness. Also, this finding prompted questions about the complexity of the test items and the content of the training of the subtests Phonemic Awareness, Writing Competence and Context-Dependent Words. No differences between typically developing children and children diagnosed with dyslexia in the extent to which they improved were found, a positive finding highlighting the potential advantages of integrating training in the testing procedure, especially for children diagnosed with dyslexia, considering that children diagnosed with dyslexia do not always respond to training (Aravena et al., 2017). However, it should be noted that the children diagnosed with dyslexia had a higher starting point, probably due to the fact that they already received extra instruction and a clinical dyslexia intervention. Furthermore, it should be noted that the group typically developing children includes children who have no problems with reading and writing and children who experience minor reading and spelling problems, as a consequence of which there is relatively large inter-individual variation within this group. The fact that the children who were not trained showed progression could be due to a practice effect, as research suggests that task performance develops when tested twice (Resing et al., 2019).

The dynamic reading and writing test generally seemed to require skills similar to those required by the conventional tests, and both tests were based on the same concepts. We unexpectedly found that the dynamic writing pretests correlated with conventional reading tests, emphasising the complementary nature of reading and writing skills (Galuschka et al., 2020). This relationship was also, although to a lesser extent, observed in children with dyslexia.

Surprisingly, compared with static pre- and posttest measurements, the dynamic reading and writing posttest measures were strongly associated with conventional reading and spelling tests and intelligence. Training seemed to influence these associations. The specific language-based skills targeted in training might align closely with skills required in conventional reading and spelling tests and verbal intelligence tasks in typically developing children and children diagnosed with dyslexia. This is an interesting finding, given the importance of language development on reading development (Lyster et al., 2020). However, this explanation requires further research to comprehend the impact of training fully.

Dynamic testing principles revolve around the learning process and may better reflect children's abilities. Indeed, dynamic tests may capture specific aspects of reading, spelling, and intelligence more effectively than static measurements. These findings advocate the importance of selecting appropriate tests in clinical practices and education. However, these statements should be interpreted cautiously as individual differences were found, given the differences captured in the standard deviations.

Some words of caution when interpreting the results, given that this study represents an initial exploration of combined dynamic testing of reading and writing in the Netherlands. Future studies might want to elaborate on and refine the test items and training content and might also include three groups of children: Typically developing children, children diagnosed with dyslexia, and children with mild reading and writing problems to investigate potential differences between these groups in more detail. Moreover, future research should aim for larger sample sizes to obtain more statistical power and generalisability.

To conclude, first and foremost, the dynamic reading and writing test can be an addition to assessment in education for typically developing children and those diagnosed with dyslexia, as it helps children demonstrate their potential for reading and writing. Consequently, by closely observing learning processes through collaboration with the child and offering explicit training, teachers and dyslexia clinicians can better understand an individual child’s educational needs. As shown in the current study, explicitly teaching writing skills also impacts the development of reading skills.

Chapter 4

Online dynamic testing of reading and writing, executive functioning and reading self-concept in typically developing children and children diagnosed with dyslexia.

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Abstract: The current study aimed to investigate the effectiveness of an online dynamic test in reading and writing, differentiating in typically developing children (n = 47) and children diagnosed with dyslexia (n = 30) aged between nine and twelve years. In doing so, it was analysed whether visual working memory, auditory working memory, inhibition, cognitive flexibility, and reading self-concept were related to the outcomes of the online dynamic test. The study followed a pretest-training-posttest design with two conditions: experimental (n = 41), who received training between the pretest and posttest, and control (n = 37), who received training after the posttest. Results showed that typically developing children and children diagnosed with dyslexia in both conditions could improve their reading and writing accuracy scores, while the training in prosodic awareness might have tapped into children's potential for learning. Moreover, results revealed that in children diagnosed with dyslexia, training in the domain of writing competence could compensate for cognitive flexibility. However, training was not found to compensate for reading self-concept in children diagnosed with dyslexia.

4.1. Introduction

To achieve academic success, literacy development is required in most educational environments (Lindeblad et al., 2019). Therefore, measuring the effectiveness of literacy instruction is crucial in education. For this purpose, in particular, static tests are used. Static tests are standardised product-oriented tests administered after a period of instruction, which aim to measure the child's actual level of functioning and obtain an insight into possible gaps in knowledge (Petersen et al., 2016; Resing, 2000). Although these tests have clear advantages, such as a one-time administration format and clear-cut results used to classify and identify children (Caffrey et al., 2008), there are some drawbacks to using these tests for dyslexia identification purposes. For instance, it has been stated that static tests tend to be biased towards children with specific learning disabilities like dyslexia (Navarro & Lara, 2017; Resing et al., 2020).

However, as the provision of feedback is not permitted in most static test procedures (Nazari, 2012), they do not provide insight into the child's potential for learning, which, as critics argue, is necessary information to gain insight into educational needs (Jeltova et al., 2007). Therefore, researchers advocate using dynamic tests, which incorporate training into the testing format to measure a child's responsiveness to instruction (Resing et al., 2020). Therefore, the main aim of this study was to gain more insight into the effects of online dynamic reading and writing test focusing on phonemic awareness, prosodic awareness, writing competence and context-dependent words amongst typically developing children and children diagnosed with dyslexia. In doing so, this study specifically focused on the effects of online administration, the roles of executive functioning, and reading self-concept in uncovering the potential for learning reading and writing skills. Online administration was specifically focused on, as due to the COVID-19 pandemic, there have been significant demands on educational professionals in terms of online teaching, measurement and intervention.

In this introduction, first online dynamic testing of reading and writing was discussed. After that, a brief description of literacy development in typically developing children and children diagnosed with dyslexia, executive functioning, and reading self-concept was given.

Dynamic Testing of reading and writing

A frequently used dynamic testing format concerns the pretest-training-posttest design (Resing et al., 2020), which enables tapping into the zone of proximal development (Vygotsky, 1978). The ZPD, which can be defined as the difference between the ability to solve a task individually, the actual zone of development, and the ability to solve a task after reciprocal help from a more knowledgeable other, the zone of potential development (Vygotsky, 1978), research employing dynamic testing of literacy and reading difficulties showed that dynamic measures of reading and writing, such as phonological awareness, predicted future academic achievements even better than conventional static measures (Caffrey et al., 2008). A drawback of dynamic testing methods is that they are time-consuming. Therefore, there was an interest in computerised test environments and online test methods, in which the computer is used as an assessment tool in a computerised test environment or as a tool to establish online contact (Ebadi & Rahimi, 2019), and research indicates that online dynamic tests strengthen particular skills, such as writing, reading or mathematics (Ebadi & Rahimi, 2019; Passig et al., 2016; Poehner & Lantolf, 2013; Puhan et al., 2007). Still, research into online dynamic administered reading and writing tests is scarce, and the usefulness of an online dynamic test of reading and writing for primary school children has not been investigated yet.

Developing Literacy

Elementary skills in early literacy, the ability to read and write, include phonological awareness, prosodic skills, letter knowledge, decoding and oral language skills (Arnoutse, 2004; Wackerle-Hollman et al., 2015). Phonological awareness, i.e. recognising and manipulating sounds in words, develops in several steps. First, children learn to understand that sentences are composed of words, words of syllables, and then rhyme sounds before segmenting words into phonemes, thus developing the letter knowledge necessary for reading and writing (Nicholas & Rouse, 2021). Prosodic awareness (rhythm perception) is the child's ability to distinguish or indicate an emphasis while listening, speaking, reading or writing (Godde et al., 2020). In addition, executive functions such as verbal fluency, working memory, inhibition and affective aspects, for example, reading self-concept, may influence literacy development (Lindeblad et al., 2019; Serrano & Defior, 2008). However, developing literacy skills is not self-evident for all children.

Dyslexia

For children diagnosed with dyslexia, unlike typically developing children, learning phonological and prosodic skills is challenging. Developmental dyslexia is a specific, neurodevelopmental language-based learning disability characterised by continual difficulties with fluent and exact word recognition and poor decoding and writing abilities despite remediation, intact sensory abilities and adequate instruction (Lyon et al., 2003; Snowling, 2013). The central deficits underlying dyslexia include weaknesses in grapheme-phoneme knowledge, rapid automatised naming and phonological awareness (Kudo et al., 2015). Effective clinical dyslexia interventions are mainly psycholinguistic intervention methods that aim to reinforce these weaknesses, for instance, by explicitly teaching phonemics (Melby-Lervåg et al., 2012; Tijms et al., 2021). Furthermore, research has shown that children diagnosed with dyslexia, compared to their typically developing peers, often also experience difficulties with, for example, self-esteem (Zuppardo et al., 2020), self-perception (Gibby-Leversuch et al., 2021) and executive functioning (Johann et al., 2020).

Executive Functions (Working Memory, Inhibitory Control and Cognitive Flexibility)

Executive functions are higher-order cognitive skills necessary to coordinate and control everyday behaviour essential in curricular activities (Diamond, 2013). They are good predictors of school success (Cortés Pascual et al., 2019) and, more specifically, literacy development (Ribner et al., 2017). Therefore, researchers and teachers are highly interested in programs strengthening children's executive functioning (Johann et al., 2020). Researchers generally distinguish three core executive functions, working memory, inhibition and cognitive flexibility, on which higher-order functions are built (Diamond, 2013; Goswami, 2019).

Working memory is defined as processing and temporally storing information or data which is no longer perceptually present (Diamond, 2013). Working memory is necessary to process words to comprehend a text visually (Peng et al., 2018). Inhibitory control enables one to control attention, behaviour, and thoughts. The construct is divided into response inhibition, responsible for suppressing a behavioural response, and cognitive inhibition, responsible for directing attention to relevant information (Friso-van den Bos & van de Weijer-Bergsma, 2020). Its implications for reading and writing seem clear: While reading or writing, one must inhibit stimuli to pay attention to what is being read or written (Friso-van den Bos & van de Weijer-Bergsma, 2020).

Cognitive flexibility concerns adapting approaches or perspectives to various tasks (Diamond, 2013). Research suggests that cognitive flexibility is essential in early literacy development as starting readers and writers must process a collection of letter-sound pairs and consider various articulations of letter strings (Vadasy et al., 2022). Cognitive flexibility is often measured by verbal fluency tasks (Diamond, 2013). Verbal fluency describes the ability to induce items according to specific rules (Smith-Spark et al., 2017).

Research showed that children diagnosed with dyslexia demonstrated weaknesses in working memory (Peng et al., 2018), inhibitory control (Peng et al., 2018), and cognitive flexibility (Dadgar et al., 2022). In addition, reduced access to phonemically structured representations of speech, phonological processing and letter and semantic fluency was found in children diagnosed with dyslexia (Melby-Lervåg et al., 2012; Shareef et al., 2018). Moreover, the importance of executive functioning concerning academic achievement can also be found in its association with social-emotional factors; for example, weaknesses in executive functions have been associated with lower academic self-concept (Bailey et al., 2018).

Reading Self-Concept

Reading self-concept can be defined as the general image of oneself as a reader (Katzir et al., 2018). Young children establish reading self-concept through their degree of fast reading and reading accuracy (Katzir et al., 2018). Implications of low reading self-concept include avoidance of reading tasks (Grills et al., 2014), lower reading motivation, and, in turn, reading skills (Katzir et al., 2018).

Surprisingly, there is little research on reading self-concept in children with dyslexia. Gibby-Leversuch et al. (2021) systematic review of self-perception concluded that being diagnosed with dyslexia may affect self-perception negatively. Furthermore, Zuppardo et al. (2020) stated that dyslexia also affects self-esteem. Moreover, whether reading self-concept plays a role in dynamic tests, which are expected to compensate for social-emotional factors such as test anxiety (Vogelaar et al., 2017) and weaknesses in executive functioning (Vogelaar et al., 2019), remains unclear.

Aims of the Current Study

The current study aimed to gain insight into the potential effects of an online-administered dynamic reading and writing test in children diagnosed with dyslexia and typically developing children. In so doing, we explored the potential relationships between executive functioning, reading self-concept and static and dynamic measures of reading and writing. The first research question addressed children's progression from pretest to posttest. We hypothesised that all groups of children would improve from pretest to posttest in the number of correct answers on phonemic awareness, prosodic awareness, writing competence, and context-dependent words (Mata & Serrano, 2019). More specifically, we expected that children in the experimental condition, who received training between pretest and posttest, would show more improvement in the number of correct answers than their peers in the control condition (Mata & Serrano, 2019; Navarro & Lara, 2017; Petersen et al., 2018). Concerning potential differences between children with dyslexia and their typically developing peers, we expected that children diagnosed with dyslexia would, in general as well as in both conditions, show less progression than their typically developing peers due to their general lack of responsiveness to treatment (Aravena et al., 2018; Mata & Serrano, 2019).

The second research question concerned the potential relationship between static and dynamic reading and writing scores and executive functioning, specifically working memory, inhibition and cognitive flexibility. Pretest scores, as well as the posttest scores of the children in the control condition, were considered static measures, and the posttest scores of the children who were trained were considered dynamic measures. In general, the static reading and writing measures were expected to be positively associated with the executive function measures (Altemeier et al., 2008). Concerning the posttest of the trained children in the experimental condition, executive functioning was expected to be associated less strongly with posttest scores, considering that training was found to compensate for weaknesses in executive functions (Vogelaar et al., 2019). The scores of the typically developing children and those with dyslexia were analysed separately to explore potential differential correlational patterns.

Our final research question involved the potential relationship between static and dynamic measures of reading and writing and the static measure of reading self-concept. Generally, the static reading and writing measures were expected to be positively associated with reading self-concept (Durik et al., 2006). Concerning the posttest scores of the trained children, it was expected that reading self-concept would be associated less strongly with the dynamic posttest scores than it would with static scores. This would imply that the dynamic test could compensate for social-emotional factors (Vogelaar et al., 2017). The scores of the typically developing children and those with dyslexia were again analysed separately to explore potential differential relationships.

4.2. Method

Participants

The sample consisted of 78 participants (35 boys and 43 girls) with a mean age of 10.6 (*SD* = .76; 9-12 years). The children diagnosed with dyslexia (*n* = 30) were recruited by OnderwijsAdvies, an educational advisory service and dyslexia treatment institute in the Netherlands. The typically developing children (*n* = 48) were recruited from regular mainstream primary schools in the province of Zuid-Holland. Moreover, all children diagnosed with dyslexia were diagnosed with single severe dyslexia and belonged to the weakest 10% on reading or writing tests compared to their age-mates. The total distribution of children with and without dyslexia over the two conditions is displayed in Table 1.

Design and Procedure

This study had an experimental pretest-training-posttest design with two conditions: control and experimental, as can be seen in Table 1. The study consisted of two sessions: During the first session, a preliminary online assessment consisting of the Picture Span and Digit Span of the Wechsler Intelligence Scale for Children-V-NL (WISC-V-NL; Wechsler, 2014), Stroop-Color-Word test (Stroop, 1935), Ideational Fluency, part of the Revisie Amsterdamse Kinder Intelligentie test (RAKIT-2; Resing et al., 2012), and the Reading Self-Concept Scale (Chapman & Tunmer, 1995) were administered. The online dynamic reading and writing test was administered during the second session. Prior to the first session, children were distributed over the control and experimental conditions by employing a randomised block design based on age and gender. Children in the experimental condition received training between the pretest and posttest. The children in the control condition received training after finishing the posttest to provide the children in the control group the opportunity also to receive training. Trained master's students in Psychology collected the data under the authors' supervision. Microsoft Teams was used to administer all online tasks.

Table 1

Schematic Overview of the Design of the Study

		Session 1: 30 minutes	Session 2: 60-75 minutes			
		Preliminary Assessment	The online dynamic test of reading and writing:			
			Pretest	Training	Posttest	Training
Experimental Condition (*n*=41)	Children diagnosed with dyslexia (*n*=16)	X	X	X	X	-
	Typically developing children (*n*=25)	X	X	X	X	-
Control Condition (*n*=37)	Children diagnosed with dyslexia (*n*=14)	X	X	-	X	X
	Typically developing children (*n*=23)	X	X	-	X	X

Note 1. The preliminary assessment consisted of the following instruments: Picture and Digit Span of the WISC-V-NL, Stroop-Color-Word test, Idea Production of the RAKIT-2 and the Reading Self-Concept Scale.

Instruments

Picture Span Wechsler Intelligence Scale for Children-V-NL (Wechsler, 2014). The Picture Span measures visual working memory. As part of the Picture Span, children are shown a series of objects, after which they have to remember from a new series of objects the objects they were shown previously and in which order. The subtest takes 10 minutes, contains 26 items of increasing difficulty level, and has a test-retest reliability of r = .60 (Wechsler, 2014).

Digit Span Wechsler Intelligence Scale for Children-V-NL (Wechsler, 2014). Digit Span measures auditory working memory. It consists of three subtests: Digit Span Forward, Digit

Span Backward, and Digit Span Sequencing, which takes up to 10 minutes. Each subtest consists of nine items with an increasing difficulty level. After a sequence of numbers is provided to the child, the child is asked to repeat this verbally. Depending on the type of the subtest, the child was asked to repeat the sequences forward, backwards or from the smallest number to the largest. The Digit Span task has a test-retest reliability of *r* =. 79 (Wechsler, 2014).

Stroop-Color-Word Test (Stroop, 1935). In about five minutes, the Stroop-Color-Word test measures the inhibition of a prepotent reading response to engage a naming response. With 100 stimuli each, three cards must be read correctly as fast as possible during the test. The names of the colours red, green, yellow, and blue are written out in black on card one. Card two shows rectangles in these colours. The words red, green, yellow, and blue are printed in mismatched colours on card three. Interference will occur on the last card, where the dominant reaction should be inhibited in naming the colour rather than reading the word. The difference in time between the third and second cards was used to measure inhibitory ability. A lower score means a better inhibitory ability. The test-retest reliability of the Stroop-Color-Word-Test is *r* = .68 (Van der Elst et al., 2008).

Ideational Fluency (Resing et al., 2012). The Ideational Fluency subtest measures ideational verbal fluency in about five minutes. Within one minute, the child has to answer five questions as quickly and realistically as possible. For example, a question could be: What do you see in a zoo? It measures the ease and speed with which new ideas and corresponding answers can be produced within a specific category. The test-retest reliability is *r* = .82 (Resing et al., 2012). In the current study, ideational fluency was considered a measure of cognitive flexibility (see e.g. Diamond, 2013).

Reading Self-Concept Scale (Chapman & Tunmer, 1995). The Reading Self-Concept Scale is a self-assessment questionnaire that measures reading self-concept. The scale consists of 30 items matching three subscales: perception of reading skills, reading difficulties, and attitudes towards reading. The items are formulated as questions, such as 'Is reading difficult for you?'. The questions are read aloud to the children, where they answer on a five-point scale: 'yes, always', 'yes, often', 'not clear/not sure', 'no, not often' and 'no, never'. The test takes approximately 5 minutes. Each answer is scored from one to five, where one represents low self-esteem when reading and five represents high self-esteem when reading. The full-scale score is calculated from the average of the 30 items, ranging from one to five. The internal reliability of the entire Reading Self-Concept Scale is α = .89 (Chapman & Tunmer, 1995).

Online Dynamic Reading and Writing test (Mata & Serrano, 2019). The dynamic reading and writing test, initially developed in Spanish and translated and cross-translated into Dutch for the current study, aims to assess children's potential for learning reading and writing skills. Two of the four subtests cover basic reading skills: phonemic awareness and prosodic awareness. The two other subtests focus on writing skills, specifically knowledge of writing rules and homophones. The dynamic reading and writing test can be administered in about 60 to 80 minutes. Each subtest consists of three phases. The child solves the task independently in the test's first (pretest) and third (posttest) phases. The task at the posttest is the same as at the pretest. For motivation, each subtest is stopped after three consecutive errors. The second phase consists of individual training: extra instruction and practice with the assistance of an adult in which the child is challenged to improve posttest scores. The training is standardised and administered hierarchically: training starts at an abstract level and ends at the task-specific level for each subtest.

Subtest 1: Phonemic Awareness: This reading subtest covers phonemic awareness of the type synthesis. In about 15-20 minutes, it evaluates the child's ability to construct words by identifying smaller units (phonemes). For example, which word will you get if you hear m/e? Fourteen words are presented in sounds, and the child must determine which word has been said while they cannot see the examiner's mouth. The training consists of four hints: Creating sentences with words presented on cards, dividing words into syllables, marking phonemes on cards, and finally, making (nonsense) words by throwing dice with syllables, vowels and consonants. The internal consistency of this subtest is α = .89 (Mata & Serrano, 2019).

Subtest 2: Prosodic Awareness: This reading subtest measures Prosodic Awareness and evaluates in about 15-20 minutes whether the child hears the emphasis in a word. After hearing eighteen words, the child has to determine which sound group is emphasised. The training consists of four hints: Tapping the table and pointing out the loudest tap, clapping words and counting the syllables, pointing out the loudest syllable on a card by putting a red plug and practising with cards, giving the child a starting point to find the emphasised sound group. The internal consistency of this subtest is α = .87 (Mata & Serrano, 2019).

Subtest 3: Writing Competence: This writing subtest evaluates writing competence in 15-20 minutes using phonological and writing rules in words and sentences. Twenty-five words are dictated to the child. Every word is said twice. The training consists of four hints: Discussing writing rules with cards circling the same letter clusters, completing words and verbs and practising with sentences to create an awareness of the link between graphemes and phonemes and the Dutch writing rules. The internal consistency of this subtest is α =.83 (Mata & Serrano, 2019).

Subtest 4: Context-Dependent Words: This writing subtest measures the child's orthographic ability to determine the correct form of a homophonic word in about 15-20 minutes. Homophonic words sound the same but have distinct meanings and spellings. Therefore, the context of eighteen sentences with a missing word must be used to determine the missing word's correct spelling. The correct answer is given in a row of three words, a word slightly similar to the homophones and the two homophones. During the training, nine pictures of word couples that sound the same, only with different writing and meaning, are presented. The hint focuses on the differences in the graphemes of the two homophones as the pictures fade into two or three letters in six steps. The internal consistency of this subtest is α .62 (Mata & Serrano, 2019).

Statistical analyses:

Before answering the research questions and investigating potential initial group differences, a one-way MANOVA was conducted. The dependent variables in this analysis included age, pretest scores on preliminary assessment tests, including visual and auditory working memory, inhibition, cognitive flexibility and reading self-concept, and the dynamic reading and writing pretest scores. The independent variables included Condition (experimental versus control condition) and Subgroup (typically developing children versus children diagnosed with dyslexia). Furthermore, a Chi-square analysis was conducted to investigate whether boys and girls were equally distributed across the two conditions and subgroups.

Test-retest reliability for all dynamic reading and writing subtests was calculated separately using Pearson correlations for the experimental and control conditions.

To answer the first research question, Repeated Measures of Multivariate Analysis of Variance (RM MANOVA) were used. Session (pretest versus posttest) was included as a within-subjects factor, and Condition (experimental condition versus control condition) and Subgroup (typically developing versus diagnosed with dyslexia) as between-subjects factors. In addition, accuracy scores on subtests of Phonemic Awareness, Prosodic Awareness, Writing Competence, and Context-Dependent Words served as the dependent variables.

To answer the second and third research questions, Pearson product-moment correlations were included between the pre-and posttest reading and writing performance measures of the typically developing children and children diagnosed with dyslexia on the one hand and the executive function measures and reading self-concept on the other. In these analyses, children with dyslexia and the typically developing children were analysed separately. Furthermore, the assumptions of normality and homogeneity were checked for all dependent variables.

4.3. Results

Prior to conducting our analyses, assumptions for normality were checked through the Kolmogorov-Smirnov test. The findings indicated that assumptions were met for age D (48) = .977, $p > .05$, cognitive flexibility D (48) = .991, $p > .05$, reading self-concept D (48) = .971, $p > .05$, Prosodic Awareness D (48) = .911, $p > .05$ in typically developing children. In children diagnosed with dyslexia, assumptions for normality were met for age D (30) = .970, $p > .05$, reading self-concept, D (30) = .973, $p > .05$, Prosodic Awareness, D (30) = .941, $p > .05$ and Writing Competence D (30) = .960, $p > .05$ for children diagnosed with dyslexia. Furthermore, assumptions for homogeneity were checked through Levene's test. The assumptions for homogeneity check indicated that assumptions were met for age $F(1,76) = 1.30$, $p > .05$, cognitive flexibility $F(1,76) = .024$, $p > .05$, reading self-concept $F(1,76) = .352$, $p > .05$, Phonemic Awareness $F(1,76) = .639$, $p > .05$, and Prosodic Awareness $F(1,76) = .124$, $p > .05$).

Initial Group Comparisons

To investigate potential initial group differences, a one-way MANOVA was conducted. An analysis of the multivariate effects revealed no significant differences in these variables between the children in the two conditions (Wilks' $\lambda = .95$, $F(5,70) = .687$, $p = .64$, $\eta_p^2 = .05$). The multivariate Subgroup effect was however, significant, (Wilks' $\lambda = .44$, $F(5,70) = 17.56$, $p < .001$, $\eta_p^2 = .56$). The univariate between-subjects Subgroup effects in combination with a visual examination of the mean scores revealed that children diagnosed with dyslexia had lower scores on visual working memory, $F(1,74) = 13.08$, $p <.001$, $\eta_p^2 =.15$), auditory working memory ($F(1,74) = 16.40$, $p <.001$, $\eta_p^2 = .18$), inhibition ($F(1,74) = 11.10$, $p = .001$, $\eta_p^2 =.13$) and reading self-concept ($F(1,74) =70.40$ $p = <.001$, $\eta_p^2 =. 49$), but not on cognitive flexibility ($F(1,74) = 1.17$, $p = .28$, $\eta_p^2 = .02$). Means and standard deviations can be found in Table 2. The Chi-square analysis revealed a similar distribution of boys and girls across conditions ($\chi 2$ (1) = 2.70, $p = .10$) as well as across subgroups ($\chi 2$ (1) = .52, $p = .47$).

Table 2

Mean Scores and Standard Deviations of Preliminary Investigation (Executive Functions and Reading Self-Concept) per Condition and Subgroup

		(1) Control Condition	(2) Experimental Condition	(3) Typically developing	(4) Diagnosed with dyslexia	(5) Total
n		37	41	48	30	78
Visual Working Memory	M	31.78	31.54	33.65	28.47	31.65
	SD	7.12	6.58	5.67	7.31	6.80
Auditory Working Memory	M	27.03	26.59	28.81	23.57	26.79
	SD	6.71	5.83	6.41	4.33	6.23
Cognitive flexibility	M	71.78	74.68	71.67	75.93	73.31
	SD	17.25	17.50	16.84	18.07	17,33
Inhibition	M	60.19	68.00	57.10	75.80	64.30
	SD	22.88	28.12	24.62	24.01	25.90
Reading Self-Concept	M	3.67	3.55	3.93	3.08	3.61
	SD	.57	.62	.40	.48	.60

Psychometric Properties of the Online Dynamic Reading and Writing Test

The psychometric properties of the online dynamic reading and writing test were analysed. Positive, strong correlations between pretest and posttest scores were found for all subtests in the control condition (Phonemic Awareness: $r(35) = .79, p < .001$; Prosodic Awareness: $r(35) = .76, p < .001$; Writing Competence $r(35) = .96, p < .001$; Context-Dependent Words: $r(35) = .94, p < .001$), indicating sufficient test-retest reliability. In the experimental condition, significant positive correlations between pretest and posttest scores were again found for all subtests (Phonemic Awareness: $r(39) = .61, p < .001$; Prosodic Awareness: $r(39) = .68, p < .001$; Writing Competence $r(39) = .93, p < .001$; Context-Dependent Words: $r(39) = .47, p <$

.001), indicating sufficient test-retest reliability. Fisher's *r*-to-*z* transformations were performed to investigate if these correlations differed significantly between the two conditions. No or almost significant differences were found for subtests of Phonemic Awareness ($z = 1.58$, $p = .057$), Prosodic Awareness ($z = .74$, $p = .230$), and Writing Competence ($z = 1.04$, $p = .150$). The correlation between pretest and posttest scores was larger in the control condition than in the experimental condition for the subtest Context-Dependent Words ($z = 5.02$, $p < .001$), providing a first indication of training effectiveness. Cronbach's alpha coefficients were calculated to analyse the internal consistency of the subtests at the pretest with scores ranging from $\alpha = .54$ for the subtest Phonemic Awareness, $\alpha = .66$ for the subtest Writing Competence, $\alpha = .70$ for the subtest Context-Dependent Words and finally $\alpha = .93$ for the subtest Prosodic Awareness.

Effect of Training

The effect of training on children's progression in reading and writing was examined through Repeated Measures of Multivariate Analysis of Variance (RM MANOVA). All effects are displayed in Table 3. The multivariate results indicated significant Session ($p = .004$, $\eta_p^2 = .11$) and Session x Condition effects ($p = .003$, $\eta_p^2 = .12$). These findings indicated that there was a significant progression from pretest to posttest in at least one of the subtests and that there was a significant differential progression from pretest to posttest between the experimental and control condition in at least one of the subtests. A visual examination of the mean scores, as can be seen in Table 4 and Figure 1, indicated that the children who were trained progressed more than the children who were not, providing a first indication that training might be effective. Moreover, no significant Session x Subgroup ($p = .351$, $\eta_p^2 = .01$) or Session x Condition x Subgroup ($p = .471$, $\eta_p^2 = .01$) effects were found, which, as can be seen in the mean scores in Figure 1, indicated that the typically developing children and children diagnosed with dyslexia, regardless of whether they were trained, demonstrated similar improvement in accuracy from pretest to posttest. Follow-up univariate effects at the subgroup level were described below.

Table 3

Multivariate, Univariate and Between-Subject Effects RM MANOVA Outcomes

	Wilk's λ	*F*	*p*	η_p^2
Multivariate effects				
Session	.89	8.97	.004	.11
Session x Condition	.89	9.63	.003	.12
Session x Subgroup	.99	.88	.351	.01
Session x Condition x Subgroup	.99	.53	.471	.01
Univariate effects				
Phonemic Awareness				
Session		19.16	< .001	.21
Session x Condition		.03	.857	<.001
Session x Subgroup		1.77	.188	.02
Session x Condition x Subgroup		.10	.759	.001
Prosodic Awareness				
Session		.02	.897	<.001
Session x Condition		9.02	.004	.11
Session x Subgroup		.11	.739	.002
Session x Condition x Subgroup		.63	.431	.01
Writing Competence				
Session		19.55	< .001	.21
Session x Condition		.10	.758	.001
Session x Subgroup		1.30	.257	.02
Session x Condition x Subgroup		.52	.473	.01
Context-Dependent Words				
Session		1.91	.171	.03
Session x Condition		1.85	.178	.02
Session x Subgroup		.004	.949	< .001
Session x Condition x Subgroup		.10	.757	.001
Between Subject Effects				
Phonemic Awareness				

Condition	1.67	.200	.02
Subgroup	4.05	.048	.05
Condition x Subgroup	2.37	.128	.03
Prosodic Awareness			
Condition	.34	.563	.01
Subgroup	2.26	.137	.03
Condition x Subgroup	2.58	.113	.03
Writing Competence			
Condition	.47	.496	.01
Subgroup	56.33	< .001	.43
Condition x Subgroup	3.51	.065	.05
Context-Dependent Words			
Condition	1.52	.222	.02
Subgroup	38.73	< .001	.34
Condition x Subgroup	1.03	.313	.01

Phonemic Awareness: The univariate effects revealed a significant Session effect ($p < .001$, $\eta_p^2 = .21$), but no significant effects of Session x Condition ($p = .857$, $\eta_p^2 < .001$), Session x Subgroup ($p = .188$, $\eta_p^2 = .02$), or Session x Condition x Subgroup ($p = .759$, $\eta_p^2 = .001$). These findings indicate that all groups of children progressed from pretest to posttest. Contrary to our hypothesis, we did not observe significant differences in the level of progression between the experimental and control conditions. Also, contrary to our hypothesis, no significant differences in progression from pretest to posttest were found between children diagnosed with dyslexia and typically developing children. In addition, a significant between-subjects effect for the Subgroup (Phonemic Awareness, ($p = .048$, $\eta_p^2 = .05$) indicated, in combination with a visual check of the mean scores, that the children diagnosed with dyslexia, as expected, in general, had lower scores than their typically developing age-mates.

Prosodic Awareness: The univariate effects revealed no significant effects of Session ($p = .897$, $\eta_p^2 < .001$). However, a significant Session x Condition effect ($p = .004$, $\eta_p^2 = .11$) was found. Furthermore, no significant effects of Session x Subgroup ($p = .739$, $\eta_p^2 =.002$) or Session x Condition x Subgroup ($p = .473$, $\eta_p^2 = .01$) were found. These findings align with our hypothesis that children in the experimental condition would show more growth from pretest to posttest than children in the control condition for this subtest. This is also reflected in the scores shown in Table 3. No significant differences in improvement in scores from pretest to posttest were observed between children diagnosed with dyslexia and typically developing children. Moreover, the fact that the between-subjects effect for the Subgroup was not significant (Prosodic Awareness, ($p = .563$, $\eta_p^2 = .01$) demonstrated that, unlike our expectations, typically developing children did not outperform those diagnosed with dyslexia.

Writing Competence: The univariate effects revealed a significant Session effect ($p < .001$, $\eta_p^2 = .21$). However, no significant effects of Session x Condition ($p = .758$, $\eta_p^2 = .001$), Session x Subgroup ($p = .257$, $\eta_p^2 = .02$), or Session x Condition x Subgroup ($p = .473$, $\eta_p^2 = .01$) was found. These findings indicate that all children showed progression from pretest to posttest. Contrary to our hypothesis, we observed no significant differences between the control and experimental conditions. Also, contrary to our hypothesis, no significant differences in progression from pretest to posttest were found between children diagnosed with dyslexia and typically developing children. In addition, a significant between-subjects effect for the Subgroup (Writing Competence, ($p = < .001$, $\eta_p^2 = .43$), indicated, in combination with a visual check of the mean scores, that the children diagnosed with dyslexia, as expected, had lower scores than their typically developing age-mates.

Context-Dependent Words: No significant univariate effects were found for this subtest. When accounting for Subgroup and Condition, no significant differences in improvement in scores from pretest to posttest were found. The significant

Subgroup between-subjects effect (Context-Dependent Words ($p = < .001$, $\eta_p^2 = .34$), in combination with a visual check of the mean scores, however, further demonstrated that children diagnosed with dyslexia, as expected, in general, had lower scores than their typically developing age-mates.

Table 4

Basic Statistics for Scores on all Online Dynamic Reading and Writing Subtests at Pre- and Posttest

		Experimental Condition		Control Condition	
		Pretest	Posttest	Pretest	Posttest
Typically developing children					
Phonemic Awareness	M (SD)	11.96 (1.97)	12.52 (2.40)	12.04 (2.06)	12.65 (1.50)
Prosodic Awareness	M (SD)	9.68 (5.89)	10.80 (6.74)	12.26 (5.45)	10.91 (6.99)
Writing Competence	M (SD)	21.84 (2.44)	22.40 (2.69)	22.74 (1.86)	23.17 (1.47)
Context-Dependent Words	M (SD)	15.64 (1.19)	16.40 (1.32)	16.09 (1.35)	16.17 (1.07)
Children diagnosed with dyslexia					
Phonemic Awareness	M (SD)	11.44 (2.22)	12.63 (1.41)	10.29 (2.40)	11.28 (2.40)
Prosodic Awareness	M (SD)	9.19 (5.87)	11.56 (6.01)	8.43 (4.77)	6.57 (6.49)
Writing Competence	M (SD)	17.81 (3.99)	18.50 (3.60)	15.86 (4.20)	16.86 (4.87)
Context-Dependent Words	M (SD)	11.81 (4.56)	12.81 (4.23)	13.50 (3.39)	13.42 (3.08)

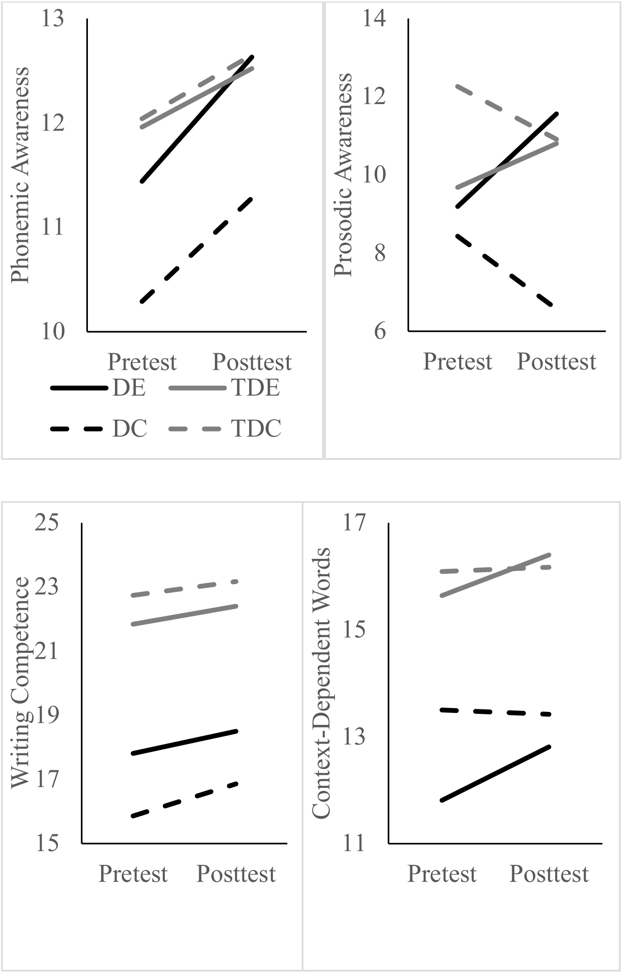

Figure 1

Mean Scores of Dynamic Reading and Writing Subtests

Note. DE= children diagnosed with dyslexia Experimental Condition, DC= children diagnosed with dyslexia Control Condition, TDE= typically developing children Experimental Condition, TDC= typically developing children Control Condition.

The Relationship between Static and Dynamic Reading and Writing Scores, Executive Functioning and Reading Self-Concept

Pearson product-moment correlations were calculated between the pre-and posttest subtests to investigate the relationship between the dynamic reading and writing measures on the one hand and executive function measures and reading self-concept on the other hand (see Table 5). Separate analyses were performed for Condition and Subgroup.

Table 5

Pearson Product-Moment Correlation Matrix between Executive Functions, Reading Self-Concept Pretest and Posttest Dynamic Reading and Writing Measures (divided by Condition and Subgroup)

	Pretest				Posttest experimental condition				Posttest control condition			
	Phonemic Awareness	Prosodic Awareness	Writing Competence	Context-Dependent Words	Phonemic Awareness	Prosodic Awareness	Writing Competence	Context-Dependent Words	Phonemic Awareness	Prosodic Awareness	Writing Competence	Context-Dependent Words
Typically developing children												
Visual Working Memory	.31*	.31*	.26	.20	.12	.46*	.35	.36	.29	.40	.24	-.13
Auditory Working Memory	.24	.17	.32*	.38*	.27	.06	.43*	.33	.04	.30	.17	.04
Cognitive Flexibility	-.24	-.04	-.18	-.03	-.14	-.08	.23	-.16	-.28	-.10	-.08	.05
Inhibition	.10	.09	-.07	-.13	-.19	-.09	.07	.28	.05	.15	-.31	-.34
Reading Self-Concept	.12	-.18	.34*	.28	-.14	-.21	.33	.27	.10	.07	.55**	.08
Children diagnosed with dyslexia												
Visual Working Memory	.22	.05	.10	-.02	.09	.16	.01	.33	.31	.03	.17	.16
Auditory Working Memory	.25	.14	.44*	.00	.03	.03	.40	.15	.31	.16	.27	.04
Cognitive Flexibility	.07	.17	.40*	.07	-.08	.23	.02	-.14	.36	-.05	.69**	.23
Inhibition	.03	-.07	.04	-.06	.14	.42	.28	.40	-.52	-.14	-.30	.09
Reading Self-Concept	.04	.19	-.01	-.19	.14	.27	-.10	-.09	.40	.30	.41	.10

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

Overall, positive moderate relationships, as anticipated, were found between the online dynamic subtests and visual and auditory working memory in the typically developing children. In the children diagnosed with dyslexia, positive moderate relationships between the online dynamic subtests and visual working memory, auditory working memory and cognitive flexibility were found. Results indicated that typically developing children with stronger visual working memory performed better on Phonemic Awareness and Prosodic Awareness at pretest, and stronger auditory working memory was related to performance on Context-Dependent Words. Concerning the children diagnosed with dyslexia, stronger auditory working memory and cognitive flexibility were related to Writing Competence performance. In addition, typically developing children with a higher reading self-concept performed better on Writing Competence. In the children diagnosed with dyslexia, we saw an opposite outcome, where we found small negative correlations between reading self-concept and writing tasks. Relationships between the static reading and writing posttest performances of the untrained children diagnosed with dyslexia in the control condition and executive functions and reading self-concept were generally stronger than for the dynamic posttest performances of the trained children in the experimental condition. Results indicated that training in Writing Competence could compensate for weaknesses in auditory working memory, visual working memory and cognitive flexibility in children diagnosed with dyslexia. Moreover, training in Phonemic Awareness compensated for visual and auditory memory; the latter also applied to the training in Prosodic Awareness. Furthermore, we found that training in Phonemic Awareness in typically developing children seemed to compensate for visual working memory and cognitive flexibility, and training in Prosodic Awareness and Context-Dependent Words seemed to compensate for auditory working memory.

4.4. Discussion

The current study investigated the usefulness of an online dynamic reading and writing test. We thereby expanded on the existing research on dynamic literacy testing by incorporating phonemic and prosodic awareness and knowledge of writing words and homophones into the online dynamic reading and writing test for primary school children. The results indicated that the online reading and writing training had improved the performances of typically developing children and children diagnosed with dyslexia on Phonemic Awareness, Writing Competence and Context-Dependent Words in the experimental condition. At the same time, only those trained in Prosodic Awareness demonstrated significant performance improvements beyond the effect of practice, suggesting that the extra instruction and practice with the assistance of an adult in Prosodic Awareness might have tapped into children's potential for learning. Unexpectedly, children diagnosed with dyslexia showed similar performance improvement as their age-related peers. This is an essential finding because training effectiveness is not always found in children diagnosed with dyslexia, as they show persistent difficulties in reading and writing (Aravena et al., 2018). This finding underlines the value of reciprocal learning of reading and writing skills in children diagnosed with dyslexia. The unexpected performance increase of the children in the control condition might be explained by a practice effect. Direct repetition and recognising test items could have improved performance scores. On the other hand, the decrease in scores on Prosodic Awareness might be caused by a reduction in motivation; completing this subtest twice in a row might have been less attractive.

Furthermore, the current study aimed to understand the relationship between static and dynamic reading and writing measures and executive functioning. Our results support prior research, which indicates the importance of working memory concerning reading and writing skills. Indeed, reading and writing require remembering what has been read or heard, implicating working memory (Peng et al., 2018).

The performances on the online dynamic reading and writing posttest seemed less dependent on executive functioning. This finding advocates the use of dynamic testing principles as scores were less biased by the level of executive functioning. Training in Phonemic Awareness and Prosodic Awareness seemed to compensate for weaknesses in executive functions in typically developing children and children diagnosed with dyslexia. These results are supported by Sadasivan et al. (2012), who found that phonological awareness training, for example, could enhance reading and visual working memory skills. The training content, which included teaching reading and writing skills on an abstract level and then working towards a concrete level, and the visually supported instructions might have contributed to the compensatory effect of training. This finding is intriguing, given the importance of well-developed executive functions in literacy development (O'Brien & Yeatman, 2021).

In some studies, it was found that children diagnosed with dyslexia are known to experience executive functioning problems like cognitive flexibility (Dadgar et al., 2022). In the current study, we did not, however, find any significant differences in the cognitive flexibility of children diagnosed with dyslexia and their typically developing peers. Needless to say, this finding requires further research, but could be due to the fact that cognitive flexibility was operationalised as verbal fluency in the current study. Research has suggested that verbal fluency tasks rely more on children's vocabulary than language knowledge, allowing children with dyslexia to complete this test at a comparable level to typically developing children (Medina & Guimarães, 2021).

Lastly, the current study aimed to understand the relationship between static and dynamic reading and writing measures and reading self-concept. However, unexpectedly, reading self-concept correlated positively with the static writing scores of the typically developing children. Although writing skills complement reading skills (Galuschka et al., 2020), this finding needs further investigation. Given the effect of lower reading self-concept on motivation (Bagazi, 2022), future studies may want to explore further the impact of explicit writing instruction on reading self-concept.

No relationship was found between the posttest online dynamic reading scores and reading self-concept. This could mean that reading self-concept did not negatively affect the ability to profit from repeated practice or instruction. Perhaps this was due to training being too short to impact, the fact that those diagnosed with dyslexia might have no clear insight into their reading and writing performance (Grills et al., 2014) or the relatively young age of the participating children. As a strong relationship between academic self-concept and academic achievement in distance learners was found (Ajmal & Rafique, 2018), the online administration of the reading and writing subtests was not expected to affect these results.

Conclusion

This study contributed to the existing research on dynamic testing of reading and writing in an online environment. It was demonstrated that children diagnosed with dyslexia could equally benefit from online dynamic reading and writing training compared to typically developing children. More importantly, it seemed that online administration did not appear to be an obstacle to improving reading and writing performances, implying that the potential for learning can be assessed in an online environment. The current study provided a first indication that dynamic testing principles can be used successfully to gain insight into the reading and writing skills of typically developing children and those with dyslexia. Moreover, it seems that, to some extent, dynamic testing seems to compensate for weaknesses in executive functioning.

Recommendations

Therefore, it is recommended that teachers or educational psychologists use dynamic testing principles when assessing the reading and writing abilities of children who are in the process of learning to read and write, especially if they are known or suspected to have weaknesses in executive functions. These principles can, as the current study demonstrates, also be applied in an online environment, for example, in times of social distancing or if geographical distance is an issue to consider. Furthermore, the results of this study can be interpreted as a step towards more research in the Netherlands in the field of (online) dynamic testing of reading and writing. In doing so, we specifically recommend that future researchers adjust the difficulty of the test items, which would make the online dynamic reading and writing test available for a wider age range. Furthermore, it is recommended that future researchers evaluate the type and amount of hints given in training to create a better connection between hints and the test items. Moreover, as sample size might have contributed to the results, future researchers should aim for a larger sample size to obtain more statistical power.

Limitations

Although our study might have been the first online dynamic test which combined reading and writing skills in the Dutch language area, the following limitations of the study should be kept in mind when interpreting the results. First, a ceiling effect might have occurred, especially regarding the results of the typically developing children, as the test items belonging to the other subtests might have been too easy for them, which left no room for further improvement from pretest to posttest. Second, relatively small subgroups were used due to the low number of participants.

Chapter 5

Predicting the receptiveness to clinical dyslexia interventions with a dynamic reading and writing test

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de Vreeze-Westgeest, M.G.J. , Mata, S., Serrano, F., Vogelaar, B. (submitted). Predicting the receptiveness to clinical dyslexia interventions with a dynamic reading and writing test.

Abstract: In this study, we were interested in the effectiveness of a dynamic reading and writing test for children diagnosed with dyslexia (*N* = 42) aged seven to eleven. Most of all, we were interested in whether the results of a dynamic reading and writing test could predict receptiveness to clinical dyslexia intervention. This study employed a pretest-training-posttest design with two conditions: experimental (*n* = 21) for trained children and control (*n* = 21) for children without training. Results showed that, despite the absence of statistically significant growth in accuracy scores from pretest to posttest, children diagnosed with dyslexia could benefit from training in phonemic awareness and writing competency. Dynamic posttest accuracy scores of the subtests Context-Dependent Words, Writing Competence and Phonemic Awareness predicted receptiveness to clinical dyslexia interventions. Implications for dyslexia clinicians are discussed.

5.1. Introduction

Dyslexia clinicians often measure the effect of their interventions by utilising one-time, single-administrated, static tests. While these tests have clear advantages, such as measuring what knowledge a child has already acquired and easily interpretable results (Caffrey et al., 2008), educational scientists have debated the usability of these static tests. Central to this discussion is whether these tests provide sufficient insight into a child's potential for learning and needs for instruction (Grigorenko, 2009; Jeltova et al., 2007). In addition, researchers have argued that static tests disadvantage certain groups of children, for example, children with learning difficulties or children from ethnic minorities (Caffrey et al., 2008; Verpalen et al., 2018).

Therefore, opponents of static testing have introduced dynamic testing as an alternative or at least as an addition to static testing (Bridges & Catts, 2011; Kazemi et al., 2021; Swanson & Howard, 2005). Dynamic tests explicitly include help or instruction in the testing procedure, whereby the relationship between the child and the adult is essential (Cho et al., 2014; Feuerstein, 2002; Grigorenko & Sternberg, 1998; Jeltova et al., 2007). In so doing, the primary aim of dynamic tests is to provide insight into the learning process and potential for an individual child's learning.

Studies show that using dynamic testing principles could reduce under- and over-identification of learning difficulties in young children (Dixon et al., 2022) and, consequently, could provide better insight into future reading and writing difficulties than static tests (Aravena et al., 2017; Gellert & Elbro, 2017; Petersen et al., 2016). Unfortunately, in the Netherlands, dyslexia clinicians have not yet embraced dynamic testing principles in their interventions. Therefore, in the current study, we aimed to gain insight into the usefulness of a dynamic reading and writing test among children diagnosed with dyslexia by examining whether children's dynamic reading and writing test outcomes could predict receptiveness to a clinical dyslexia intervention.

Dynamic testing

Unlike static tests, which focus on evaluating existing skills and knowledge, dynamic tests focus on measuring the potential for learning by tapping into the zone of proximal development (Jeltova et al., 2007). In short, the zone of proximal development concerns the distance between what a child can do alone, the current level of development, and what a child can do under an adult or expert's supervision, the level of potential development (Vygotsky, 1978). Often, this is done by incorporating a training procedure into the testing procedure (Resing et al., 2020), for instance, as part of a pretest-training-posttest design (Grigorenko, 2009). In these designs, the pretest measures the child's independent, actual level of performance, while the posttest, similar in form and content to the pretest, is believed to measure the level of potential development (Donovan, 2019). These designs enable a clinician or researcher to obtain a closer insight into a child's learning processes (Donovan, 2019) and receptiveness to instruction, which are essential in determining a child's educational needs. In this respect, dynamic testing outcomes can be used as a first step to determine which areas in the skills tested could develop further and what help or instructions are necessary to facilitate this (Dixon et al., 2022).

Dynamic testing can take different forms depending on the purpose of the study, varying, for example, in the extent to which they are individualised or standardised (Kazemi et al., 2021) or the domain in which the skills are being evaluated. Numerous studies have explored the usefulness of dynamic testing in various domains. However, research into dynamic testing of reading and writing mainly occurred in Kindergarten settings and concentrated on children's decoding processes and phonological awareness (Petersen et al., 2016). Although dynamic testing can be laborious (Caffrey et al., 2008), research indicated that dynamic tests could be used to predict future reading difficulties over and beyond the effects of static tests (Caffrey et al., 2008; Dixon et al., 2022; Dörfler et al., 2009). More importantly, dynamic tests are instrumental in identifying responsiveness to instruction, distinguishing between children with and without language difficulties and predicting learning difficulties before formal reading instruction starts (Aravena et al., 2017; Caffrey et al., 2008; Gellert & Elbro, 2017; Petersen et al., 2016).

Reading and writing

Reading or decoding is the process of understanding and interpreting written words and involves recognising graphemes (written symbols representing a unit of sound) and subsequently connecting them to corresponding phonemes (the individual letter sounds; Serrano & Defior, 2008). In contrast, writing or encoding is the ability to produce words by correctly arranging graphemes to represent the phonemes of words based on knowledge of letter-sound relationships and oral language (Vadasy et al., 2022). In every language, literacy development consistently progresses from an initial declarative phase to a procedural one. During the declarative phase, children acquire knowledge through conscious, effortful engagement with language skills as they lay the foundation for their reading and writing abilities (Tilanus et al., 2016). This phase involves explicit instruction on grapheme-phoneme correspondence, grammar rules and techniques for memorising frequently used words. As children transition into the procedural phase, they move towards perfecting their skills and adopting more strategies. Here, literacy is more characterised by automaticity, fluency and reduced reliance on conscious effort and explicit knowledge (Melby-Lervåg et al., 2012; Tilanus et al., 2016). In this phase, children develop advanced decoding abilities, comprehend textual content more effectively, and grasp basic decoding skills essential for structuring their thoughts into coherent narratives (Graham et al., 2002).

Basic decoding and encoding skills involve acquiring alphabetical knowledge and understanding grapheme-phoneme correspondences (Galuschka et al., 2020), phonological awareness and prosodic awareness (Serrano et al., 2016; Vadasy et al., 2022). Phonological awareness refers to listening and consciously understanding that sentences consist of words, words of syllables and letters, and it is a requirement for the ability to rhyme (Jing et al., 2019).

In orthographically transparent writing systems, correspondences between graphemes and phonemes are predominantly direct and transparent, with a grapheme typically representing one phoneme. In contrast, orthographically opaque systems involve more complex relationships in which multiple graphemes may represent the same phoneme or one grapheme may represent multiple phonemes (Serrano & Defior, 2008). It is widely recognised that alphabetic writing systems vary in their degree of orthographic transparency or opacity, depending on the consistency of their coding. On this continuum, for example, Spanish is often seen as having orthographic transparency, while English as having orthographic opacity.

On the other hand, Dutch falls somewhere between orthographic transparency and orthographic opacity (Hengeveld & Leufkens, 2018; Serrano & Defior, 2008). Research has indicated that phonological decoding abilities are acquired earlier in orthographically transparent languages than in orthographic opaque languages (Serrano & Defior, 2008). The level of orthographic transparency influences whether children use indirect or direct reading routes (Ardila & Cuetos, 2016). In transparent orthographic languages, readers typically rely on the indirect strategy of converting graphemes to phonemes individually due to the consistent grapheme-phoneme correspondence, which leads to accurate pronunciation. Conversely, in orthographic opaque languages, the direct strategy relies upon word recognition directly from memory, where word representations are stored as necessary due to inconsistent grapheme-phoneme correspondence (Ardila & Cuetos, 2016). Phonological awareness strongly predicts reading and writing development (Bridges & Catts, 2011; Carroll et al., 2014; Lyster et al., 2020; Wackerle-Hollman et al., 2015).

Furthermore, basic decoding and encoding skills require phonemic awareness, which concerns the smallest units of spoken language and the ability to manipulate, isolate and process these sound representations (Nithart et al., 2011; Pfost et al., 2019). Prosodic awareness indicates or distinguishes an emphasis while reading or writing (Godde et al., 2020; Serrano & Defior, 2008; Serrano et al., 2016). As such, phonological, phonemic and prosodic awareness are essential to developing reading and writing skills, which can remain challenging for many children, especially those diagnosed with dyslexia.

Dyslexia

Dyslexia is a language-based learning and neurodevelopmental disorder that affects decoding, fluent word recognition, accurate reading and writing despite adequate instruction (Catts et al., 2016; Elbro et al., 2012; Lyon et al., 2003). Dyslexia manifests differently in orthographic transparent and orthographic opaque languages, with reading speed difficulties being a key marker in orthographic transparent languages and accuracy difficulties more prevalent in orthographic opaque languages (Serrano & Defior, 2008). Although the aetiology of dyslexia is multifactorial (Werth, 2018), and the manifestation of dyslexia is heterogeneous (McArthur & Castles, 2016), dyslexia is primarily believed to be a phonological deficit (O'Brien & Yeatman, 2021; Sigurdardottir et al., 2017), and involves deficits in verbal processing speed, phonological processing and verbal short-term memory (Catts et al., 2016; Tilanus et al., 2016). In addition, other factors, such as visual difficulties, sensory deficits, tone perception deficits and heredity (Carroll et al., 2014; O'Brien & Yeatman, 2021) cannot be excluded because there are also children who, despite phonological deficits, learn to read and write at an acceptable level (Lyster et al., 2020). Solid language skills and good executive functioning (O'Brien & Yeatman, 2021) are believed to compensate for reading and writing difficulties.

In addition to reading and writing difficulties, dyslexia can affect children's social-emotional development. Research, for example, shows that being diagnosed with dyslexia affects self-confidence and can lead to social problems, anxiety and even depression (McArthur & Castles, 2016; van der Zandt et al., 2018). In light of these findings and those mentioned above, it comes as no surprise that much research has been conducted on appropriate and effective clinical dyslexia intervention (Macdonald et al., 2021). Clinical dyslexia interventions aim to improve or compensate for reading and spelling difficulties. Although clinical dyslexia interventions vary in approach, use of a computer, theoretical background, and duration, they generally improve short- and longer-term reading and writing skills (Vaessen et al., 2014). Various factors have been shown to influence the effect of such interventions, including the age of children and the severity of dyslexia (Vaessen et al., 2014). Research indicates that interventions are particularly effective if they focus on morphological and phonemic awareness and integrate explicit reading and spelling instruction (Galuschka et al., 2020; Hall et al., 2022). Moreover, at least 20 weekly clinical dyslexia treatment sessions are necessary to achieve observable intervention effects (Isabel et al., 2012). While static tests have been employed to predict responsiveness to clinical dyslexia interventions (Tilanus et al., 2016), dynamic tests have not been utilised yet.

Aims of the current study

The current study had two aims. The first aim was to evaluate the applicability of a dynamic reading and writing test for children between seven and eleven, an age group that has received limited attention in dynamic research on reading and writing, diagnosed with dyslexia. Secondly, this study aimed to investigate the potential predictive value of dynamic reading and writing measures in relation to the outcomes of a clinical dyslexia intervention.

The first research question concerned children's progression on the dynamic test for reading and writing from the pretest to the posttest. It was expected that all children, regardless of condition, would show progression in accuracy scores, but, more importantly, that those who were trained would show significantly more progression in accuracy scores (Aravena et al., 2017; Dixon et al., 2022; Mata & Serrano, 2019; Navarro & Lara, 2017), indicating that training contributed to developing reading and writing skills (Mata & Serrano, 2019).

The second research question focused on the potential predictive value of dynamic reading and writing measures in relation to the outcomes of clinical dyslexia intervention. Posttest scores of the children in the control condition were regarded as static measures, and the posttest scores of the trained children were regarded as dynamic measures. We hypothesised that dynamic reading and writing measures would better predict the outcomes of the evaluation of intervention than static reading and writing measures (posttest scores of the children in the control condition). This hypothesis was based on previous studies in which dynamic decoding and phonological awareness measures were found to significantly predict intervention response (Cho et al., 2014; Fuchs et al., 2011; Petersen et al., 2018b).

5.2. Method

Participants

In the current study, children diagnosed with dyslexia, aged between seven and eleven, participated, including 20 boys and 22 girls ($M_{age} = 9.5$ years, $SD_{age} = 1.3$ years). The children attended regular or special primary schools and were recruited from 1801 Jeugd en Onderwijsadvies, an educational service and clinical dyslexia assessment and intervention centre in the Netherlands. All children were classified with severe dyslexia, according to the definition used in the Dutch Protocol for Dyslexia Diagnostics and Intervention (Tijms et al., 2021), which implied that their reading and writing performance was at or lower than the 10th percentile compared to their age mates.

Design and procedure

This study had an experimental pretest-training-posttest design with two conditions: experimental (training) and control (no training). Furthermore, it consisted of three phases, as seen in Table 1. Children were allocated to the experimental or the control condition, using a randomised block design based on age and gender. In the first phase, the dynamic test was administered. Children in the experimental condition received training between the pretest and posttest, while children in the control condition did not receive training. Then, in phase two, all the children received the clinical dyslexia intervention 'Letterlicht' (see below for more details). Finally, in phase three, an evaluation of the clinical dyslexia intervention was administered. Trained master's students and clinicians acted as test leaders under the supervision of the first author.

Table 1

Schematic Overview of the Design of the Study

	Phase 1 60-75 minutes			Phase 2 12 x 45 minutes	Phase 3 45-60 minutes
	The dynamic test of reading and writing			Dyslexia treatment [1]	Evaluation of intervention [2]
	Pretest	Training	Pos-test		
Control Condition (n= 22)	X	-	X	X	X
Experimental Condition (n= 20)	X	X	X	X	X

Note 1. Clinical dyslexia intervention Letterlicht.

Note 2. The evaluation of the intervention consisted of the following tests: Word Reading Fluency, Pseudoword Reading, Letter Dictation, Naming Letters and Word Dictation.

Materials and methods

Word Reading Fluency[EenMinuut Test](Brus &Voeten, 2019): Word Reading Fluency tests measures real-world reading skills. In one minute, the child had to recognise words as accurately and efficiently as possible. The child received a piece of paper with 116 words of increasing difficulty and length. The words are placed in four columns of equal length and presented in Universe typeface, font size 18. The child was given a minute to read as many words as possible. Scoring is based on the number of words read correctly. The test consisted of two parallel tests, form A, administered during the dyslexia assessment, and form B, administered during the evaluation of intervention. Brus and Voeten (2019) reported a test-retest reliability of r =. 96.

Pseudoword Reading [Klepel-$R_{1\ min}$ form A](van den Bos et al., 2019): Pseudoword Reading $_{1\ min}$ was used to assess the children's decoding skills. Alphabetical knowledge must be deployed to integrate the graphemes into a word. The child received a paper with 116 unrelated pseudowords of increasing difficulty. The words were placed in four columns of equal length and presented in Universe typeface, font size 18. The child had to read as many words as correctly as possible in one minute. Scoring is based on the amount of correctly read words. The test consists of two parallel tests: form A, administered during the dyslexia assessment, and form B, administered during the evaluation of intervention. The Klepel-R_{1min} has a test-retest reliability r =. 97 for nine and ten-year-old children and test-retest reliability of r = .91 for seven and eight-year-olds (van den Bos et al., 2019).

Letter Dictation [Foneemkennisaccuratesse](Struiksma et al., 2018): This task was used to test the accuracy of writing 36 phoneme-grapheme associations in about five minutes.

Letter Naming [Letterbenoemtaak](Struiksma et al., 2018). This task was used to test the accuracy and speed of 34 grapheme-phoneme associations presented on a card. Scoring is based on the number of correctly named graphemes and the time on task. The required time is displayed in an A score for completing the task within 26 seconds and an E score for completing the task in more than 48 seconds.

Word Dictation [PI-dictee](Geelhoed et al., 2019): word dictation assessed single-word writing skills. The dictation consisted of nine blocks of 15 words, and new spelling categories appeared in each block. The words were read aloud, and the child was asked to write down the specific word first presented in a sentence. The test was discontinued when a child had written seven or fewer words out of 15 words correctly. The maximum score is 135. Therefore, the duration of the dictation is, at the most, 45 minutes. Scoring was based on the number of correctly written words. The test consisted of two parallel tests, form A, administered during the dyslexia assessment, and form B, administered during the evaluation of intervention. The testing manual reports an internal consistency of α =. 87 for the A form and α = .89 for the B form.

Dynamic reading and writing test (Mata & Serrano, 2019) assesses the potential for learning reading and writing. The test is structured into four subtests: Phonemic Awareness, Prosodic Awareness, Writing Competence skills and Context-Dependent Words. Each subtest follows a consistent format, comprising a pretest, a standardised training phase and a posttest. During the pretest, the child solves the tasks independently. During the posttest, the child is challenged to show what was learned by solving the same tasks of the pretest. The second or training phase involves task accuracy scores reflection, task retelling and various exercises using materials. These exercises advance from abstract to task-specific levels to improve the targeted skills. Each subtest yields two scores: the pretest score, reflecting the current level of (a static test score), and the posttest score, which measures the improvement from pretest to posttest. The test lasts 60 to 80 minutes and designates 15 to 20 minutes for each subtest. The dynamic reading and writing test was initially developed in Spanish by Mata and Serrano (2019) and translated into Dutch.

Phonemic Awareness: The Phonemic Awareness subtest assesses the ability to construct words by identifying smaller units (phonemes). Fourteen words are presented in sounds, and the child must determine which word has been said. The test is stopped after three consecutive errors. The reported reliability of this subtest is α = .89 (Mata & Serrano, 2019).

Prosodic Awareness: The Prosodic Awareness subtest measures the awareness of emphasis in a word. The children listen to eighteen recorded words and must determine the sound group with the most force. The test is stopped after three consecutive errors. The reliability of this subtest is α = .87 (Mata & Serrano, 2019).

Writing Competence: The subtest evaluates the child's ability to write words correctly, and the use of writing and phonological rules in words and sentences are evaluated with this subtest. Twenty-five words are dictated twice to the child. The test is stopped after three consecutive errors. The reported reliability of this subtest α = .83 (Mata & Serrano, 2019).

Context-Dependent Words: The subtest measured the ability to determine the correct form of a homophonic word in the context of a sentence. Eighteen sentences with a missing homophone are presented. The correct answer must be chosen from three words: a word slightly similar to the homophones and two homophones. The test is stopped after three successive errors. The reported reliability of this subtest is α = .62 (Mata & Serrano, 2019).

Clinical Dyslexia Intervention [Letterlicht by 1801 jeugdenonderwijsadvies]: Letterlicht is a computer-controlled dyslexia intervention that aims to improve language skills and increase motivation and pleasure in reading and writing. It is created by 1801 jeugd- en onderwijsadvies. Although the program is protocolled, it can be adjusted to the child's educational needs by speeding up, slowing down or providing additional exercises. Letterlicht aims to strengthen basic literacy skills like phonemic awareness by mainly working on auditory perception (listening to the sounds in a word). The sound structure of words is taught explicitly. For example, much attention is paid to the vowels because the pronunciation of vowels in Dutch does not always correspond to the writing. Furthermore, the position of the vowels is essential because the properties of the vowel (long or short) will determine the basic writing rules. The primary strategy taught is to divide words into sounds (phonological awareness), starting with one sound group of words and, after that, with more than one sound group. Roadmaps and visual support cards are deployed to support the children visually.

The total duration of the intervention more or less equals a school year, including 38 weekly 45-minute sessions with a trained dyslexia clinician who provides feedback and support. Each session has the same structure every week, including discussing homework, activating prior knowledge, learning new writing rules, reading letters and words, and reading sentences/texts. At the end of each session, the child is given four homework assignments on which he or she must work with the parents. The child's progress in reading and writing is evaluated regularly pending the duration of the clinical dyslexia intervention and at the end of the intervention. Parents and teachers are expected to be involved in the intervention by helping with homework.

5.3. Results

Before conducting our analyses, assumptions for normality were checked for the accuracy scores of the dynamic reading and writing subtests through the Shapiro-Wilk test. The findings indicated that assumptions for normality were met in the control group for Prosodic Awareness D (21) = .910, p > .05. In the experimental condition, assumptions for normality were met for Prosodic Awareness D (21) = .919, p > .05. Furthermore, assumptions for homogeneity were checked through Levene's test. The assumptions for the homogeneity analysis indicated that assumptions were met for all variables.

Initial group comparisons

A one-way MANOVA was conducted to explore potential initial group differences. The dependent variables in this analysis included age and the pretest accuracy scores of the four dynamic reading and writing subtests. The independent variable was Condition (experimental versus control condition). An analysis of the multivariate and univariate Condition effects revealed no significant differences between the children in the two conditions, as seen in Table 2 (Means and standard deviations can be found in Table 3).

Table 2

MANOVA results for differences in condition

n	Wilk's λ	*F(1,40)*	*p*	η_p^2
Multivariate between-subjects effect of condition	.98	.17	.97	.02
Univariate condition effects				
Age		.18	.67	.01
Phonemic Awareness		.35	.56	.01
Prosodic Awareness		.01	.93	<.01
Writing Competence		.04	.85	<.01
Context-Dependent Words		.03	.86	<.01

Table 3

Basic Statistics for Scores on all Dynamic Reading and Writing Subtests at Pre- and Posttest

		Experimental Condition		Control Condition		Total	Total
		Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
n		21	21	21	21	42	42
Phonemic Awareness	*M* *(SD)*	8.95 (2.58)	10.62 (2.46)	8.38 (3.60)	9.14 (4.68)	8.67 (3.11)	9.88 (3.77)
Prosodic Awareness	*M* *(SD)*	5.76 (4.88)	5.29 (5.93)	5.90 (5.30)	4.67 (5.62)	5.83 (5.03)	4.98 (5.72)
Writing Competence	*M* *(SD)*	14.33 (5.76)	15.67 (6.41)	14.67 (5.27)	14.52 (5.41)	14.50 (5.45)	15.10 (5.89)
Context-Dependent Words	*M* *(SD)*	11.24 (4.35)	11.29 (5.39)	11.00 (4.18)	11.62 (3.50)	11.12 (4.22)	11.45 (4.49)

Finally, a Chi-square analysis was conducted to investigate whether boys and girls were equally distributed across the two conditions. Results revealed a similar distribution of boys and girls across conditions ($\chi 2$ (1) < .001, *p* = 1.00).

Psychometric properties of dynamic reading and writing test

Test-retest reliability of all dynamic reading and writing subtests was analysed using Pearson's correlations separately for the control and experimental conditions. Positive, significant correlations, ranging from moderate to strong, between pretest and posttest scores were found for all subtests in the control and experimental conditions, as seen in Table 4.

Table 4

Pearson Product-Moment Correlation Matrix between Dynamic Reading and Writing Measures at Pretest and Posttest

	Pretest			
	Phonemic Awareness	Prosodic Awareness	Writing Competence	Context-Dependent Words
Posttest				
Control condition	.92**	.67**	.82**	.55**
Experimental condition	.78**	.64**	.73**	.48*

Significance * $p< .05$, ** $p< .01$

Fisher's r-to-z transformations were performed to investigate if these correlations differed significantly between the two conditions. These analyses revealed that the difference between test-retest correlations of the Phonemic Awareness subtest bordered on statistical significance ($z = 1.63$, $p = .051$). In contrast, no statistically significant differences were found for the test-retest correlations of Prosodic Awareness ($z = 0.16$, $p = .437$), Writing Competence ($z = 0.68$, $p = .247$) and Context-Dependent Words ($z = 0.29$, $p = .387$).

Cronbach's alpha coefficients were calculated to analyse the internal consistency of the subtests at the pretest with scores ranging from $\alpha = .83$ for the subtest Phonemic Awareness, $\alpha = .84$ for the subtest Context-dependent Words, $\alpha = .91$ for the subtest Prosodic Awareness and finally $\alpha = .98$ for the subtest Writing Competence.

Effect of training

A Repeated Measures Multivariate Analysis of Variance (RM MANOVA) was employed to address the first research question. Session (pretest versus posttest) was considered a within-subjects factor, and Condition (experimental versus control) a between-subjects factor. In addition, the dependent variables were accuracy scores on the dynamic reading and writing subtests of Phonemic Awareness, Prosodic Awareness, Writing Competence, and Context-Dependent Words.

All effects are displayed in Table 5. The multivariate results indicated a significant Session effect ($p < .001$, $\eta_p^2 = .44$) but no significant Session x Condition effect ($p =.781$, $\eta_p^2 = .05$). These findings indicate a significant difference between pretest and posttest in at least one dynamic reading and writing subtest, irrespective of whether the children were trained. Basic statistics for the different subtest scores are provided in Table 6. Additionally, the mean scores of all subtests are displayed in Figure 1.

Follow-up analyses of the univariate effects further demonstrated that only the Session effect for Phonemic Awareness ($p < 001$, $\eta_p^2 = .42$) was significant, indicating in combination with a visual check of the mean scores that all groups of children progressed from the pretest to the posttest. Moreover, no significant differences in progression were found between the two conditions, as witnessed by non-significant Session x Condition effects for all subtests.

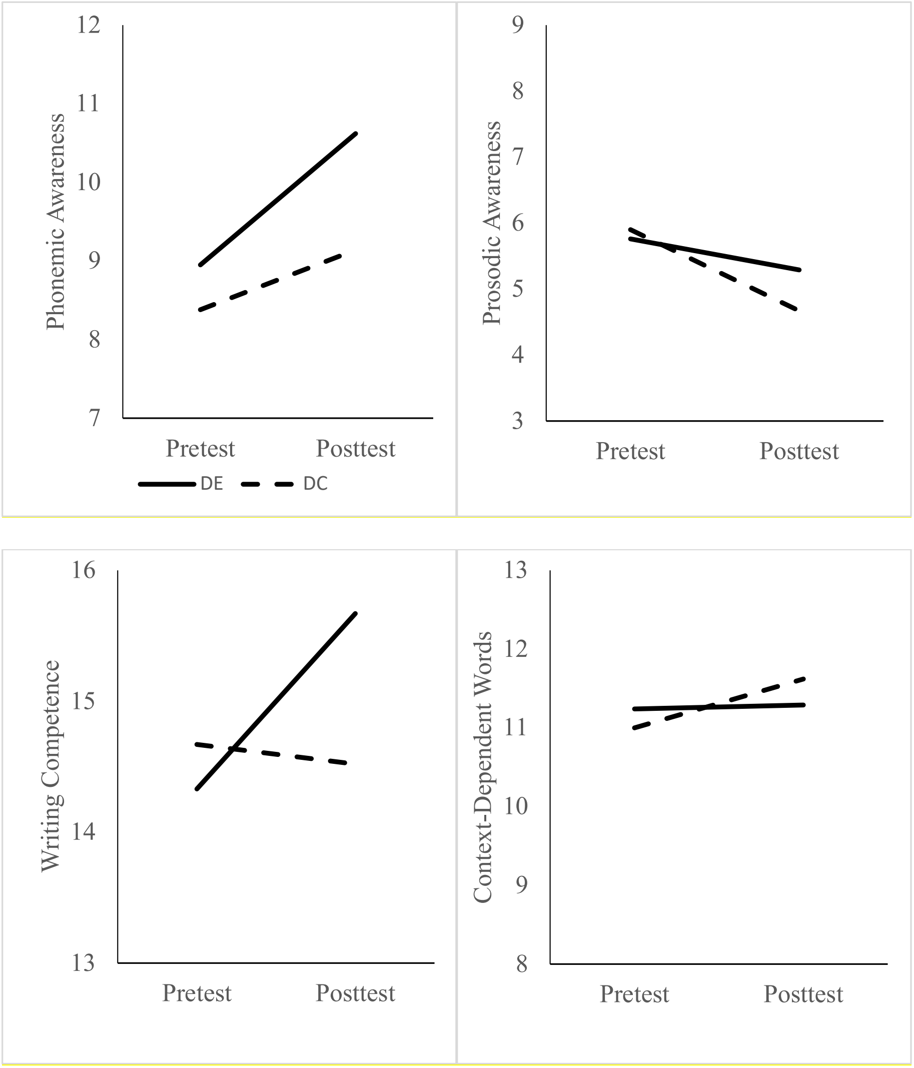
Table 5

Between-subject effects and Multivariate and Univariate RM MANOVA outcomes

	Wilk's λ	*F*	*p*	η_p^2
Multivariate within-subjects effects				
Session	.57	7.11	<.001	.44
Session x Condition	.96	.44	.781	.05
Univariate within-subjects effects				
Phonemic Awareness				
Session		29.23	< .001	.42
Session x Condition		.36	.551	.01
Prosodic Awareness				
Session		1.49	.230	.04
Session x Condition		.29	.591	.01
Writing Competence				
Session		1.62	.211	.04
Session x Condition		.91	.346	.02
Context-Dependent Words				
Session		.17	.679	.00
Session x Condition		.12	.730	.00

Figure 1

Mean Accuracy Scores of Dynamic Reading and Writing Subtests



Note. DE= children diagnosed with dyslexia Experimental Condition, DC= children diagnosed with dyslexia Control Condition.

Predicting receptiveness to clinical dyslexia intervention

Six linear regression analyses were performed, one for each measure of the evaluation of the intervention, to investigate whether the dynamic test's posttest scores could predict the evaluation of the intervention. For this analysis, the results of the children in the two conditions were analysed separately. The dependent variables included Word Reading Fluency, Pseudoword Reading, Word Dictation, Letter Dictation and Letter Naming (speed and accuracy). The independent variables were the posttest accuracy scores on Phonemic Awareness, Prosodic Awareness, Writing Competence and Context-Dependent Words. All effects of these analyses are provided in Table 6, and only the significant effects are discussed in the text.

In the experimental condition, a significant model fit was found for Word Reading Fluency ($F(1,16) = 7.94$, $p = .001$), explaining 67% of the variance ($R^2 = 0.67$). Both Writing Competence ($b = 1.03$ $p = .003$) and Context-Dependent Words ($b = 1.16$, $p = .004$) significantly predicted Word Reading Fluency. Furthermore, a significant model fit was found for Word Dictation ($F(4,16) = 12.00$, $p <.001$), explaining 75% of the variance ($R^2 = 0.75$). Both Writing Competence ($b = 3.53$, $p < .001$) and Context-Dependent Words ($b = 2.19$, $p = .014$) were found to predict Word Dictation significantly. Lastly, results revealed a significant model fit for Letter Naming (speed) ($F(4,16) = 3.06$, $p = .047$), explaining 43% of the variance ($R^2 = 0.43$). Phonemic Awareness ($b = -2.01$, $p = .010$) significantly predicted the subtest Letter Naming (speed). These findings suggest that higher accuracy scores on Writing Competence and Context-Dependent Words led to children scoring higher on Word Reading Fluency and Word Dictation. Furthermore, higher accuracy scores on Phonemic Awareness could predict Letter Naming (speed). Overall, these findings support the hypothesis that the posttest scores of the children in the experimental condition could predict the outcomes of the evaluation of the intervention, especially for the subtests Phonemic Awareness, Writing Competence and Context-Dependent words.

For the children in the control condition, results also revealed a significant model fit for Pseudoword Reading ($F(4,16) = 3.99$, $p = .02$), explaining 50 % of the variance ($R^2 = 0.50$). Prosodic Awareness ($b = 1.17$, $p = .032$) significantly predicted Pseudoword Reading. Furthermore, a significant model fit for Word Dictation ($F(4,16) = 7.30$, $p = .002$) was found, explaining 65% of the variance ($R^2 = 0.65$). Writing Competence ($b = 2.68$, $p = .001$) significantly predicted Word Dictation. These findings, in turn, suggest that higher accuracy scores on Prosodic Awareness could predict pseudoword reading, and scores on Writing

Competence could predict word dictation. These findings partially align with our hypothesis that the dynamic measures would possess greater predictive validity for outcomes of clinical dyslexia interventions.

Table 6

Linear regression Matrix between the Dynamic Reading and Writing posttest subtests and the First Dyslexia Intervention Test Results

	Experimental Condition		Control Condition	
Independent variables	*B (SE)*	β	*B (SE)*	β
Word Reading Fluency				
Constant	-0.42 (9.34)		10.72 (9.50)	
Phonemic Awareness	0.59 (0.77)	0.12	0.15 (0.53)	0.06
Prosodic Awareness	0.18 (0.32)	0.09	0.55 (0.44)	0.24
Writing Competence	1.03 (0.29)	0.53**	1.33 (0.47)	0.56
Context-Dependent Words	1.16 (0.35)	0.50**	0.61 (0.67)	0.17
R^2	0.67		0.511	
F	7.94**		4.19*	
Pseudoword Reading				
Constant	0.40 (11.63)		-12.23(10.72)	
Phonemic Awareness	0.65 (0.96)	0.16	0.86 (0.60)	0.28
Prosodic Awareness	0.20 (0.40)	0.12	1.17 (0.50)	0.46*
Writing Competence	0.40 (0.37)	0.25	0.71 (0.53)	0.27
Context-Dependent Words	0.49 (0.43)	0.28	1.07 (0.76)	0.26
R^2	0.215		0.499	
F	1.10		3.99*	
Word Dictation				
Constant	-34.30 (21.44)		6.67 (14.14)	
Phonemic Awareness	1.73 (1.77)	0.13	0.83 (0.79)	0.17
Prosodic Awareness	0.73 (0.73)	0.13	0.44 (0.66)	0.11
Writing Competence	3.53 (0.67)	0.68**	2.68 (0.70)	0.64**
Context-Dependent Words	2.19 (0.80)	0.36*	1.28 (1.00)	0.20

R^2	0.750		0.646	
F	12.00**		7.30**	
Letter Dictation				
Constant	33.61** (1.44)		34.54** (1.89)	
Phonemic Awareness	-0.03 (0.12)	-0.05	-0.06 (0.11)	-0.01
Prosodic Awareness	0.004 (0.05)	0.02	0.09 (0.09)	0.25
Writing Competence	0.05 (0.05)	0.25	0.05 (0.09)	0.15
Context-Dependent Words	0.09 (0.05)	0.37	-0.07 (0.13)	-0.13
R^2	0.225		0.120	
F	1.16		0.54	
Letter Naming (speed)				
Constant	54.65** (8.36)		31.48* (11.98)	
Phonemic Awareness	-2.01 (0.69)	-0.58*	-0.24 (0.67)	-0.09
Prosodic Awareness	0.06 (0.28)	0.04	0.85 (0.56)	0.38
Writing Competence	0.20 (0.26)	0.15	-0.07 (0.59)	-0.03
Context-Dependent Words	-0.62 (0.31)	-0.39	-0.13 (0.85)	-0.04
R^2	0.434		0.173	
F	3.06*		0.84	
Letter Naming (accuracy)				
Constant	33.10** (0.93)		32.36** (0.68)	
Phonemic Awareness	0.08 (0.08)	0.22	0.06 (0.04)	0.40
Prosodic Awareness	-0.05 (0.03)	-0.37	0.04 (0.03)	0.29
Writing Competence	-0.05 (0.03)	-0.33	-0.03 (0.03)	-0.24
Context-Dependent Words	0.06 (0.04)	0.36	0.07 (0.05)	0.31
R^2	0.316		0.251	
F	1.85		1.34	

*p<.05. **p<.01.

5.4. Discussion

This study sought answers to two questions. We investigated whether a dynamic reading and writing test could provide insights into the potential for learning in children diagnosed with dyslexia. Research on dynamic testing has mainly concentrated on predicting future reading and writing difficulties among Kindergarten children (Dixon et al., 2022). Nonetheless, we took a different approach and examined whether the posttest accuracy scores of children, on average in second grade, could be utilised to predict their receptiveness to a clinical dyslexia intervention.

All groups of children showed improved accuracy scores from the pretest to the posttest in Phonemic Awareness, suggesting a learning effect. These findings are consistent with previous studies demonstrating that children diagnosed with dyslexia could improve their accuracy scores from the pretest to the posttest (Mata & Serrano, 2019; de Vreeze-Westgeest et al., 2023). However, unlike in those studies, where significant improvements in accuracy as a consequence of training were observed, this study did not find that training significantly impacted children's accuracy scores beyond the impact of practice. One possible reason for this discrepancy could lie in the different characteristics of the participants in the current study vis-à-vis those conducted in the past. In the current study, children were generally older and had not yet undergone targeted reading and writing interventions typically associated with clinical dyslexia interventions. It is plausible that children might need some time to adapt to the interventions. Perhaps the duration of the training procedure that was part of the dynamic test was not sufficient to capture significant improvement in accuracy scores (Isabel et al., 2012). It is conceivable that a more intensive training procedure would give the children more adaptation time. This remark seems especially salient, considering that a key aspect of a reading disorder is often a limited or insufficient response to treatment, making it challenging to demonstrate responsiveness to interventions, particularly in studies with small sample sizes (Toffalini et al., 2021).

Moreover, differences in orthographic language transparency between Dutch and Spanish could also explain the lack of significant progress from the pretest to the posttest in the current study. The influence of orthographic transparency on the direct route Dutch children take in learning to read may result in variations in the pace at which Dutch children diagnosed with dyslexia develop reading and writing skills compared to their Spanish age-mates. It is proposed that the progression of reading skills in children diagnosed with dyslexia reflects differences in the orthographic complexity of the writing system (Serrano & Defior, 2008).

Additionally, it is speculated that Dutch children diagnosed with dyslexia might encounter more errors in accuracy, potentially impacting their ability to demonstrate progress from pretest to posttest compared to Spanish children (Serrano & Defior,2008). Nevertheless, although no significant effect of training on children's accuracy scores was observed, it was found that children in both conditions, trained or not trained, demonstrated large individual differences in their level of initial ability on the reading and writing subtests, as well as their performance after training, as evidenced by examining their mean and standard scores. These findings indicate that utilising a dynamic reading and writing test, and in so doing obtaining information about individual children's learning curves and progress, may be a useful starting point for teachers and dyslexia clinicians to better understand the specific assistance required by children diagnosed with dyslexia and tailor their interventions to their individual needs.

More importantly, this study revealed that the dynamic posttest measures were better predictors of receptiveness for clinical dyslexia interventions than the static posttest measures. The subtests Writing Competence and Context-Dependent Words mainly emerged consistently as predictors of various reading and writing subtests of the dyslexia evaluation of the intervention. The writing skills focused on during training may especially correspond with the reading and writing skills addressed in the clinical dyslexia intervention program. In this respect, our findings align with the literature where the predictive value of dynamic testing, especially for children with learning difficulties, exceeded that of static tests (Caffrey et al., 2008; Cho et al., 2014; Dixon et al., 2022).

Limitations and Recommendations

In this study, we encountered some limitations. We worked with children diagnosed with dyslexia who had not started clinical dyslexia treatments yet. Because of these strict criteria, there was only a short window to find children eligible for research participation and connect them with dyslexia clinicians and trained master students, leading to logistical challenges. Even though the logistical challenges will remain, in the future, it would be better to aim for larger groups of participants to improve the statistical power. Furthermore, finding no significant training effect raised questions about the specific effectiveness of the dynamic reading and writing test. Evaluating the test items, the content of the training, and the training intensity will present an opportunity for future studies to build upon these findings. In addition, the original dynamic reading and writing test (Mata & Serrano, 2019) contained an observation scale. Integrating quantitative and qualitative dynamic reading and writing measures might help comprehend the individual differences between children.

The utilisation of the scale was beyond the scope of this research. However, future studies may consider employing the observation scales. In doing so, they might be able to develop even more personalised interventions.

Conclusion

The current study indicates that dynamic measures of reading and writing have robust predictive abilities for receptiveness to dyslexia interventions, where the writing subtests had the greatest predictive value. The findings underscored the ability of dynamic reading and writing tests to capture additional information beyond static tests, offering valuable insight to dyslexia clinicians for tailoring the interventions to the educational needs of children diagnosed with dyslexia, as it has been demonstrated that no two children with dyslexia are identical.

Chapter 6

General discussion

As education moves towards greater inclusivity, pinpointing each child's unique educational needs becomes even more crucial, especially in the face of limited education and youth care resources. Teachers are challenged to include all children. Embracing alternative test approaches, such as those described in the current dissertation, holds promise in addressing this challenge.

The present dissertation aimed to investigate the potential effects of cognitive training in mathematical problem-solving and a dynamic test of reading and writing. In so doing, the current dissertation explored the potential for learning and the learning processes of three groups of children: the potentially gifted, typically developing and those diagnosed with dyslexia.

In this concluding chapter, a recapitulation of the main results from the research studies presented in this dissertation was provided. In this way, a perspective on the implications of these alternative approaches compared to the traditional approaches were given from a theoretical and a practical point of view. Finally, limitations and potential avenues for future research were explored.

6.1. Summary of the findings

Cognitive training in mathematical problem-solving in mathematical problem-solving

The study described in Chapter 2 aimed to evaluate how cognitive training in mathematical problem-solving impacted gifted children's working memory and metacognitive knowledge, particularly in mathematical problem-solving, while also investigating the predictive value of intelligence on working memory and metacognitive knowledge. Results revealed improved working memory and metacognition among participants in both experimental and control conditions. Nonetheless, while cognitive training in mathematical problem-solving led to more notable improvements in metacognition than no training, it did not significantly affect working memory. Additionally, intelligence was a significant predictor of verbal and visual working memory but not of metacognitive knowledge.

Dynamic testing of reading and writing

The studies described in Chapters 3, 4, and 5 aimed to evaluate the potential effectiveness of dynamic reading and writing tests. Overall, both typically developing children and children diagnosed with dyslexia in experimental and control conditions showed similar levels of improvement from pretest to posttest in their reading and writing accuracy scores.

Specifically, the training in Prosodic Awareness provided information about children's potential for learning (Chapters 3 and 4), as significant levels of improvement from pretest to posttest over and beyond the effect of practice were observed.

In addition to focusing on the effect of training, Chapter 3 described the relationship between dynamic reading and writing test outcomes on the one hand and static reading and writing outcomes and intelligence on the other. It was found that the dynamic reading and writing measures correlated with static reading and writing tests and intelligence. Particularly noteworthy was the observation that the dynamic writing subtests correlated with the conventional reading tests. Furthermore, a positive relationship was found between intelligence and reading and writing skills, where higher intelligence would imply higher reading and writing scores and vice versa. This relationship was generally the strongest in typically developing children.

Additionally, while concentrating on the effect of training, the study described in Chapter 4 investigated the relationship between online dynamic reading and writing test outcomes on the one hand and executive functioning and reading self-concept on the other. Training in Phonemic Awareness and Prosodic Awareness appeared to compensate for weaknesses in executive functions in typically developing children and children diagnosed with dyslexia. Additionally, among children diagnosed with dyslexia, training in Writing Competence appeared to compensate for weaknesses in cognitive flexibility. Through training, children might exhibit reduced reliance on their executive functions, potentially attributed to the skills acquired during the training.

In addition, training only compensated for reading self-concept in typically developing, not for children diagnosed with dyslexia. Conducting the test online did not hinder improving reading and writing capabilities.

The study described in Chapter 5, while focusing on the effect of training, additionally focused on whether the dynamic reading and writing test could predict receptiveness to clinician dyslexia interventions. Specifically, the dynamic posttest accuracy scores of the subtests Writing Competence, Context-Dependent Words and Phonemic Awareness predicted the children's receptiveness to clinical dyslexia interventions better than the static measures could. The writing skills emphasised during training might align particularly with the reading and writing abilities targeted in the clinical dyslexia intervention.

6.2. Theoretical and practical implications

Cognitive training in mathematical problem-solving

The cognitive training in mathematical problem-solving presented here was based on the original study by Cornoldi et al. (2015). Novel to this context, however, were the participants, the potentially gifted children. By comparing pretest and posttest scores, it became evident that cognitive training in mathematical problem-solving could facilitate potentially gifted children to show their potential for learning on metacognitive knowledge, as measured by a metacognitive questionnaire (Cornoldi et al., 2015). This finding might indicate that the cognitive training in mathematical problem-solving had equipped them with the necessary skills and strategies to reflect on their metacognitive knowledge. These results supported the assertions of multiple authors (Alloway & Elsworth, 2012; Kornman et al., 2015; Veenman et al., 2005; Wexler et al., 2016), emphasising that metacognitive development in potentially gifted children does not develop automatically. This points to the necessity of explicitly teaching metacognitive knowledge through guided discussions and instructions in education, which supports the academic success of potentially gifted children (Othani & Hisasaka, 2018; Taylor & Zaghi, 2021).

Regarding working memory, the potential for learning beyond practice was not revealed. These findings could be explained by several factors related to the nature of cognitive training in mathematical problem-solving. The working memory tasks used in training differed significantly from the pre-and posttest working memory measures. Furthermore, the multifaceted nature of working memory, including its reliance on attention control, susceptibility to interference and demands for manipulation and updating, poses significant challenges to effectively training working memory (Diamond, 2013; Melby-Lervåg et al., 2016).

These findings suggested that cognitive training in mathematical problem-solving had differential effects on different cognitive domains. It further suggests that metacognitive knowledge and working memory are distinctive cognitive processes with varying levels of complexity (Diamond, 2013). Additionally, the study contributed to understanding the relationship between intelligence and metacognition and supported suggestions that intelligence alone might not fully determine the breadth of an individual's metacognitive knowledge (Veenman et al., 1997). Metacognitive knowledge challenges might be encountered despite higher levels of intelligence.

Analysing individual performance revealed unique learning processes of potentially gifted children, allowing strengths and weaknesses to be identified and learning paths to be observed. Cognitive training in mathematical problem-solving seemed beneficial, yet differences in learning processes, as seen in the mean scores and standard deviations of working memory and metacognition, highlighted the diverse nature of the potentially gifted group. Metacognitive knowledge helps children become self-regulated learners, critical thinkers, and problem-solvers who can effectively monitor, control, and adapt their learning. As such, cognitive training is a promising learning instrument. The results of this study underscore the necessity of teaching metacognitive skills to potentially gifted children.

Dynamic testing of reading and writing

The dynamic reading and writing test presented in this dissertation was based on the original Spanish dynamic reading and writing test of Mata and Serrano (2019). Innovative in their assessment was the combined administration of reading and writing tasks in a dynamic test. Previous dynamic testing studies in the Netherlands primarily focused on phonological awareness or decoding skills (Dixon et al., 2022).

The (online) dynamic reading and writing test enabled typically developing children and children diagnosed with dyslexia in a relatively short timeframe to show their potential for learning on Prosodic Awareness (Chapters 3 and 4).

Differences among children, such as the complexity of dyslexia, variations in levels of executive functioning (Peng et al., 2019), levels of motivation (Grills et al., 2014), reading self-concept (Gibby-Leversuch et al., 2021; Zuppardo et al., 2020) and external factors, like access to clinical dyslexia interventions, might have influenced how children responded to the training. Some of these factors are further investigated and described in this dissertation.

Analysing the mean scores of the dynamic reading and writing test shed light on the individual learning paths of typically developing children and children diagnosed with dyslexia. Crucially, children diagnosed with dyslexia notably improved from the pretest to the posttest, mirroring the progress observed in their typically developing peers.

These outcomes contributed to understanding the potential for reading and writing learning and emphasised the diverse nature of reading and writing development in children with dyslexia (Werth, 2018). Considering these factors, the dynamic reading and writing tests further support studies noting that they can be valuable in education as they seemed to be less biased toward children diagnosed with dyslexia (Dixon et al., 2022).

In addition, given that interventions for dyslexia frequently result in limited or inadequate receptiveness progress due to the typical challenges associated with dyslexia (Lyon et al., 2003), the finding of a compelling dynamic reading and writing test is noteworthy.

The finding (Chapter 5) that the dynamic writing subtests consistently emerged as strong predictors of various conventional, static reading and writing tests utilised in clinical dyslexia intervention is novel. Previous studies on dynamic reading and writing have demonstrated that dynamic tests could identify children at risk for reading and writing difficulties in the future (Caffrey et al., 2008; Fuchs et al., 2011; Gellert & Elbro, 2017). Although this was not the focus of the current dissertation, it was also found that dynamic measures could predict receptiveness to clinical dyslexia interventions. Future studies may further investigate this receptiveness.

The dynamic reading and writing posttest measures (Chapter 4) appeared less affected by executive functioning levels compared to static tests, suggesting that the dynamic reading test might be less biased and, therefore, provided a fairer evaluation of abilities.

Additionally (Chapter 3), individual variations in posttest scores revealed changes in correlations between the trained children's posttest scores and intelligence. To fully understand the impact of training on these correlations, further research is necessary. However, findings emphasised the importance of selecting appropriate tests, like dynamic reading and writing tests, in clinical and educational settings to assess and accurately address children's needs. Additionally, the results align with the notion that static intelligence testing may have limitations in guiding specific educational interventions for children, highlighting the value of tailored approaches in supporting literacy development (Elliott & Resing, 2015).

To conclude with practical implications, the dynamic reading and writing test presents itself as a valuable, less biased (Dixon et al., 2022) aid for teachers and dyslexia clinicians in addressing the specific challenges associated with dyslexia for a child and assessing reading and writing skills. Additionally, the information gained from the dynamic reading and writing test leads to better alignment in clinical dyslexia interventions, ultimately resulting in more effective support for children diagnosed with dyslexia.

6.3. Limitations and future research

The studies described in this dissertation faced some limitations. Firstly, the sample size was relatively small, affecting the generalisability and statistical power of the results. Increasing participant numbers in future research will improve statistical power and simplify proving receptiveness to interventions (Toffalini et al., 2021). Additionally, more precise differentiation between poor readers and writers diagnosed with dyslexia and those without dyslexia in dynamic reading and writing test studies could be beneficial (Chapter 4). Struggling readers within the typically developing children group may made improvements from the pretest to the posttest harder to discern (Galuschka, 2018).

Furthermore, it is essential to reconsider test items, training materials, and the frequency of training sessions to maximise the effectiveness of both approaches (Galuschka et al., 2020). Expanding working memory training for cognitive training in mathematical problem-solving with visual tasks could improve its efficacy, given that the original tasks differed from the working memory measurements utilised during the pre-and posttest. Adjustments were already made to the test items of the subtest Phonemic Awareness (after the research described in Chapter 3) and the items and training content of the subtest Writing Competence (after the research described in Chapter 4). Although these modifications improved results, they did not significantly change accuracy scores from the pretest to the posttest.

6.4. Conclusion

Cognitive training in mathematical problem-solving and the dynamic reading and writing test presents an opportunity to improve educational practices and clinical dyslexia interventions by offering a deeper understanding of children's learning paths, strengths and weaknesses, and educational needs. They enable children to demonstrate their potential for learning. By embracing these methodologies, teachers and dyslexia clinicians can further tailor their approach in classrooms and clinical dyslexia interventions to better meet the educational needs of children.

References

A

Ajmal, M. & Rafique, M. (2018). Relationship between academic self-concept and academic achievement of distance learners. *Pakistan Journal of Distance and Online Learning, IV*(11), 225-244. https://doi.org/10.30971/pjdol.v4i2.449

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of experimental child psychology, 106*(1), 20-29. https://doi.org/10.1016/j.jecp.2009.11.003

Alloway, T. P., & Elsworth, M. (2012). An investigation of cognitive skills and behaviour in high ability students. *Learning and Individual Differences, 22*(6), 891-895. https://doi.org/10.1016/j.lindif.2012.02.001

Altemeier, L. E., Abbott, R. D., & Berninger, V. W. (2008). Executive functions for reading and writing in typical literacy development and dyslexia. *Journal of Clinical and Experimental Neuropsychology, 30*(5), 588–606. https://doi.org/10.1080/13803390701562818

Aravena, S., Tijms, J., Snellings, P., & van der Molen, M. W. (2017). Predicting individual differences in reading and spelling skills with artificial script–based letter–speech sound training. *Journal of Learning Disabilities*, *51*(6), 552–564. https://doi.org/10.1177/0022219417715407

Arnoutse, C. A. J. (2004). *Ontwikkeling van beginnende geletterdheid* [Development of early literacy]. Thieme media center.

B

Barab, S. A., & Plucker, J. A. (2002). Smart people or smart contexts? Cognition, ability, and talent development in an age of situated approaches to knowing and learning *Educational Psychologist*, *37*(3), 165–182. https://doi.org/10.1207/s15326985ep3703_3

Bagazi, A. (2022). Reading self-concept and motivation: A perspective from students with reading difficulties. *International Journal of Education and Practice, 10*(4), 334–349. https://doi.org/10.18488/61.v10i4.3197

Bailey, B. A., Andrzejewski, S. K., Greif, S. M., Svingos, A. M., & Heaton, S. C. (2018). The role of executive functioning and academic achievement in the academic self-concept of children and adolescents referred for neuropsychological assessment. *Children (Basel)*, *5*(7), 83. https://doi.org/10.3390/children5070083

Baten, E., Praet, M., & Desoete, A. (2017). The relevance and efficacy of metacognition for instructional design in the domain of mathematics. *ZDM Math Education, 49*(4), 613 623. https://doi.org/10.1007/s11858-0170851-y

Berg, D. H., & McDonald, P. A. (2018). Differences in mathematical reasoning between typically achieving and gifted children. *Journal of Cognitive Psychology, 30*(3), 281 291. https://doi.org/10.1080/20445911.2018.1457034

Berninger, V., & Richards, T. (2010). Inter-relationships among behavioural markers, genes, brain and intervention in dyslexia and dysgraphia. *Future Neurology*, *5*(4), 597– 617. https://doi.org/10.2217/fnl.10.22

Bosma, T., & Resing, W. C. M. (2006). Dynamic assessment and a reversal task: a contribution to needs-based assessment. *Educational and Child Psychology*, *23*(3), 81–98. https://doi.org/10.53841/bpsecp.2006.23.3.81

Bridges, M., & Catts, H. W. (2011). The use of a dynamic screening of phonological awareness to predict risk for reading disabilities in kindergarten children. *Journal of Learning Disabilities*, *44*(4), 330–338. https://doi.org/10.1177/0022219411407863

Brody, L. E., & Mills, C. J. (1997). Gifted children with learning disabilities: A review of the issues. *Journal of learning disabilities, 30*(3), 282-296. https://doi.org/10.1177/002221949703000304

Brus, B. Th. & Voeten, M.J.M. (2019). *Een-Minuut-Test vorm A en B. Verantwoording en Handleiding* [one-minute-test form A and B. accountability and manual]. Herziene versie. Amsterdam, Pearson.

Bürki, C. N., Ludwig, C., Chicherio, C., & de Ribaupierre, A. (2014). Individual differences in cognitive plasticity: an investigation of training curves in younger and older adults. *Psychological Research, 78*(6), 821-835. https://doi.org/10.1007/s00426-014-0559-3

C

Caffrey, E., Fuchs, D. & Fuchs, L. S. (2008). The predictive validity of dynamic assessment: A review. *Journal of Special Education,* 41, 254–270. http://dx.doi.org/10.1177/0022466907310366

Calamia, M., Markon, K. E., & Tranel, D. (2012). Scoring higher the second time around: Meta- analyses of practice effects in neuropsychological assessment. *Clinical Neuropsychologist, 26*(4), 543–570. https://doi.org/10.1080/13854046.2012.680913

Calero, M. D., Belen, G. M. M., & Robles, M. A. (2011). Learning potential in high intelligence children: The contribution of dynamic assessment to the identification of gifted children. *Learning and Individual Differences, 21*(2), 176–181.https://doi.org/10.1016/j.lindif.2010.11.025

Carr, M., Alexander, J., & Schwanenflugel, P. (1996). Where gifted children do and do not excel on metacognitive tasks. *Roeper Review, 18*(3), 212-217. https://doi.org/10.1080/02783199609553740

Carroll, J. M., Mundy, I. R., & Cunningham, A. J. (2014). The roles of family history of dyslexia, language, speech production and phonological processing in predicting literacy progress. *Developmental Science, 17*(5), 727–742. https://doi.org/10.1111/desc.12153

Carretti, B., Caldarola, N., Tencati, C., & Cornoldi, C. (2013). Improving reading comprehension in reading and listening settings: The effect of two training programmes focusing on metacognition and working memory. *British Journal of Educational Psychology, 84*(2), 194-210. https://doi.org/101111/bjep.12022

Catts, H. W., McIlraith, A., Bridges, M. S., & Nielsen, D. C. (2016). Viewing a phonological deficit within a multifactorial model of dyslexia. *Reading and Writing, 30*(3), 613–629. https://doi.org/10.1007/s11145-016-9692-2

Chapman, J. W., & Tunmer, W. E. (1995). Development of young children's reading self-concepts: An examination of emerging subcomponents and their relationship with reading achievement. *Journal of Educational Psychology, 87*(1), 154–167. https://doi.org/10.1037/0022-0663.87.1.154

Cho, E., Compton, D. L., Fuchs, D., & Bouton, B. (2012). Examining the predictive validity of a dynamic assessment of decoding to forecast response to Tier 2 intervention. *Journal of Learning Disabilities*, *47*(5), 409–423. https://doi.org/10.1177/0022219412466703

Cho, E., Compton, D. L., & Josol, C. K. (2019). Dynamic assessment as a screening tool for early identification of reading disabilities: a latent change score approach. *Reading and Writing*, *33*(3), 719–739. https://doi.org/10.1007/s11145-019-09984-1

Christopher, M. E., Miyake, A., Keenan, J. M., Pennington, B., DeFries, J. C., Wadsworth, S. J., Willcutt, E. G., & Olson, R. K. (2012). Predicting word reading and comprehension with executive function and speed measures across development: a latent variable analysis. *Journal of Experimental Psychology: General, 141*(3), 470. https://doi.org/10.1037/a0027375

Compton, D. L., Fuchs, L. S., Bouton, B., Gilbert, J. K., Barquero, L. A., Cho, E., & Crouch, R. (2010). Selecting at-risk first-grade readers for early intervention: Eliminating false positives and exploring the promise of a two-stage gated screening process. *Journal of Educational Psychology, 102*(2), 327–340. https://doi.org/10.1037/a0018448

Cornoldi, C., Caponi, B., Focchiatti, R., Lucangeli, D., Todeschini, M., Falco, G. (1995). Mathematics and metacognition. Centro study Erickson, Torento, Italy.

Cornoldi, C., Carretti, B., Drusi, S., & Tencati, C. (2015). Improving problem solving in primary school students: The effect of a training programme focusing on metacognition and working memory. *British Journal of Educational Psychology, 85*(3), 424-439. https://doi.org/10.1111/bjep.12083

Crepeau-Hobson, F., & Bianco, M. (2013). Identification of gifted students with learning disabilities. *Journal of Learning Disability, 46*(4), 304–316.

D

Dadgar, H., Karimzadegan, A., Soleymani, Z., & Tehranidoost, M. (2022). Relationship between cognitive flexibility, attention shifting, and planning with accuracy, speed, and reading comprehension in normal children and children with dyslexia. *Rehabilitation Medicine*, *11*(3), 462–473. https://doi.org/10.32598/sjrm.11.3.10

Dahlin, K. I. E. (2010). Effects of working memory training on reading in children special needs. *Reading and Writing*, *24*(4), 479–491. https://doi.org/10.1007/s11145-010-9238-y

Deary, I. J., & Caryl, P. G. (1997b). Neuroscience and human intelligence differences. *Trends in Neurosciences*, *20*(8), 365–371. https://doi.org/10.1016/s0166-2236(97)01070-9

De Boer, G. C., Minnaert, A., & Kamphof, G. (2013). Gifted education in the Netherlands. *Journal for the Education of the Gifted, 36*(1), 133–150. https://doi.org/10.1177/0162353212471622

Desoete, A., & De Craene, B. (2019). Metacognition and mathematics education: An overview. *ZDM Math Educational Psychology, 51*(4), 565-575. https://doi.org/10.1007/s11858019-01060-w

De Vreeze-Westgeest, M.G.J., Mata, S., Serrano, F., Resing, W.C.M., Vogelaar, B. (2023). Online dynamic testing of reading and writing, executive functioning and reading self-concept in typically developing children and children diagnosed with dyslexia. *European Journal of Psychology and Educational Research, 6* (4), 165-179. https://doi.org/10.12973/ejper.6.4.165

Diamond, A. (2013). Executive functions. *Annual review of psychology, (64)*, 135-168. https://doi: 10.1146/annurev-psych-113011-143750

Dixon, C., Oxley, E., Nash, H. & Gellert, A. S. (2022). Does dynamic assessment offer an alternative approach to identifying reading disorder? A systematic review. *Journal of learning disabilities, 1*-17. Doi:10.1177/00222194221117510

Djapo, N., Kolenovic-Djapo, J., Djokic, R., & Fako, I. (2011). Relationship between Cattell's 16PF and fluid and crystallised intelligence. *Personality And Individual Differences*, *51*(1), 63–67. https://doi.org/10.1016/j.paid.2011.03.014

Donovan, J.L. (2019). *Exploring the efficacy of a dynamic assessment procedure of spelling in children with dyslexia.* UCL (University College London)

Dörfler, T., Golke, S., & Artelt, C. (2009). Dynamic assessment and its potential for the assessment of reading Competence. *Studies in Educational Evaluation, 35* (2–3), 77–82. https://doi.org/10.1016/j.stueduc.2009.10.005

Durik, A. M., Vida, M., & Eccles, J. S. (2006). Task values and ability beliefs as predictors of high school literacy choices: A developmental analysis. *Journal of Educational Psychology, 98*(2), 382–393. https://doi.org/10.1037/0022-0663.98.2.382

E

Ebadi, S., & Rahimi, M. (2019). Mediating EFL learners' academic writing skills in online dynamic assessment using Google Docs. *Computer Assisted Language Learning, 32*(5–6), 527–555. https://doi.org/10.1080/09588221.2018.1527362

Ehri, L.C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading, 18*(2),116-125. http://dx.doi.org/10.1111/j.1467-9817.1995.tb00077.x

Elbro, C., Daugaard, H. T. & Gellert, A. S. (2012). Dyslexia in a second language? A dynamic test of reading acquisition may provide a fair answer. *Annals of Dyslexia, 62*, 172–185. http://dx.doi.org/10.1007/s11881-012-0071-7

Elliott, J., & Resing, W. (2015). Can intelligence testing inform educational intervention for children with reading disability? *Journal of Intelligence*, *3*(4), 137–157. https://doi.org/10.3390/jintelligence3040137

Elliott, J. G., Resing, W. C. M. & Beckmann, J. F. (2018). Dynamic assessment: a case of unfulfilled potential? *Educational Review, 70*, 7–17. http://dx.doi.org/10.1080/00131911.2018.1396806

Eun, B. (2017). The zone of proximal development as an overarching concept: A framework for synthesising Vygotsky's theories. *Educational Philosophy And Theory*, *51*(1), 18–30. https://doi.org/10.1080/00131857.2017.1421941

F

Feuerstein, R. (2002). *The Dynamic Assessment of Cognitive Modifiability*. Amsterdam University Press.

Friso-van den Bos, I., & Van de Weijer-Bergsma, E. (2020). Classroom versus individual working memory assessment: Predicting academic achievement and the role of attention and response inhibition. *Memory, 28*(1), 70–82. https://doi.org/10.1080/09658211.2019.1682170

Fuchs, D., Compton, D. L., Fuchs, L. S., Bouton, B., & Caffrey, E. (2011). The construct and predictive validity of a dynamic assessment of young children learning to read: Implications for RTI frameworks. *Journal of Learning Disabilities*, *44* (4), 339–347. https://doi.org/10.1177/0022219411407864

Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C. L., Owen, R., & Schroeter, K. (2003). Enhancing third-grade student' mathematical problem solving withself-regulated learning strategies. *Journal of educational psychology, 95*(2), 306. https://doi.org/10.1037/00220663.95.2.306

G

Galuschka, K., Görgen, R., Kalmar, J., Haberstroh, S., Schmalz, X., & Schulte-Körne, G. (2020). Effectiveness of spellling interventions for learners with dyslexia: A meta-analysis and systematic review. *Educational Psychologist, 55*(1), 1–20. https://doi.org/10.1080/00461520.2019.1659794

Geelhoed, J. & Reitsma, P., Berends, I., Eenshuistra, R. (2019). *Pi-dictee. Handleiding* [Pi-dictation manual]. Research en Boom Uitgevers.

Gellert, A. S., & Elbro, C. (2017). Try a little bit of teaching: A dynamic assessment of word decoding as a kindergarten predictor of word reading difficulties at the end of grade 1. *Scientific Studies of Reading*, *21*(4), 277–291. https://doi.org/10.1080/10888438.2017.1287187

Gibby-Leversuch, R., Hartwell, B. K., & Wright, S. (2021). Dyslexia, literacy difficulties and the self-perceptions of children and young people: A systematic review. *Current Psychology, 40*(11), 5595–5612. https://doi.org/10.1007/s12144-019-00444-1

Giofrè, D., & Cornoldi, C. (2015). The structure of intelligence in children with specific learning disabilities is different as compared to typically development children. *Intelligence*, *52*, 36–43. https://doi.org/10.1016/j.intell.2015.07.002

Godde, E., Bosse, M. L., & Bailly, G. (2020). A review of reading prosody acquisition and development. *Reading and Writing, 33*(2), 399–426. https://doi.org/10.1007/s11145-019-09968-1

Goswami, U. (2019). *Cognitive Development and Cognitive Neuroscience: The learning brain*. Routledge.

Grigorenko, E. L. (2009). Dynamic assessment and response to intervention: two sides of a coin. *Journal of Learning Disabilities, 42*(2), 111–132. https://doi.org/10.1177/0022219408326207

Grigorenko, E. L. & Sternberg, R. J. (1998). Dynamic testing. *Psychological Bulletin Journal, 124,* 75–111. http://dx.doi.org/10.1037/0033-2909.124.1.75

Grills, A. E., Fletcher, J. M., Vaughn, S., Barth, A., Denton, C. A., & Stuebing, K. K. (2014). Anxiety and response to reading intervention among first grade students. *Child & Youth Care Forum*, *43*(4), 417–431. https://doi.org/10.1007/s10566-014-9244-3

Grob, A., Hagmann-von Arx, P. (2018). *IDS-2 Intelligentie en ontwikkelingschalen voor kinderen en jongeren [IDS-2 Intelligence and developmental scales for children and young people]*. Nederlandse bewerking door Ruit, S, Timmerman, M & Visser, L.

H

Hakkarainen, P., & Bredikyte, M. (2008). The zone of proximal development in play and learning. *Cultural-Historical Psychology, 2* (11). https://psyjournals.ru/en/kip/2008/n4/Hakkarainen_full.shtml

Hall, C., Dahl-Leonard, K., Cho, E., Solari, E. J., Capin, P., Conner, C., Henry, A. R., Cook, L., Hayes, L., Vargas, I., Richmond, C. L., & Kehoe, K. F. (2022). Forty years of reading intervention research for elementary students with or at risk for dyslexia: A systematic review and meta-analysis. *Reading Research Quarterly*, *58*(2), 285–312. https://doi.org/10.1002/rrq.477

Harrison, T. L., Hicks, K. L., Draheim, C., Redick, T. S., & Engle, R. W. (2017). Do the effects of working memory training depend on baseline ability level? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 43(*11), 1677. https://doi.org/10.1037/xlm0000426

Haywood, H. C., & Lidz, C. S. (2006). *Dynamic assessment in Practice: Clinical and Educational Applications*.https://assets.cambridge.org/97805216/14122/frontmatter/9780521614122

Hendriks, M. P. H.; Ruiter, S. *WISC-V-NL: technische handleiding, [technical Manual Dutch revision]*. Pearson Amsterdam, 2018.

Hill, J. (2015). How useful is dynamic assessment as an approach to service delivery within educational psychology? *Educational Psychology in Practice*, *31*(2), 127–136. https://doi.org/10.1080/02667363.2014.994737

Hohn, R. L., & Frey, B. (2002). Heuristic training and performance in elementary mathematical problem solving. *The Journal of Educational Research, 95*(6), 374- 380. https://doi.org/10.1080/00220670209596612

Holliman, A., Critten, S., Huges, J., Wood, C., Cunnane, H., Pillinger, C. & Deacon, S. (2001). Prosodic sensitivity and early literacy. *Reading Research Quarterly, 49*, 469–482. Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental science, 12*(4). https://doi.org/10.1111/j.1467-7687.2009.00848.x

Hübner, N., Merrell, C., Cramman, H., Little, J. B., Bolden, D., & Nagengast, B. (2022). Reading to learn? The co-development of mathematics and reading during primary school. *Child Development*, *93*(6), 1760–1776. https://doi.org/10.1111/cdev.13817

I

Intelligentie en ontwikkelingsschalen voor kinderen en jongeren: Verantwoordingen psychometrie. Hogrefe, Amsterdam, 2018.

Isabel, E., Engel, R. R., & Schulte-Körne, G. (2012). Was hilft bei der Lese-Rechtschreibstörung? [Effective treatment of dyslexia: A meta-analysis of intervention studies]. *Kindheit Und Entwicklung*, *21*(2), 122–136. https://doi.org/10.1026/0942-5403/a000077

J

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences, 105*(19), 6829 6833. https://doi.org/10.1073/pnas.0801268105

Jeltova, I., Birney, D., Fredine, N., Jarvin, L., Sternberg, R. J., & Grigorenko, E. L. (2007). Dynamic assessment as a process-oriented assessment in educational settings. *Advances in Speech-Language Pathology*, *9*(4), 273–285. https://doi.org/10.1080/14417040701460390

Jeltova, I., Johann, V., Könen, T., & Karbach, J. (2019). The unique contribution of working memory, inhibition, cognitive flexibility, and intelligence to reading comprehension and reading speed. *Child Neuropsychology, 26*(3), 324–344. https://doi.org/10.1080/09297049.2019.1649381

Jing, L., Vermeire, K., Mangino, A., & Reuterskiöld, C. (2019). Rhyme awareness in children with normal hearing and children with cochlear implants: an exploratory study. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02072

K

Katzir, T., Kim, Y. S. G., & Dotan, S. (2018). Reading self-concept and reading anxiety in second grade children: The roles of word reading, emergent literacy skills, working memory and gender. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.01180

Kazemi, A., Bagheri, M., & Rassaei, E. (2021). Impact of interventionist dynamic assessment on Iranian EFL learners' L2 reading comprehension and classroom engagement. *International Journal of Foreign Language Teaching and Research*, *9*(39), 67–79 . https://doi.org/10.52547/jfl.9.39.67

Kontostavlou, E. Z., & Drigas, A. S. (2022). Executive functions training and giftedness. *Retos: nuevas tendencias en educación física, deporte y recreación, (43),* 1005-1014.

Kornmann, J., Zettler, I., Kammerer, Y., Gerjets, P., & Trautwein, U. (2015). What characterizes children nominated as gifted by teachers? A closer consideration of working memory and intelligence. *High Ability Studies, 26*(1), 75-92. https://doi.org/10.1080/13598139.2015.1033513

Kort, W., Bos, K.P. van den, Spelberg, H.C. Lutje, Wild, S. van der, Schittekatte, M.,Vermeir G. & Verhaeghe, P. (2005). *Dyslexie Screening Test, DST-Nl. Handleiding [Dyslexia screeningtest, DST-NL. Manual]*. Harcourt Test Publishers.

Koshy, V., & Pinheiro-Torres, C. (2012). 'Are we being de-gifted, Miss?' Primary school gifted and talented co-ordinators' responses to the gifted and talented education policy in England. *British Educational Research Journal, 39*(6), 953-978. https://doi.org/10.1002/berj.3021

Kudo, M. F., Lussier, C. M., & Swanson, H. L. (2015). Reading disabilities in children: A selective meta-analysis of the cognitive literature. *Research in Developmental Disabilities, 40*, 51–62. https://doi.org/10.1016/j.ridd.2015.01.002

L

Lai, Y., Zhu, X., Chen, Y., & Li, Y. (2015). Effects of mathematics anxiety and mathematical metacognition on word problem solving in children with and without mathematical learning difficulties. *PloS one, 10*(6), e0130570. https://doi.org/10.1371/journal.pone.0130570

Letterlicht versie 1.16.5. Powered by Emmia, Created by 1801.

Leung, P., Orgeta, V., & Orrell, M. (2017). The effects on carer well-being of carer involvement in cognition-based interventions for people with dementia: a systematic review and meta-analysis. *International Journal of Geriatric Psychiatry, 32*(4), 372-385. https://doi.org/10.1002/gps.4654

Lindeblad, E., Nilsson, S., Gustafson, S., & Svensson, I. (2019). Self-concepts and psychological health in children and adolescents with reading difficulties and the impact of assistive technology to compensate and facilitate reading ability. *Cogent Psychology, 6*(1). https://doi.org/10.1080/23311908.2019.1647601

Lucangeli, D., Tressoldi, P. E., Cendron, M. (1998). Cognitive and metacognitive abilities involved in the solution of mathematical word problems: Validation of a comprehensive model. *Contemp Educational Psychology, 23*(3), 257–275. https://doi.org/10.1006/ceps.1997.0962

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of Dyslexia, 53*(1), 1–14. https://doi.org/10.1007/s11881-003-0001-9

Lyster, S. H., Snowling, M. J., Hulme, C., & Lervåg, A. O. (2020). Preschool phonological, morphological and semantic skills explain it all: following reading development through a 9-year period. *Journal of Research in Reading, 44*(1), 175–188. https://doi.org/10.1111/1467-9817.12312

M

Macdonald, K. T., Cirino, P. T., Miciak, J., & Grills, A. E. (2021). The role of reading anxiety among struggling readers in fourth and fifth Grade. *Reading & Writing Quarterly, 37*(4),382–394. https://doi.org/10.1080/10573569.2021.1874580

Martin, M., Clare, L., Altgassen, A. M., Cameron, M. H., & Zehnder, F. (2011). Cognition based interventions for healthy older people and people with mild cognitive impairment. *Cochrane database of systematic reviews,* (1). https ://doi.org/10.1002/14651858.cd006220.pub2

Mata, S., & Serrano, F. (2019). *EPALE; Test de evaluación del potencial de aprendizaje para lecto-escritura* [Assessment test of learning potential for reading and writing]. Spain: Editorial Universidad de Granada

McArthur, G., & Castles, A. (2016). Helping children with reading difficulties: some things we have learned so far. *Nature Partner Journals Science of Learning, 2* (1). https://doi.org/10.1038/s41539-017-0008-3

McGrew, K. S. (2009). CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research. *Intelligence*, *37*(1), 1–10. https://doi.org/10.1016/j.intell.2008.08.004

Medina, G. B. K., & Guimarães, S. R. K. (2021). Reading in developmental dyslexia: The role of phonemic awareness and executive Functions. *Estudos De Psicologia (Campinas)*, *38*. https://doi.org/10.1590/1982-0275202138e180178

Melby-Lervåg, M., Lyster, S. A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin, 138*(2), 322–352. https://doi.org/10.1037/a0026744

Miller, C.J. & Bernacki, M.L. (2019). Training preparatory mathematic students to be high ability self-regulation: Comparative and case-study analyses of impact on learning behaviour and achievement. *High Abiltity Studies, 30* (1-2, 167-197). https://doi.org/10.1080/13598139.2019.1568829

Motallebzadeh, K., & Tabatabaee Yazdi, M. (2016). The relationship between EFL learners' reading comprehension ability and their fluid intelligence, crystallised intelligence, and processing speed. *Cogent Education*, *3*(1), 1228733. https://doi.org/10.1080/2331186x.2016.1228733

N

Navarro, J. J., & Lara, L. (2017). Dynamic assessment of reading difficulties: predictive and incremental validity on attitude toward reading and the use of dialogue/participation strategies in classroom activities. *Frontiers in Psychology*, *8*. 179-181 https://doi.org/10.3389/fpsyg.2017.00173

Navarro, J. J., & Mora, J. (2011). Analysis of the implementation of a dynamic assessment device of processes involved in reading with learning-disabled children. *Learning and Individual Differences*, *21*(2), 168–175. https://doi.org/10.1016/j.lindif.2010.11.008

Nazari, B. (2012). Teach-to-test instruction of dynamic assessment: A critical overview. *Bellaterra Journal of Teaching & Learning Language & Literature, 5*, 56-68 .

Nelwan, M., Vissers, C., & Kroesbergen, E. H. (2018). Coaching positively influences the effects of working memory training on visual working memory as well as mathematical ability. *Neuropsychologia*, *113*, 140-149. https://doi.org/10.1016/j.neuropsychologia.2018.04.002

Nicholas, M., & Rouse, E. (2021). Learning to read: Where should early childhood educators begin? *Literacy, 55*(1), 3–13. https://doi.org/10.1111/lit.12229

Nithart, C., Demont, E., Metz-Lutz, M. N., Majerus, S., Poncelet, M., & Leybaert, J. (2011). Early contribution of phonological awareness and later influence of phonological memory throughout reading acquisition. *Journal of Research in Reading*, *34*(3), 346–363. https://doi.org/10.1111/j.1467-9817.2009.01427.x

O

O'Brien, G., & Yeatman, J.D.(2021). Bridging sensory and language theories of dyslexia: Toward a multifactorial model. *Developmental science, 24* (3), e13039. http://dx.doi.org/10.1111/desc.13039

Ohtani, K., & Hisasaka, T. (2018). Beyond Intelligence: A meta-analytic review of the relationship among metacognition, intelligence, and academic performance. *Metacognition and Learning*, *13*(2), 179–212. https://doi.org/10.1007/s11409-018-9183-8

Oppong, E., Shore, B. M., & Muis, K. R. (2018). Clarifying the connections among giftedness, metacognition, self-regulation, and self-regulated learning: Implications for theory and practice. *Gifted Child Quarterly, 63(*2), 102-119. https://doi.org/10.1177/0016986218814008

P

Pascual, A. C., Muñoz, N. M., & Robres, A. Q. (2019). The relationship between executive functions and academic performance in primary education: Review and meta-analysis. *Frontiers in Psychology, 10* (1582), 1-18. https://doi.org/10.3389/fpsyg.2019.01582

Passig, D., Tzuriel, D., & Eshel-Kedmi, G. (2016). Improving children's cognitive modifiability by dynamic assessment in 3D immersive virtual reality environments. *Computers & Education, 95*, 296-308. https://doi.org/10.1016/j.compedu.2016.01.009

Passolunghi, M. C., & Pazzaglia, F. (2004). Individual differences in memory updating in relation to arithmetic problem solving. *Learning and Individual Differences, 14*(4), 219-230. https://doi.org/10.1016/j.lindif.2004.03.001

Peng, P., Barnes, M., Wang, C., Wang, W., Li, S., Swanson, H. L., Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychological Bulletin, 144*(1), 48–76. https://doi.org/10.1037/bul0000124

Peng, P., Wang, T., Wang, C., & Lin, X. (2019). A meta-analysis on the relation between fluid intelligence and reading/mathematics: Effects of tasks, age, and social economics status. *Psychological Bulletin*, *145*(2), 189–236. https://doi.org/10.1037/bul0000182

Perfetti, C., & Hart, L. (2002). The lexical quality hypothesis. In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 189–213). The Netherlands: John Benjamin.

Petersen, D. B., Allen, M. M., & Spencer, T. D. (2014). Predicting reading difficulty in first grade using dynamic assessment of decoding in early kindergarten. *Journal of Learning Disabilities*, *49*(2), 200–215. https://doi.org/10.1177/0022219414538518

Petersen, D. B., Gragg, S. L., & Spencer, T. D. (2018). Predicting reading difficulties 6 years into the future: dynamic assessment reduces bias and increases classification accuracy. *Language Speech and Hearing Services in Schools, 49*(4), 875–888. https://doi.org/10.1044/2018_lshss-dyslc-18-0021

Peterson, R. L. & Pennington, B. F. (2012). Developmental dyslexia. *Lancet*, 379, 19972007.

Poehner, M. E., & Lantolf, J. P. (2005). Dynamic assessment in the language classroom. *Language Teaching Research*, *9*(3), 233–265. https://doi.org/10.1191/1362168805lr166oa

Poehner, M. E., & Lantolf, J. P. (2013). Bringing the ZPD into the equation: Capturing development during computerized dynamic assessment (C-DA). *Language Teaching Research, 17*(3), 323-342. https://doi.org/10.1177/1362168813482935

Pfost, M., Blatter, K., Artelt, C., Stanat, P., & Schneider, W. (2019). Effects of training phonological awareness on children's reading skills . *Journal of Applied Developmental Psychology*, *65*(September), 101067. https://doi.org/10.1016/j.appdev.2019.101067

Puhan, G., Boughton, K., & Kim, S. (2007). Examining differences in examinee performance in paper and pencil and computerised testing. *Journal of Technology, Learning and Assessment, 6*(3), 4-20.

R

Reis, S. M., Baum, S. M., & Burke, E. (2014). An operational definition of twice-exceptional learners: Implications and applications. *Gifted Child Quarterly, 58*(3), 217-230. https://doi.org/10.1177/0016986214534976

Renzulli, J. S. (2011). What makes giftedness?: Reexamining a definition. *Phi Delta Kappan*, *92*(8), 81-88. https://doi.org/10.1177/003172171109200821

Resing, W.C.M. (2000). Assessing the learning potential for inductive reasoning in young children. In: Lidz C.S., Elliot J. (Eds.) *Dynamic assessment: Prevailing models and applications. Advances in cognition and educational practice (series editor: J.S. Carlson).* Elsevier Inc. 229-262.

Resing, W.C.M. (2013). Dynamic testing and individualised instruction: Helpful in cognitive education? *Journal of Cognitive Education and Psychology*, *12*(1), 81– 95. https://doi.org/10.1891/1945-8959.12.1.81

Resing, W. C., Bakker, M., Elliott, J. G., & Vogelaar, B. (2019). Dynamic testing: Can a robot as tutor be of help in assessing children's potential for learning? *Journal of Computer Assisted Learning*, *35*(4), 540–554. https://doi.org/10.1111/jcal.12358

Resing, W.C.M., Bleichrodt, N., Drenth, P. J. D., & Zaal, J. N. (2012). *Handleiding verantwoording RAKIT-2 Deel 2 Normen, betrouwbaarheid, validiteit en interpretatie. [Manual RAKIT-2 Part 2 Norms, reliability, validity and interpretation].* Pearson Assessment and Information.

Resing, W. C. M., & Elliott, J. G. (2010). Dynamic testing with tangible electronics: Measuring children's change in strategy use with a series completion task. *British Journal of Educational Psychology*, *81*(4), 579–605. https://doi.org/10.1348/2044-8279.002006

Resing, W. C. M., Elliott, J., & Vogelaar, B. (2020). Assessing potential for learning in school children. *Oxford Research Encyclopedia of Education*. https://doi.org/10.1093/acrefore/9780190264093.013.943

Ribner, A. D., Willoughby, M. T., Blair, C. B., & The Family Life Project Key Investigators (2017). Executive function buffers the association between early math and later academic skills. *Frontiers in Psychology. 8.* https://doi.org/10.3389/fpsyg.2017.00869

Rodríguez Naveiras, E., Verche Borges, E., Hernández Lastiri, P., Montero López, R. Borges del Rosal, M. Á. (2019). Differences in working memory between gifted or talented students and community samples: A meta-analysis. *Psicothema, 31*(3), 255 262. https://doi.org/10.7334/psicothema2019.18

Rueda, M. R., Cómbita, L. M., & Pozuelos, J. P. (2021). Cognitive training in childhood and adolescence. *In Cognitive Training, 127-139*. Springer, Cham. https://doi:10.1007/978-3-030-39292-5_9

Ruiter, S. A. J., Visser, L., & Timmerman, M. E. (2020). Integratieve diagnostiek met de Intelligence and Development Scales-2 (IDS-2). [Integrative diagnostics with the intelligence and developmental scales IDS-2] *Kind En Adolescent*, *41*(1), 4–30. https://doi.org/10.1007/s12453-019-00229-0

Ruissenaars , A.J.J.M., Van Luit, J.E.H., van Lieshout E.C.D. M. (2006). Reken problemen en dyscalculie. Theorie, onderzoek, diagnostiek en behandeling [Mathematical problems and dyscalculia. Theory, research, diagnostics and treatment]. Lemniscaat.

S

Sadasivan, A., Rucklidge, J.J., Gillon, G., Kapur, M. (2012). Role of executive functions in improving reading accuracy in Indian children with reading disorder, comparing two types of interventions. *Journal of Special Needs Education 2*, 9-25.

Sala, G., Aksayli, N. D., Tatlidil, K. S., Tatsumi, T., Gondo, Y., & Gobet, F. (2019). Near and far transfer in cognitive training: A second-order meta-analysis. *Collabra*, *5*(1). https://doi.org/10.1525/collabra.203

Schneider, W., & Artelt, C. (2010). Metacognition and mathematics education. *ZDM*, *42*(2), 149–161. https://doi.org/10.1007/s11858-010-0240-2

Schneider, W. J., & McGrew, K. S. (2012). The Cattell-Horn-Carroll model of intelligence. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 99–144). The Guilford Press.

Scionti, N., Cavallero, M., Zogmaister, C., & Marzocchi, G. M. (2020). Is cognitive training effective for improving executive functions in preschoolers? A systematic review and meta-analysis. *Frontiers in* psychology, 10, 1-23.

Serrano, F., & Defior, S. (2008). Dyslexia speed problems in a transparent orthography. *Annals of Dyslexia*, *58*(1), 81–95. https://doi.org/10.1007/s11881-008-0013-6

Serrano, F. (2015). *Intervención logopédica en problemas de lectura y escritura [speech therapy intervention in reading and writing problems].* Editorial Técnica Avicam.

Serrano, F., Sánchez, J. B., & Olmedo, M. G. (2016). Galexia; Evidence-based software for intervention in reading fluency and comprehension. *Inted2016 proceedings*, 2001-2007. https://doi.org/10.21125/inted.2016.1419

Shareef, Z., Östberg, P., & Hedenius, M. (2019). Verbal fluency in relation to reading ability in students with and without dyslexia. *Applied Psycholinguistics, 40*(2), 445–472 https://doi.org/10.1017/s0142716418000644

Sigurdardottir, H. M., Danielsdottir, H. B., Gudmundsdottir, M., Hjartarson, K. H., Thorarinsdottir, E. A., & Kristjánsson, R. (2017). Difficulties with visual statistical learning in developmental dyslexia. *Scientific Reports, 7*(1). https://doi.org/10.1038/s41598-017-00554-5

Sihotang, R. O., & Hutagalung, E. E. (2020, April). Metacognition skills of the gifted and talented students. In Journal of Physics: *Conference Series, (1521)*3, 032017). IOP Publishing. https://doi.org/10.1088/1742-6596/1521/3/032017

Smith-Spark, J. H., Henry, L. A., Messer, D. J., & Zięcik, A. P. (2017). Verbal and non-verbal fluency in adults with developmental dyslexia: Phonological processing or executive control problems? *Dyslexia, 23*(3), 234–250. https://doi.org/10.1002/dys.1558

Snowling, M. J. (2013). Early identification and interventions for dyslexia: a contemporary view. *Journal of Research in Special Educational Needs, 13*(1), 7–14. https://doi.org/10.1111/j.1471-3802.2012.01262.x

Snowling, M. J., Hulme, C., & Nation, K. (2020). Defining and understanding dyslexia: past, present and future. *Oxford Review of Education*, *46*(4), 501–513. https://doi.org/10.1080/03054985.2020.1765756

Snyder, K. E., Nietfeld, J. L., & Linnenbrink-Garcia, L. (2011). Giftedness and metacognition: A short term longitudinal investigation of metacognitive monitoring in the classroom. *Gifted Child Quarterly, 55*(3), 181-193. https://doi.org/10.1177/0016986211412769

Sobkow, A., Fulawka, K., Tomczak, P., Zjawiony, P., & Traczyk, J. (2019). Does mental number line training work? The effects of cognitive training on real-life mathematics, numeracy, and decision making. *Journal of Experimental Psychology: Applied, 25*(3), 372-385.

Stad, F. E., Vogelaar, B., Veerbeek, J., & Resing, W. C. (2017). Young children's transfer of series completion in a dynamic test setting: Does cognitive flexibility play a role? *International Journal of School and Cognitive Psychology*, *04*(04). https://doi.org/10.4172/2469-9837.1000199

Sternberg, R.J. (1988). The triarchic mind: A new theory of human intelligence. New York, NY: Viking.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-661.

Struiksma, A.J.C., van der Leij, A, & Vieijra, J.P.M. (2018). *Diagnostiek van het technisch lezen en aanvankelijk spellen.* [*Diagnostics of technical reading and intitial spelling*]. Herziene druk Amsterdam: VU Uitgeverij.

Stuebing, K. K., Fletcher, J. M., LeDoux, J. M., Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2002). Validity of IQ-discrepancy classifications of reading disabilities: A meta-analysis. `*American Educational Research Journal*, *39*(2), 469–518. https://doi.org/10.3102/00028312039002469

Subotnik, R. F., Olszewski-Kubilius, P., Worrell, F. C. (2011). Rethinking giftedness and gifted education: A proposed direction forward based on psychological science. *Psychological Science in the Public Interest, 12*(1), 3-54 https://doi.org/10.1177/1529100611418056

Suranata, K., Rangka, I. B., Ifdil, I., Ardi, Z., Susiani, K., Prasetyaningtyas, W. E., Daharnis, D., Alizamar, A., Erlinda, L., & Rahim, R. (2018). Diagnosis of students zone proximal development on math design instruction: A Rasch analysis. *Journal Of Physics: Conference Series*, *1114*, 012034. https://doi.org/10.1088/1742-6596/1114/1/012034

Swanson, H. L.; Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology, 96*(3), 471- 491. https://doi.org/10.1037/00220663.96.3.471

Swanson, H. L., & Howard, C. B. (2005). Children with reading disabilities: Does dynamic assessment help in the classification? *Learning Disability Quarterly, 28* (1), 17–34. https://doi.org/10.2307/4126971

T

Taylor, C. H., & Zaghi, A. E. (2021). The nuanced relationship between creative cognition and the interaction between executive functioning and intelligence. *The Journal Of Creative Behavior*, *55*(3), 857–874. https://doi.org/10.1002/jocb.493

Thorsén, C., Gustafsson, J., & Cliffordson, C. (2014). The influence of fluid and crystallised intelligence on the development of knowledge and skills. *British Journal Of Educational Psychology*, *84*(4), 556–570. https://doi.org/10.1111/bjep.12041

Tijms, J., De Bree, E.H., Bonte, M., De Jong, P.F., Loykens, E., Reij, R. (2021). *Protocol Dyslexie Diagnostiek en Behandeling- versie 3.0. [Protocol dyslexia diagnostics and intervention version 3.0]* Nederlands kwaliteitsinstituut Dyslexie (NKD).

Tilanus, A.T., Segers, E., & Verhoeven, L. (2016). Receptiveness to intervention in children with dyslexia. *Dyslexia, 22*(3), 214-232. http://dx.doi.org/10.1002/dys.1533

Titz, C., & Karbach, J. (2014). Working memory and executive functions: effects of training on academic achievement. *Psychological Research*, *78*(6), 852–868. https://doi.org/10.1007/s00426-013-0537-1

Toffalini, E., Giofrè, D., Pastore, M., Carretti, B., Fraccadori, F., & Szűcs, D. (2021). Dyslexia treatment studies: A systematic review and suggestions on testing treatment efficacy with small effects and small samples. *Behaviour Research Methods*, *53*(5), 1954–1972. https://doi.org/10.3758/s13428-021-01549-x

Touw, K. W. J., Vogelaar, B., Bakker, M., & Resing, W. C. M. (2019). Using electronic technology in the dynamic testing of young primary school children: Predicting school achievement. *Educational Technology Research and Development*, *67*(2), 443–465. https://doi.org/10.1007/s11423-019-09655-6

Träff, U. (2013). The contribution of general cognitive abilities and number abilities to different aspects of mathematics in children. *Journal of Experimental Child Psychology, 116*(2), 139-156. https://doi.org/10.1016/j.jecp.2013.04.007

Tzuriel, D. (2011). Revealing the effects of cognitive education programmes through dynamic assessment. *Assessment in Education: Principles, Policy & Practice*, *18*(2), 113–131. https://doi.org/10.1080/0969594x.2011.567110

V

Vadasy, P. F., Sanders. E. A., & Cartwright, K. B. (2022). Cognitive flexibility in beginning decoding and encoding. *Journal of Education for Students Placed at Risk (JESPAR)*. https://doi.org/10.1080/10824669.2022.2098132

Vaessen, A., Gerretsen, P. & Ekkebus, M. (2014). Verbetering van leestempo bij (zeer) ernstige dyslexie met een computerondersteunende, fonologisch gebaseerde behandeling: kort en lange termijn effecten [Improving reading speed in (very) severe dyslexia with a computer-assisted phonologically based treatment: Short and long term effects]. *Stem-, Spraak- en Taalpathologie 19*, 58- 102.

Van den Bos, K.P., de Groot, B.J.A., A.J.M., de Vries, J.R (2019). *Klepel-R een test voor de leesvaardigheid van pseudowoorden* [*Klepel-R a test for the reading skills of pseudowords*]. Pearson.

Van den Bos, K.P. , Lutje Spelberg, H.C., Scheepstra, A.J.M. & Vries, J.R. de. (2019 *De Klepel. Vorm A en B. Verantwoording, Handleiding, Diagnostiek en Behandeling*. [*Klepel, form A and B, accountability, manual, diagnostics and treatment.]* Harcourt Test Publishers.

Van der Elst, W., Van Boxtel, M. P. J., Van Breukelen, G. J. P. & Jolles, J. (2008). Detecting the significance of changes in performance on the Stroop Color-Word Test, Rey's Verbal Learning Test, and the Letter Digit Substitution Test: The regression-based change approach. *Journal of the International Neuropsychological Society, 14*, 71–80. https://doi.org/10.1017/s1355617708080028

Van der Stel, M., & Veenman, M. V. (2014). Metacognitive skills and intellectual ability of young adolescents: A longitudinal study from a developmental perspective. *European Journal of Psychology of Education, 29(*1), 117-137. https://doi.org/10.1007/s10212-013-01905

Van der Zandt, M., van Weerdenbrug, M., Arntz, A., van Waterschoot, F. (2018). *Voortgang in lezen en spellen bij kinderen met dyslexie tijdens behandeling met Fonoco* [*Progress in reading and spelling in children with dyslexia during intervention with Fonoco*]. *Tijdschrift voor orthopedagogiek, 57*, 203-217.

Veenman, M. V. J., Elshout, J. J., & Meijer, J. (1997). The generality vs domain-specificity of metacognitive skills in novice learning across domains. *Learning And Instruction*, *7*(2), 187–209. https://doi.org/10.1016/s0959-4752(96)00025-4

Veenman, M. V., Kok, R., & Blöte, A. W. (2005). The relation between intellectual and metacognitive skills in early adolescence. *Instructional Science, 33*(3), 193-211.https://doi.org/10.1007/s11251-004-2274-8

Veerbeek, J., Vogelaar, B., Verhaegh, J., &Resing, W. C. (2019). Process assessment in dynamic testing using electronic tangibles. *Journal of Computer Assisted Learning*, *35*(1), 127–142. https://doi.org/10.1111/jcal.12318

Verpalen, A., Van de Vijver, F. & Backus, A. (2018). Bias in dyslexia screening in a Dutch multicultural population. *Annals of Dyslexia, 68*, 43–68. http://dx.doi.org/10.1007/s11881-018-0155-0

Vogelaar B.; Bakker, M.; Hoogeveen, L. Resing, W. C. M. (2017). Dynamic testing of gifted and average ability children’s analogy problem solving: Does executive functioning play a role? *Psychology in Schools, 54*(8), 837-851.https://doi.org/10.1002/pits.22032.

Vogelaar, B., Resing, W. C. M., Stad, F. E., & Sweijen, S. (2019). Is planning related to dynamic testing outcomes? Investigating the potential for learning of gifted and average-ability children. *Acta Psychologica, 196*, 87–95. https://doi.org/10.1016/j.actpsy.2019.04.004

Vogelaar, B., Veerbeek, J., Splinter, S. E., & Resing, W. C. M. (2020). Computerised dynamic testing of children's potential for reasoning by analogy: the role of executive functioning. *Journal of Computer Assisted Learning*, *37*(3), 632–644. https://doi.org/10.1111/jcal.12512

Vygotsky, L. S. (1978). *Mind in Society: The development of higher psychological processes* . Harvard University Press.

Vygotsky, L. S. (1980). *Mind in Society*. University Press.

W

Wackerle-Hollman, A. K., Schmitt, B. A., Bradfield, T. A., Rodriguez, M. C., & McConnell, S.R. (2015). Redefining individual growth and development indicators. *Journal of Learning Disabilities, 48*(5), 495–510. https://doi.org/10.1177/0022219413510181

Wason-Ellam (2020). Interactive dynamic assessment, a diagnostic tool for children with fetal alcohol spectrum disorder. *International journal of pediatrics & Neonatal care, 6*, 161. https://doi.org/ 10.15344/2455-2364/2020/161

Wechsler, D. (2018). *WISC-V-NL. Wechsler Intelligence Scale for children* (5th ed.). Pearson.

Weissheimer, J., Fujii, R. C., & Souza, J. G. M. D. (2019). The effects of cognitive training on executive functions and reading in typically developing children with varied socioeconomic status in Brazil. *Ilha do Desterro*, 72, 85-100. https://doi.org/10.5007/2175-8026.2019v72n3p85

Werth, R. (2018). Rapid improvement of reading accuracy scores in children with dyslexia by altering the reading strategy: A novel approach to diagnoses and therapy of reading deficiencies. *Restorative Neurology and Neuroscience*, *36*(6), 679–691. https://doi.org/10.3233/rnn-180829

Wexler, B. E., Iseli, M., Leon, S., Zaggle, W., Rush, C., Goodman, A., Imal, A.E., & Bo, E. (2016) Cognitive priming and cognitive training: immediate and far transfer to academic skills in children. *Scientific Reports, 6*(1), 1-9. https://doi.org/10.1038/srep32859

Y

Yang, L., Li, C., Li, X., Zhai, M., An, Q., Zhang, Y., Zhao, J., & Weng, X. (2022). Prevalence of developmental dyslexia in primary school children: A systematic review and meta-analysis. *Brain Sciences*, *12*(2), 240. https://doi.org/10.3390/brainsci12020240

Yu, K. C., Fan, S. C., & Lin, K. Y. (2014). Enhancing students' problem solving skills through context-based learning. *International Journal of Science and Mathematics Education, 13*(6), 1377-1401. https://doi.org/10.1007/s10763-014-9567-4

Z

Zarić, J., Hasselhorn, M., & Nagler, T. (2020). Orthographic knowledge predicts reading and spelling skills over and above general intelligence and phonological awareness. *European Journal of Psychology of Education*, *36*(1), 21–43. https://doi.org/10.1007/s10212-020-004647

Zhang, Q., Wang, C., Zhao, Q., Yang, L., Buschkuehl, M., & Jaeggi, S. M. (2018). The malleability of executive function in early childhood: Effects of schooling and targeted training. *Developmental science, 22*(2), e12748. https://doi.org/10.1111/desc.12748

Zuppardo, L., Fuentes, A. R., Pirrone, C., & Serrano, F. (2020). Las repercusiones de la dislexia en la autoestima, en el comportamiento socioemocional y en la ansiedad en escolares [The repercussions of dyslexia on self-esteem, socio-emotional behaviour and anxiety in schoolchildren]. *Psicología Educativa, 26*(2), 175–183. https://doi.org/10.5093/psed2020a4

Zuppardo, L., Fuentes, A. R., & Serrano Chica, F. (2020). Software lecto escritores contra la dyslexia y disortografía [Software for readers with dyslexia and disortography]. *EduTicInnova. Revista de Educación Virtual, 7*, 27–39. http://hdl.handle.net/10481/63097

Samenvatting in het Nederlands

In het onderwijs en in de klinische behandeling van dyslexie worden de effecten van instructie en begeleiding vaak gemeten met schooltoetsen. Kinderen maken deze toetsen na een korte, gestandaardiseerde instructie geheel zelfstandig. Deze toetsen geven inzicht in het huidige niveau van functioneren, de verworven kennis en mogelijke hiaten in de kennis en worden gezien als statische testen (Petersen et al., 2016; Resing et al., 2000). Hoewel statische testen eenvoudig af te nemen en te interpreteren zijn, hebben ze ook nadelen. Critici beweren dat deze testen onvoldoende inzicht bieden in de onderwijsbehoeften en cognitieve ontwikkeling van kinderen, en zelfs hun potentieel om te leren kunnen onderschatten (Touw et al., 2019; Caffrey et al., 2008; Gellert & Elbro, 2017; Hill, 2015; Resing et al., 2020). Dit geldt in het bijzonder voor kinderen met leerproblemen (Navarro & Lara, 2017; Swanson & Howard, 2005), taalproblemen (Touw et al., 2019), kinderen met testangst (Vogelaar et al., 2017) en voor kinderen met diverse culturele achtergronden (Caffrey et al., 2008; Verpalen et al., 2018).

Daarom pleiten critici voor alternatieve test methoden die een duidelijker inzicht geven in het potentieel om te leren en de onderwijsbehoeften van kinderen. Naarmate het onderwijs steeds inclusiever wordt en leraren worden uitgedaagd om alle kinderen bij hun onderwijs te betrekken, wordt het nog belangrijker om deze onderwijsbehoeften van kinderen goed in kaart te brengen. Deze dissertatie beschreef dan ook twee van deze alternatieve test methoden: een cognitieve training gericht op het oplossen van rekenkundige problemen en een dynamische lees- en schrijftest. Beide alternatieve test methoden waren gericht op de zone van naaste ontwikkeling, de cognitieve training in rekenkundig probleem oplossen met focus op metacognitieve kennis en werkgeheugen en de dynamisch lees- en schrijftest met de focus op fonologisch bewustzijn, prosodisch bewustzijn, schrijfvaardigheid van (context-afhankelijke) woorden. Het belangrijkste doel van deze dissertatie was het onderzoeken van de effectiviteit van deze twee alternatieve test methoden, online, in de klas of in een behandelsetting. Het richtte zich op potentieel om te leren en de leerprocessen van drie groepen kinderen: potentieel begaafde kinderen op het gebied van rekenen, typisch ontwikkelende kinderen en kinderen met dyslexie op het gebied van lezen en schrijven.

In Hoofdstuk 1 werd de onderliggende theorie van cognitieve training en dynamisch testen beschreven: Vygotsky's (1978) sociaal-constructivistische theorie. In deze theorie stelt Vygotsky dat leren plaats vindt in de zone van naaste ontwikkeling. De zone van naaste ontwikkeling geeft de afstand weer tussen de mogelijkheid van een kind om een taak zelfstandig op te lossen en de mogelijkheid tot het oplossen van een taak met de juiste begeleiding en ondersteuning van een bekwame ander. Vygotsky's theorie benadrukt het belang van sociale interactie en de rol van begeleiding in het leerproces.

Studies wijzen uit dat er variaties bestaan binnen de zone van naaste ontwikkeling tussen verschillende domeinen, bijvoorbeeld afhankelijk van de ontwikkelingsfase van een kind (Eun, 2018; Suranata et al., 2018). Omdat kinderen zich op meerdere gebieden tegelijkertijd, mogelijk verschillend, ontwikkelen, is het interessant om zowel domein specifieke als domein algemene taken op te nemen in dynamische tests en cognitieve trainingen. Deze manier van testen en trainen levert waardevolle inzichten op in het potentieel om te leren, de respons op instructie, de benodigde ondersteuning en het vermogen van kinderen om nieuwe kennis vast te houden (Resing et al., 2020). Verschillende testprocedures focussen zich op deze zone van naaste ontwikkeling en doen dit door training en/of feedback in het testproces op te nemen. De testprocedure wordt dan ook vaak vormgegeven in een drie fasen format: pretest-training-posttest fase, ook wel het sandwich format genoemd (Touw et al., 2019).

Een cognitieve training is een specifieke methode die meerdere sessies omvat om verschillende cognitieve en intellectuele vaardigheden te verbeteren (near transfer). Er wordt geleerd door systematisch te oefenen met gestandaardiseerde taken (Leung et al., 2017; Martin et al., 2011). Een cognitieve training kan variëren in duur, aantal sessie, taken en begeleidingsniveau. Onderzoek wijst uit dat het trainen cognitieve vaardigheden als metacognitie, aandacht en probleemoplossend vermogen (Cornoldi et al., 2015); Leung et al., 2017; Sala et al., 2019), andere vaardigheden zoals lezen en rekenen kunnen verbeteren (far transfer). Ook dynamische tests kunnen uit verschillende taken bestaan; te denken valt aan bijvoorbeeld inductief redeneren, een meer domein algemene taak (Hakkarainen & Bredikyte, 2008; Vogelaar et al., 2017), of bijvoorbeeld lezen, een meer domein specifieke taak (Mata & Serrano, 2019).

Na de korte beschrijving van onderliggende theorie, cognitieve training en de dynamische test werd de cognitieve training in de context van rekenkundig probleem oplossen nader toegelicht, evenals de dynamisch test lees- en schrijftest bij typisch ontwikkelende kinderen en kinderen met dyslexie. Hoofdstuk 1 sloot daarnaast af met een overzicht van de studies die in deze dissertatie zijn opgenomen.

In Hoofdstuk 2 werden de effecten van een cognitieve training in rekenkundig probleem oplossen op de ontwikkeling van executieve functies beschreven. De cognitieve training was gebaseerd op het werk van Cornoldi et al. (2015) en speciaal ontwikkeld voor mogelijk begaafde kinderen tussen de acht en twaalf jaar. Er werd expliciet aandacht besteed aan de trainbaarheid van visueel en auditief werkgeheugen. Daarnaast werd de relatie tussen intelligentie en werkgeheugen en metacognitieve kennis onderzocht. De resultaten toonden dat zowel kinderen in de experimentele groep als kinderen in de controlegroep hun werkgeheugenvaardigheden konden verbeteren en hun metacognitieve kennis konden vergroten. Daarnaast bleek de cognitieve training in rekenkundig probleem oplossen specifiek bij te dragen aan groei van metacognitieve kennis. Intelligentie bleek een significante voorspeller te zijn voor visuele en auditieve werkgeheugen vaardigheden. Er werd geen betekenisvolle relatie gevonden tussen intelligentie en metacognitieve kennis.

De studies in Hoofdstuk 3, 4 en 5 hadden als doel de effectiviteit van een dynamische lees- en schrijftest, gebaseerd op het werk van Mata en Serrano (2019), te evalueren. Door de scores van de pretest en de posttest te vergelijken werd onderzocht of de training effect had op de lees- en schrijfvaardigheden van kinderen. Daarnaast werd onderzocht of de test informatie kon leveren over het potentieel om te leren van kinderen op het gebied van lezen en schrijven. In Hoofdstuk 3 en 4 werd gedifferentieerd tussen typisch ontwikkelende kinderen en kinderen met dyslexie in de respectievelijke leeftijden van zeven tot negenenhalf jaar en negen tot twaalf jaar. Hoofdstuk 5 werd de effectiviteit van de dynamische lees- en schrijftest bij kinderen in de leeftijd van zeven tot elf jaar met dyslexie geëvalueerd.

In Hoofdstuk 3 werd niet alleen de effectiviteit van de dynamische lees- en schrijftest beschreven, maar ook de relatie tussen deze dynamische test en conventionele lees-, schrijf- en intelligentietest. Tijdens de training voerden kinderen lees- en schrijftaken uit onder begeleiding van een volwassene, met visueel materiaal en mondelinge uitleg om het leren en begrip te verbeteren. De typisch ontwikkelende kinderen als kinderen met dyslexie lieten vergelijkbare verbeteringen zien in aantal goede antwoorden van pretest tot posttest. De kinderen in de experimentele groep toonden specifiek een trainingseffect op de subtest Prosodisch Bewustzijn.

De hulp die tijdens de training Prosodisch Bewustzijn werd gegeven heeft mogelijk bijgedragen aan het ontplooien van het potentieel om te leren van typisch ontwikkelende kinderen en kinderen met dyslexie. Daarnaast bleek de dynamische lees- en schrijftest gerelateerd aan conventionele lees- en spellingstests. Het leek erop dat beide testen en beroep hebben gedaan op vergelijkbare vaardigheden en mogelijk waren gebaseerd op overlappende concepten. De dynamische schrijftest posttest scores bleken, bij typisch ontwikkelende kinderen, ook te correleren met conventionele leestesten. Deze bevinding liet zien dat lees- en schrijfvaardigheden elkaar mogelijk aanvullen. De posttest scores van de typisch ontwikkelende kinderen en de kinderen met dyslexie op de subtest Fonologisch Bewustzijn in de experimentele groep lieten onverwacht een significante correlatie met intelligentie zien. Het is belangrijk om door middel van verder onderzoek de impact van de training op intelligentie te leren begrijpen.

De studie in Hoofdstuk 4 beschreven, analyseerde niet alleen de effectiviteit van de dynamische lees- en schrijftest, maar ook of werkgeheugenvaardigheden, inhibitie, cognitieve flexibiliteit en het zelfbeeld met betrekking tot lezen, verband hielden met de resultaten van deze online dynamische test. De resultaten toonden aan zowel typisch ontwikkelende kinderen als kinderen met dyslexie in de controle en experimentele onderzoeksgroep hun lees- en schrijfvaardigheden konden verbeteren. Ook hier lieten de resultaten van zowel de typische ontwikkelende kinderen als de kinderen met dyslexie in de experimentele groep een specifiek trainingseffect op de subtest Prosodisch Bewustzijn zien. De posttest scores op de dynamische schrijftesten leken minder afhankelijk van de executieve functies van typisch ontwikkelende kinderen en kinderen met dyslexie. De inhoud van de training waarin lees- en schrijfvaardigheden van een abstract naar een meer concreet niveau werden aangeleerd is hier mogelijk van invloed op geweest. Er werd geen verband gevonden tussen de posttest scores van de online dynamische lees- en schrijftest en het zelfbeeld met betrekking tot het lezen. Dit zou kunnen betekenen dat het zelfbeeld met betrekking tot het lezen geen negatieve invloed had op het vermogen om te profiteren van herhaalde oefening of instructie. Mogelijk was dit te wijten aan de duur van de training die te kort was om effect te hebben en of het feit dat kinderen met dyslexie wellicht geen duidelijk inzicht hebben in hun lees- en schrijf prestaties. Deze bevinding vraagt uiteraard om meer onderzoek. Belangrijk is dat de online afname geen belemmering is geweest op het verbeteren van de lees- en schrijfresultaten.

De studie in Hoofdstuk 5 analyseerde naast de effectiviteit van de dynamische lees- en schrijftest tevens of de uitkomsten van deze test konden voorspellen of een klinische dyslexie interventie succesvol zou zijn. De resultaten toonden aan dat kinderen met dyslexie een verbetering in het aantal goede antwoorden van pre- tot posttest lieten zien op de subtesten Fonemisch Bewustzijn en Schrijfvaardigheid van Woorden. Deze groei was tegen de verwachting in niet significant, wat mogelijk te maken kan hebben met de leeftijd van de kinderen uit deze studie en het feit deze kinderen nog geen dyslexiebehandelingen hebben ondergaan. Meewerken aan deze studie was voor hen een eerste kennismaking met een doelgerichte interventie op het gebied van lezen en schrijven. Daarnaast liet een nadere analyse van de gemiddelden en standaardscores zien dat er grote individuele verschillen tussen het startniveau en het niveau na training in de kinderen in de experimentele en controle groep waarneembaar waren. Uit dit onderzoek is verder gebleken dat de dynamische posttestscores van de subtesten Fonemisch Bewustzijn en Schrijfvaardigheid van (Context Afhankelijke) Woorden mogelijk betere voorspellers zijn voor de respons op dyslexie behandelingen dan de statische posttestscores. De schrijfvaardigheden waar de training op heeft gefocust corresponderen mogelijk met de lees- en schrijfvaardigheden die werden geoefend in de dyslexiebehandelingen.

Hoofdstuk 6 sloot af met een samenvatting van de onderzoeksresultaten. Implicaties van de belangrijkste bevindingen werden besproken en er werden aanbevelingen gedaan voor toekomstige studies naar potentieel om te leren. Geconcludeerd werd dat mogelijk begaafde kinderen kunnen profiteren van cognitieve trainingsprogramma's, zeker wanneer het metacognitieve kennis betreft. In de praktijk wordt soms aangenomen dat mogelijk begaafde kinderen excelleren in executive functies en daarom geen extra begeleiding (in de les) nodig hebben. Dit onderzoek daarentegen wees uit dat mogelijk begaafde kinderen ook baat hadden bij gerichte interventies en expliciete instructie. Gebleken is dat niet elk kind dat bovengemiddelde schoolresultaten haalt al in staat is om metacognitieve kennis zelfstandig in te zetten. De cognitieve training kan gezien worden als een interessante interventie die potentieel begaafde kinderen meer in staat stelt hun potentieel om te leren te benutten.

De studies naar de dynamische lees- en schrijftest in deze dissertatie zijn vernieuwend, omdat eerdere (Nederlandse) studies met betrekking tot lezen en schrijven zich vooral richtten op fonologisch bewustzijn of decodeervaardigheden. De studies gaven een eerste indicatie dat de principes van het dynamisch testen met succes kunnen worden gebruikt om inzicht te krijgen in de lees- en schrijfvaardigheden van typisch ontwikkelende kinderen en kinderen met dyslexie. Beide groepen konden hun potentieel om te leren, vooral op het gebied van prosodisch bewustzijn laten zien. Daarnaast leek de dynamische lees- en schrijftest vergelijkbare vaardigheden te meten als meer conventionele lees- en schrijftesten. De uitkomsten op de dynamische lees- en schrijftest leken minder beïnvloed te worden door de executieve functies van typisch ontwikkelende kinderen en kinderen met dyslexie. Een andere belangrijke bevinding was dat de posttest-scores op de dynamische schrijftests sterkere voorspellers zijn gebleken van de respons op klinische dyslexiebehandelingen dan de posttest-scores op conventionele lees- en schrijftesten. Dit geeft aan dat dynamisch testen waardevol kan zijn bij kinderen met dyslexie. Eerdere onderzoeken suggereerden al (Dixon et al., 2022) dat dynamische tests mogelijk een realistischer beeld geven van de mogelijkheden van kinderen met dyslexie dan de meeste conventionele tests.

Geconcludeerd werd dat zowel de cognitieve training in het oplossen van rekenkundige problemen als de dynamische lees- en schrijftest kansen bieden om het onderwijs en klinische behandelingen van dyslexie verder te verbeteren omdat er meer inzicht werd geboden in verschillen tussen kinderen, hun sterke en zwakke punten en hun onderwijsbehoeften. Ze stellen kinderen in staat hun potentieel om te leren te demonstreren. Door deze alternatieve testmethodes te omarmen kunnen leraren en dyslexiebehandelaren hun aanpak in klaslokalen en behandelingen verder afstemmen om nog beter tegemoet te komen aan de onderwijsbehoeften van alle kinderen.

Curriculum Vitae

Mirjam de Vreeze-Westgeest was born on 7 June 1966 in Leidschendam. She completed her HAVO in 1983 and her VWO diploma in 1985 from Veurs College in Leidschendam.

She earned her propaedeutic diploma in Pedagogical and Andragogical Science from the Faculty of Social Sciences at Leiden University in 1986 and her master's degree in Pedagogical Sciences from the same institution in 1990. By 1990, she had obtained her professional diagnostic registration, and in 2005, her Generalistic Orthopedagogue registration.

After several years as a childcare manager, she joined the predecessors of what is now called 1801 jeugd en onderwijsadvies, where she dedicated nearly 25 years of service. 1801 supports children, parents and teachers throughout the Netherlands and advises schools on learning, teaching and organisation.

In October 2019, she began her external PhD program at Leiden University under the supervision of professor Michiel Westenberg and dr. Bart Vogelaar while continuing working for 1801. Much of her time was devoted to being the primary therapist for children diagnosed with dyslexia. In 2020, she also completed her supervisor training.