COMPENSATING
reading and spelling abilities in children with
DYSLEXIA

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“Tot op de dag van vandaag heeft het verschijnsel dyslexie mij gefascineerd en als de meest op de voorgrond tredende leerstoornis beziggehouden”

Joep Dumont

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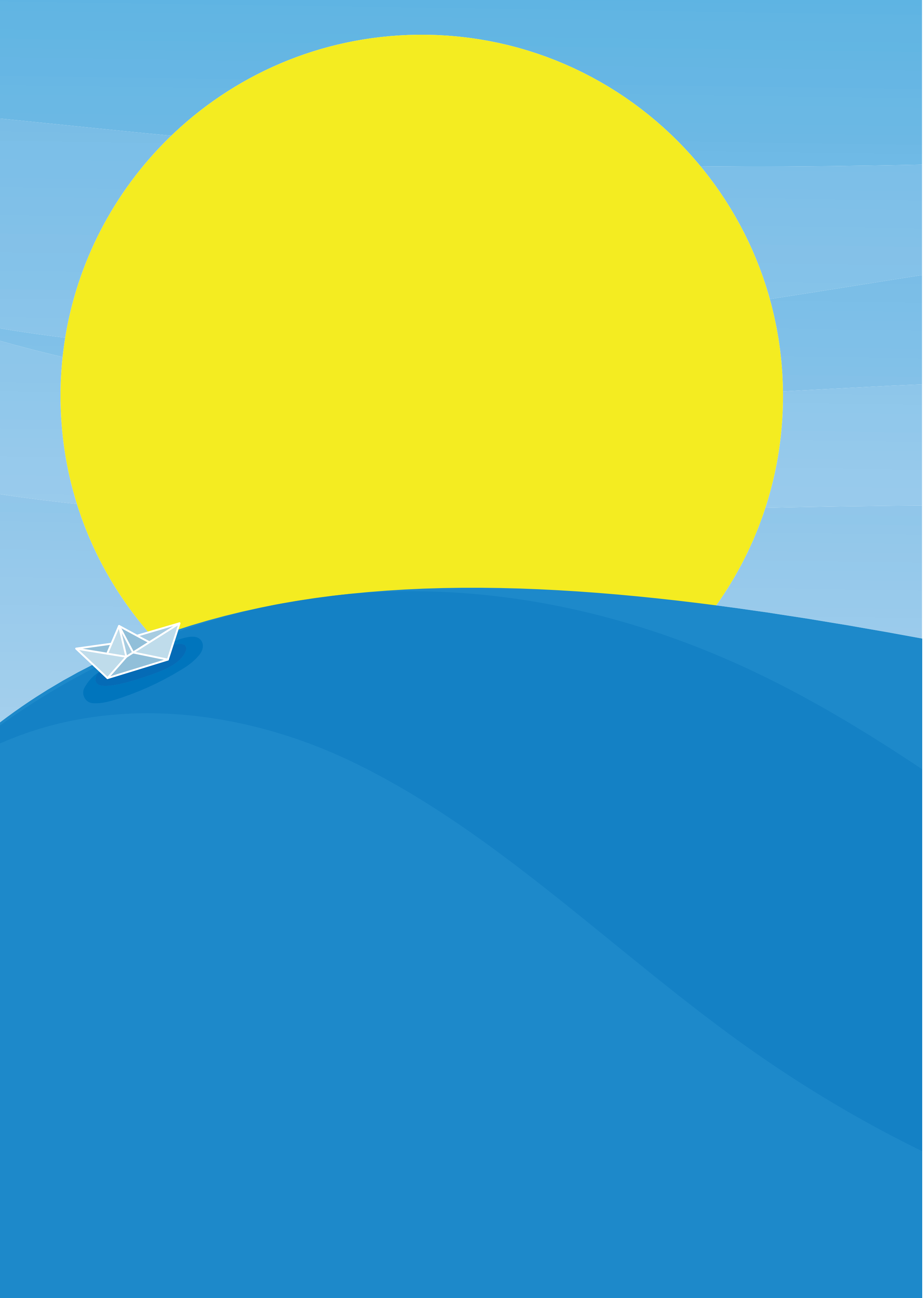

CHAPTER 1

General introduction

Reading and spelling abilities are crucial for school success (Savolainen et al., 2008), access to the labour market, and communication in todays (digital) knowledge society (de Greef et al., 2014). Theories regarding learning to read and spell emphasise that in order to become a proficient reader and speller, an efficient recurrent network of phonological, orthographic, and semantic representations needs to be built, which is also known as the triangular framework (e.g., Seidenberg & McClelland, 1989). A strong recurrent network enables children to decode words fluently, which is essential for the future development of reading comprehension (Stanovic, 2000; Verhoeven & Van Leeuwe, 2009). Children with developmental dyslexia (henceforward dyslexia) stay behind in their reading and spelling development and there seems to be consensus that multiple factors combine and/or interact to cause difficulties in learning to read and spell (Catts et al., 2017; McGrath et al, 2020; O'Brien & Yeatman, 2021; Pennington, 2006; Protopapas, 2019; Van Bergen et al., 2014b). This Multifactorial model of dyslexia includes causes from genetic, neural, cognitive, and environmental level (see Zuk et al., 2020). Among the factors on a cognitive level a large amount of research supports the notion that reading and spelling problems of children with dyslexia are associated with deficiencies in phonological processing (Melby-Lervåg et al., 2012; Pennington et al., 2012). As a consequence, children with dyslexia often have inaccurate and underspecified phonological representations (Conrad, 2008; Nation & Snowling, 2004), which results in difficulties in accurate and fluent reading and correct spelling (Lyon et al., 2003). Besides the weaknesses associated with dyslexia, there are also several resources/strengths that foster the reading and spelling proces (Catts & Petscher, 2020) and these are important to build on when addressing weaknesses (Protopapas, 2019). It is possible that children with dyslexia to a greater extent draw upon on relative strengths in the semantic and orthographic representations, the two other parts of the triangular framework, as a way to compensate for their weak phonological pathways. When the quality of the semantic representations increases, the lexical restructuring hypothesis assumes that this may cause pressure on phonological representations be strengthened as well (Metsala & Walley, 1998). A reciprocal connection between semantic abilities and phonology in the mental lexicon (Li et al., 2004) could indicate that the development of semantic abilities may give a boost to the development of phonological abilities (Van Goch et al., 2014) and thus indirectly facilitate the process of learning to read (e.g., Van Bergen et al. 2014a) and spell (Ouellette, 2010; Tainturier & Rapp, 2001). It has also been suggested that children use their semantic knowledge to circumvent phonological decoding deficits (Haft et al., 2016) and that children at risk for developing reading problems may use their early vocabulary knowledge to compensate for deficient phonological and reading abilities (Duff et al., 2015; Hulme et al. 2010; Torppa et al., 2010). So far, the possible compensatory role of semantic abilities and the ability to expand semantic abilities among children with dyslexia received scant attention in behavioural research.

To overcome reading and spelling problems, children with dyslexia need interventions to build strong and bi-directional phonology-orthography connections. However, most interventions thus far focused primarily on reading (see Galuschka, 2014) and thus only stimulate the orthography-phonology connections instead of stimulating the bi-directional relationship via combining both reading and spelling. As a case in point, prior research showed that spelling development benefits reading development as well (see Ehri & Wilce, 1987) and so more focus on orthographic learning could compensate for phonological shortcomings. The response to a so-called phonics through spelling intervention, aiming to enhance the bi-directional relationships between phonology and orthography, has not yet been studied and could give more insight in the benefits of adding a solid amount of spelling to an intervention for children with dyslexia. Furthermore, it is important to gain insight in relative strengths and weakness, profiles and its relation to intervention outcomes in order to optimize the (choice of) interventions and to build upon strengths to overcome difficulties (see Protopapas, 2019). In line with the reasoning above, the focus of this dissertation was to examine two sources of compensation for the phonological shortcomings underlying the reading and spelling problems of children with dyslexia: (i) enhancing semantic representations and (ii) enhancing orthographic representations by means of a phonics through spelling intervention.

Dyslexia

Learning to read and spell

According to the lexical quality hypothesis (Perfetti, 2007), becoming a proficient reader or speller requires high-quality lexical representations. According to the triangular framework, phonological, orthographic, and semantic representations are built throughout literacy development, which together form an efficient and recurrent network that is necessary to read and spell efficiently (Seidenberg & McClelland, 1989). Words with more high-quality phonological, orthographic and semantic representations are easier to read and spell than words with lower lexical quality (Perfetti, 2007; Perfetti et al., 2005). According to the lexical quality hypothesis word representations can be characterized by two dimensions: specificity and redundancy. Lexical specificity refers to the degree to which words are specified phonologically, semantically, and orthographically. Redundancy refers to the extent that lexical representations can be retrieved from memory; lexically and/or sublexically (Perfetti, 2007).

Already at young age, the foundation of literacy is laid, as children start to develop their spoken language. Children learn large numbers of words (phonological representations) and their meanings (semantic representations). By learning these words phonological and semantic representations are connected (Levelt, 1989; Levelt et al., 1999). Reading and spelling development builds upon this basis of representations (Shaywitz et al., 2003) as children become aware that the known words consist of speech sounds (phonological representation) that can be represented by graphemes (orthographic representation) and vice versa. This awareness of 'phonemes' is associated with a growing understanding of the alphabetical principle (Galuschka et al., 2014). In this phase of literacy development, children learn to recode graphemes into sounds in order to read (orthography-phonology connection) and to code phonemes into graphemes in order to spell (phonology-orthography connection). During this process, children recognize the meaning of words, which connects both phonology and orthography to the semantic representations. The more children practice the grapheme-sound correspondences, the faster the correct graphemes or sounds are retrieved from long-term memory, and decoding and coding words gets faster and more fluent. In addition, as a result of encountering printed or written words several times, children learn to read or write the whole word (or sometimes parts of words) accurately and instantly without decoding or recoding each grapheme. This process is also known as sight reading or spelling from memory (Ehri, 2005a) and enables readers and spellers to become even more fluent. The graphemes or sounds are then immediately connected to semantic representations (see Pugh et al., 2013). Both decoding and coding as well as the sight word reading and spelling from memory, stimulate high-quality bi-directional relationships between phonological and orthographic representations, which makes children proficient in both reading and spelling (see Ehri, 2005b; Perfetti & Hart, 2002). As can be seen throughout literacy development, reading and spelling are reversed processes, which could clarify why it has been shown in previous research among typically developing children that combining an emphasis on both reading and spelling can be beneficial for both learning to read and learning to spell (e.g., Conrad, 2008; De Graaff et al., 2009; Ehri, 2000; Ehri & Wilce, 1987; Ellis & Cataldo, 1990; Fitzgerald & Shanahan, 2000; Ise & Schulte-Körne, 2010; Ouellette & Sénéchal, 2008).

Reading and spelling problems

Despite the effort schools puts into learning children to read and spell, large individual differences occur in the extent to which children benefit from reading and spelling lessons. According to the lexical quality hypothesis, these differences in reading and spelling levels are mainly due to differences in the strength of the bi-directional relationship and the specificity of both phonological and orthographic representations (Perfetti & Hart, 2002). When the bi-directional relations are weaker, children may develop reading and spelling problems (Melby-Lervåg et al., 2012; Wimmer & Mayringer, 2002). This is especially the case for children with dyslexia, who read and spell at much lower levels than can be expected based on their age and educational level. Dyslexia is a specific learning disability that is characterized by difficulties in reading and spelling with a base in neurobiological development (American Psychiatric Association, 2013). There seems to be consensus that dyslexia can best be understood from a Multifactorial model (see Catts & Petscher, 2020; Catts et al., 2017; McGrath et al, 2020; O'Brien & Yeatman, 2021; Pennington, 2006; Van Bergen et al., 2014b). According to the Multifactorial model multiple factors combine and/or interact and cause difficulties in learning to read and spell (see Catts & Petscher, 2020). These factors occur at genetic, neural, cognitive, and environmental level (see Zuk et al., 2020). A large amount of research supports the notion that reading and spelling problems of children with dyslexia are associated with deficiencies in phonological processing on the cognitive level (see Pugh & Verhoeven, 2018). These deficiencies are reflected in problems in manipulating speech sounds that may hamper the grasping of the alphabetic principle (Bradley & Bryant, 1983). This so-called phonological deficit seems to underlie most reading and spelling problems of children with dyslexia (Melby-Lervåg et al., 2012, Pennington et al., 2012) and causes inaccurate or underspecified phonological and orthographic representations (Conrad, 2008). This, as a result, leads to problems in accurate and fluent reading and spelling among children with dyslexia (Lyon et al., 2003). The phonological deficit is domain-specific and independent of other linguistic abilities (Shaywitz et al., 2003). Already at a preliterate age, the phonological deficit influences the development of reading and spelling. Children at risk for dyslexia have been found to lag behind in phonological awareness, rapid naming, and verbal working memory (Melby-Lervåg et al., 2012; Puolakanaho et al., 2007). *Phonological awareness* is the awareness of spoken sounds in a language and has been found to be related to the process of mastering the systematic grapheme-sound correspondences and contribute to accurate and fluent word decoding (Melby-Lervåg et al., 2012) and spelling (Landerl & Wimmer, 2008). *Rapid automatized naming* involves accurate and efficient storing of detailed phonological or orthographic information, and has been found to be closely related to word decoding as well (Georgiou et al., 2012; Norton & Wolf, 2012). *Verbal working memory* is the ability to store verbal information temporarily and can be a constraint when excessive demands are being made, such as is the case in reading and spelling (Swanson et al., 1996).

Despite the fact that the phonological deficit is often associated with reading and spelling problems in children with dyslexia, not all children with reading and spelling problems have the same underlying deficit (Catts et al, 2017; O'Brien & Yeatman, 2021; Pennington et al., 2012; Snowling, 2008) and there is considerable variation in the causal base of reading and spelling difficulties (O'Brien & Yeatman, 2021; Pennington et al., 2012; Snowling, 2008). According to Multifactorial causal models of dyslexia, reading and spelling problems and variation in these problems could be caused by a complex interplay of weaknesses, but also strengths (Astle & Fletcher-Martin, 2020). Following a Multifactorial account of dyslexia, an important question is to what extent children with dyslexia may compensate for weaknesses with relative strengths.

Compensatory semantic abilities in children with dyslexia

Results from neuroimaging studies have indicated that children with dyslexia, in contrast to typically developing children, show differences in brain activation during reading and spelling with underactivation in the posterior regions of the brain and relative overactivation in the anterior regions of the brain (Georgiewa et al, 2002; Hoeft et al., 2007; Shaywitz et al., 2005; Turkeltaub et al., 2003). The posterior regions are associated with the phonological deficit (Brunswick et al., 1999; Georgiewa et al., 1999). The anterior regions are known for various aspects of language processing (Bookheimer, 2002), making efficient processing of language possible (Bookheimer, 2002), such as encoding new memories, retrieval and selection of declarative and procedural knowledge (Buckner et al., 2001; Ullman, 2004), and memorization of verbal information (Smith & Jonides, 1999). Based on these findings, Kearns and colleagues (2019) and Hoeft et al. (2011) suggested that children with dyslexia may use different pathways to read compared to typically developing peers in an attempt to compensate for the dysfunctions in the posterior regions of the brain. This line of reasoning fits with the idea of Multifactorial causal models of dyslexia, in which both weaknesses and strengths together determine reading and spelling levels. It is also in line with the triangular framework, in which semantic representations are reciprocally connected to both phonological and orthographic representations (Seidenberg & McClelland, 1989). When the quality of semantic representations increases, phonological representations are pressured to improve as well according to the lexical restructuring hypothesis (Metsala & Walley, 1998). Indeed, prior behavioural research found a reciprocal connection between semantic and phonological representationsin the mental lexicon (Li et al., 2004). The development of these semantic representations may therefore give a boost to the development of phonological abilities (Duff et al., 2015; Haft et al., 2016; Hulme et al. 2010; Torppa et al.; 2010; Van Goch et al., 2014) and facilitate the process of learning to read (e.g., Van Bergen et al., 2014a) and spell (Ouellette, 2010; Tainturier & Rapp, 2001). Phonological and semantic skills may influence reading development from its earliest stages and influence each other as well (e.g., Laing & Hulme, 1999). In addition, Nation and Snowling (2004) and Ouellette and Beers (2010) showed that within the typically developing readers, semantic abilities beyond phonology make important contributions to word recognition development. Furthermore, Gijsel (2007) concluded that semantic orientated reading programs worked just as well as programs that focus on phonological training only. Prior research regarding reading indeed showed the benefits of well-developed semantic representations (e.g., Gijsel, 2007; Nation & Snowling, 2004; Torppa et al., 2010) and suggested semantic representations to play a role in spelling development as well (Ouellette, 2010; Ouellette & Fraser, 2009; Tainturier & Rapp, 2001).

In line with the lexical restructuring hypothesis, converging evidence from neuroimaging studies (e.g., Shaywitz et al., 2005) as well as the triangular framework (Seidenberg & McClelland, 1989) suggest that high-quality semantic representations could be a source of compensation for the weak orthographic and phonological representations in children with dyslexia. However, most studies regarding the role of semantic abilities in reading and spelling were performed among typically developing children, children with reading problems, or children at risk for dyslexia. Research among children with the actual diagnoses of dyslexia is currently missing. Furthermore, the existing research mostly included the broadness of vocabulary (i.e., quantity). However, in contrast to the broadness of the available semantic network, the depth of the semantic representations seems to be a better indicator of the semantic representations that are necessary in order to compensate for weaknesses in the phonological representations. To be more specific, according to the lexical quality hypothesis, semantic abilities can be defined as a fuller range of meaning dimensions to discriminate among words in the same semantic field (Perfetti, 2007), which is reflected in the quality of the meaning network surrounding a word (i.e., Nagy & Herman, 1987). In order to find out the compensatory role that semantic abilities can play, the depth of the semantic representations should therefore be included as well.

As children with dyslexia could benefit from a well-developed semantic network, the ability to expand the specificity and redundancy of the (phonological) lexicon could be important too. In order to develop such a lexicon, one needs to be able to learn and consolidate verbally presented information in memory, processes that are also known as verbal learning and verbal consolidation (Kibby, 2009). As differences between children with dyslexia and typiccaly developing children were found in verbal learning (e.g., Elbro et al., 2005; Kibby, 2009) and in a single case also in consolidation (e.g. Kibby, 2009; Kramer et al., 2002) this could possibly be a facilitating or constraining factor causing differences in reading and spelling outcomes. Only two studies related verbal learning and consolidation (measured by verbal list learning) to reading and spelling outcomes (Kibby, 2009; Tijms, 2004) and only one study did so for verbal consolidation (Tijms, 2004). However, the debate on the compensatory role of verbal learning and consolidation can best be called inconclusive for several reasons. First, research so far, did not include a typically developing control group, nor did it control for all other important cognitive factors (phonological awareness, rapid automatized naming, verbal working memory and already acquired semantic abilities). Second, differences in conceptualization of verbal learning could have influenced the results because the operationalization of a learning measure should not reflect the result at the end of the learning process (see Tijms, 2004; Kibby, 2009) but should rather focus on the learning process itself. No prior study related this dynamic aspect of verbal learning and consolidation to reading and spelling outcomes, which is important because this shows the learning potential of semantic information that could facilitate phonological representations.

To sum up, the Multifactorial causal model of dyslexia implies that reading and spelling difficulties are a consequence of a complex interplay of strengths and weaknesses (Astle & Fletcher-Martin, 2020) and in such a model semantic abilities could be a strength to rely on. However, despite the clear role of semantic abilities in brain studies that found overcompensation among children with dyslexia in verbal areas (e.g., Shaywitz et al., 2005) and the triangular framework (see Seidenberg & McClelland, 1989), most research regarding children with dyslexia focused on the weak bi-directional relationship between phonological and orthographic representations, instead of focusing on the possible compensatory role of broad and deep semantic abilities. Research on the role of semantic abilities is limited and mostly includes measures of broad semantic knowledge rather than the deeper knowledge that is important in order to compensate for weak phonological representations (Li et al., 2004). Moreover, the available research mostly does not include children with the actual diagnosis of dyslexia, while specific explanations, such as a general learning disability, inadequate teaching, or sensory impairments are ruled out in the assessment and therefore a group of children with a specific reading and/or spelling problem remains. Furthermore, besides the role of verbal abilities present in children, the possibility to learn and maintain new verbal information could be important as well. These processes take place in the overactivated areas of the brain of children with dyslexia. Research regarding learning and maintaining verbal information (verbal learning and consolidation), however, is limited and still inconclusive.

Compensatory phonics through spelling intervention

As reading and spelling are both very important skills (see De Greef et al., 2014; Savolainen et al., 2008;), children with dyslexia need help to overcome their difficulties and become better at reading and spelling by building strong and bi-directional phonology-orthography connections. Previous research showed that phonics interventions were relatively successful at helping children with reading disabilities in strengthening the connections between phonological and orthographic representations and thereby improved both reading and spelling results (see review by Galuschka et al., 2014 and meta-analysis by Ehri et al., 2001). Galuschka and colleagues (2014) showed that a phonics intervention was, compared to reading fluency training, phoneme awareness instructions, reading comprehension trainings, auditory trainings, medical treatment, and coloured overlays or lenses, the only intervention with statistical confirmed efficacy on reading and spelling. A phonics intervention (i.e., a combination of reading fluency training and phonemic awareness training) includes systematic instruction of letter-sound-correspondences, decoding strategies, and the application of these skills in reading and writing activities (Galuschka et al., 2014). However, considerable individual variation in response to intervention exists (Galuschka et al., 2014) and research including both strengths and weakness profiles is limited (see Burns et al., 2016). In a subgroup analysis of Galuschka and colleagues (2014) it was mentioned that some studies did incorporate some writing activities, whereas other studies did not include writing activities at all. As mentioned earlier, reading and spelling are reversed processes and combining reading and spelling during instruction and practice can be beneficial for both learning to read and learning to spell (e.g., Conrad, 2008) as better orthographic representations (e.g., spelling) could facilitate phonological growth. Thus, according to Galuschka and colleagues (2014) most interventions focus on the orthography to phonology relationship instead of the bi-directional relationship that is stimulated when reading and spelling are combined.

A phonics intervention that incorporates spelling is a so-called phonics through spelling intervention (as described in Ehri et al., 2001) in which the recoding process of spelling is learned in addition to the decoding process. The few studies regarding phonics through spelling intervention (i.e., phonics interventions with the inclusion of writing activities) found effects for word decoding (e.g., Tijms, 2011), pseudoword decoding (e.g., Kirk & Gillon, 2009), and spelling (e.g., Kirk & Gillon, 2009). These findings highlight the importance of a high-quality bi-directional relationship between both phonological and orthographic representations in learning to read and spell and show the benefits of a phonics through spelling intervention. As spelling is more difficult to learn than reading (Bosman & Van Orden, 1997; Ehri, 1997; O'Connor & Jenkins, 1995) one would expect that phonics through spelling interventions would include both reading and spelling instructions and divide time at least evenly. However, in the aforementioned studies very limited amounts of time were spent on spelling activities (at most one-third in Tilanus et al., 2016). Therefore, more research is needed to determine whether a phonics through spelling intervention with more time for spelling can be effective in increasing both reading and spelling levels of children with dyslexia.

When including spelling it is important to start with a strong base of phonological processes in spelling based on grapheme-phoneme translation and add specific and complex orthographic processes in spelling by learning children morphological and orthographic patterns later on (Caravolas et al., 2001). For spelling, it was found that phonics, morphological, and orthographic interventions are all effective in treating spelling problems of children with dyslexia (Galuschka et al., 2020). One way of addressing phonological and orthographic errors separately is to analyze and categorize spelling errors. Spelling errors can be subdivided into three broad categories in order to define the source of the errors: phonological, morphological, and orthographic errors (Tops et al., 2014; Vanderswalmen et al., 2010). Previous studies showed that children with dyslexia (before an intervention) do not make qualitatively different, but more phonological, morphological, and orthographic spelling errors compared to typically developing children (Bourassa & Treiman, 2003; Bourassa et al., 2006). However, studies so far did not incorporate all three errors types (phonological, morphological, and orthographic errors) in one study in order to compare phonological and orthographic processes in spelling with one another.

As known from previous studies, not all children with dyslexia benefit from interventions to the same extent, and individual differences in responsiveness have been reported repeatedly (see, e.g., Galuschka et al., 2014; Singleton, 2009; Snowling & Hayiou-Thomas, 2006; Torgesen, 2006). In order to gain insight in which children benefit from certain interventions it is necessary to match profiles of relative strengths and weaknesses with specific intervention approaches (see also Burns et al., 2016). These profiles could include phonological awareness, rapid automatized naming, verbal working memory, semantic abilities, verbal learning, and verbal consolidation. Currently, research including effects all of the aforementioned predictors on response to phonics through spelling intervention (with time evenly spent on reading and spelling) in children with dyslexia is missing. Strengths in semantic representations or the ability to expand these could, as mentioned earlier, be sources of compensation for both reading and spelling. Furthermore, regarding individual spelling profiles of children with dyslexia, results of phonics interventions on spelling have only been expressed in the number of words written correctly, whereas comparing spelling error profiles before and after the intervention could give new insights in the phonological and orthographic processes in spelling development among children with dyslexia due to the intervention.

It can thus be concluded that weak phonological abilities in children with dyslexia can be compensated by enhancing the orthographic representations and its connections with the phonological part of the recurrent network. However, more in-depth knowledge is needed regarding the spelling profiles of children with dyslexia to determine what effects phonics through spelling interventions have on spelling development of children with dyslexia. Moreover, most intervention studies regarding children with dyslexia have focused on reading or spelling whereas both processes can enhance the quality of the bi-directional relations between phonological and orthographic representations and benefit each other as well. Phonics through spelling interventions (i.e., interventions in which at least 50% of the time is spent on spelling activities) could have many beneficial effects but research regarding this specific type of intervention is scarce and have not yet been related to relevant cognitive precursors (i.e., phonological awareness, rapid automatized naming, working memory, semantic abilities, and verbal learning and consolidation).

Present research

The present research focused on compensating reading and spelling in children with dyslexia in the Netherlands. The first goal was to examine the compensatory role of semantic abilities of children with dyslexia on word reading, pseudoword reading, and spelling. The second goal is to study whether strengthening the orthographic representations by means of a phonics through spelling intervention has positive effects on word reading, pseudoword reading, and spelling and if cognitive profiles (including phonological awareness, rapid automatized naming, working memory, semantic abilities, and verbal learning and consolidation) influence response to intervention.

Diagnosis of dyslexia in the Netherlands

In the Netherlands, all children learn to read and spell by means of highly structured phonics reading and spelling instructions starting from grade 1. Since Dutch is a rather transparent language (see Landerl & Wimmer, 2008) most children benefit from these instructions and learn to read and spell at appropriate levels. However, some children do not reach appropriate levels. The Netherlands has a nation-wide protocol for diagnosis of and intervention for dyslexia (Blomert, 2006). The nation-wide protocol is recently revised based on developments in research and clinical practice and this renewed protocol (Tijms et al., 2021) was implemented in January 2022. Throughout the current study, the preceding protocol was used but the results of the present study will be related to the changes in the renewed protocol in the discussion section of this thesis.

The protocol used in this thesis (Blomert, 2006) states that children with severe and persistent reading problems or combined reading and spelling problems can be referred to a specialized clinic for assessment (private institutes). Teachers have to prove that the persistent and severe reading problems or combined reading and spelling problems were at place during one and a half school year (word reading scores below 10^{th} percentile or below 15^{th} percentile combined with spelling scores below 10^{th} percentile). Children visit the clinic at different moments in their school carriers (varying from grade 2 to grade 6). In the subsequent diagnosis, a phonological deficit needs to be evidenced and other explanations of reading or spelling problems need to be excluded by a certified clinical psychologist. This is in line with the definition of dyslexia in the International Dyslexia Association (2002). After formally being diagnosed with dyslexia, children in the Netherlands receive a free, in-service intervention in a specialized clinic that aims to help these children to learn to read and spell at age-appropriate levels. During and after the intervention word reading, pseudoword reading and word spelling levels are monitored to see whether the intervention is beneficial.

Design and research questions

For the purpose of this study, 99 files of Dutch children with dyslexia were made available by a clinic for assessment and intervention of children with learning difficulties in the east of the Netherlands. Parents had given active consent to use the data collected during the intervention for research purposes. All assessments and interventions were performed between 2009 and 2012 by a certified clinic at various locations in the east of the Netherlands. The files of the selected children included data from assessment and intervention based on the previously described protocol and included an extensive history of the child's development and school results, information about school-based interventions, Brus One Minute test (Brus & Voeten, 1973) for word reading, Klepel (Van den Bos et al., 1994) for pseudoword reading, the PI-dictation (Kingsma & Van den Burg, 2005) for word spelling, the complete Wechsler Intelligence Scale for Children-III (WISC-IIINL; Kort et al., 2005b) for verbal reasoning skills, verbal working memory, and perceptual organization, Continuous Naming and Reading Words (Van den Bos & Lutje Spelberg, 2007) for rapid automatized naming, and in most cases the 15 Words test for children (Kingsma & Van den Burg, 2005) for verbal learning tasks. For Phonological Awareness, three measures were administered; subtests of the Screening Test for Dyslexia (Kort et al., 2005b), the phonemic analysis Test (Van den Bos et al., 2010), and subtests from 3DM (Blomert & Vaessen, 2009). Most files were present containing the Screening Test for Dyslexia and considering the required power for our analyses these files were selected. Because of the variety in instruments for phonological awareness, a group of 63 children (43 boys and 20 girls) with Dutch as their first language remained for the present research. All children with dyslexia scored, weak on word reading (n = 61, M = 4.42, SD = 1.816), and pseudoword reading (n = 62, M = 5.25, SD = 1.795) when compared to norms (n = 62, M = 10, SD = 3). For spelling, these children scored weak (n = 62, M = 7.27, SD= 14.228) compared to norms (M = 50, SD = 34). Some additional variables were missing that were important for some papers only and thus group size can differ per study. In Chapter two, eight children were excluded since data was missing on reading tests, semantic abilities, and/or working memory. In Chapter three, nine children were excluded since data was missing on semantic abilities and/or working memory and some did not have an intervention. In Chapter four, the same nine children as in chapter three were excluded, supplemented with two children of whom the dictation tasks were not in the files. For Chapter five, eight children were excluded, since data was missing on verbal learning and consolidation and/or reading tests. Two research questions were formulated:

1. To what extent can semantic abilities compensate for reading and spelling development in children with dyslexia?
2. To what extent can the reading and spelling development of children with dyslexia with varying cognitive profiles benefit from a phonics to spelling intervention?

During the project two control groups of typically developing children were collected for studies on spelling errors (Chapter 4, n = 104) and verbal learning (Chapter 5, n = 36). The first control group was gathered at six different schools in the east of the Netherlands. The second control group was gathered at one school in the east of the Netherlands. Schools were addressed by BSc and MSc students and when schools agreed to participate parents were informed about the research and asked for permission. Parents of all children within the control groups gave active consent to participate in the presented studies.

Outline of this thesis

This thesis studied clinical data in order to find out more about two possible ways of compensating for a phonological deficit in reading and spelling development of children with dyslexia. Each chapter in the present thesis represents an empirical article. Each of these articles have been accepted for publication.

The goal of Chapter 2 was to explore the direct and indirect contribution of semantic abilities to the levels of phonological and orthographical abilities in 55 children with dyslexia. Semantic abilities, phonological awareness, rapid automatized naming and, verbal working memory were included as precursor measures.

In Chapter 3, an attempt was made to test the response to intervention in a phonics through spelling intervention for 54 children with dyslexia in word and pseudoword reading efficiency, and word spelling. Furthermore, we investigated to what extent the response to intervention is robust across different cognitive profiles (phonological awareness, rapid automatized naming, and working memory). Response to intervention was studied using change-scores.

Chapter 4 examined the differences in phonological, morphological, and orthographic spelling errors between 52 children with dyslexia and 105 typically developing spellers. Cognitive profiles (phonological awareness, rapid automatized naming, working memory, and semantic abilities) of children with dyslexia were related to these errors with a special interest for the effect of semantic abilities. Furthermore, the response to a phonics through spelling intervention was measured by studying the change in spelling errors and profiles. The change in each spelling error category was related to cognitive profiles as well, again with a special interest for the effects of semantic abilities.

Chapter 5 reports about the extent to which reading and spelling performances of 54 children with dyslexia both before and after a phonics through spelling intervention were predicted by their verbal learning and consolidation. The ability to learn and maintain verbal information and its influence on reading and spelling measured before the intervention were compared to 36 typically developing children. Response to intervention was studied using change-scores.

In Chapter 6, the key findings of this dissertation are discussed along with limitations and direction for future research and implications for practice. Finally, in the Appendix a Dutch summary of the findings from the preceding chapters was provided along with Acknowledgments, Curriculum Vitae of the author, List of publications, and information about datamanagement and transparency.

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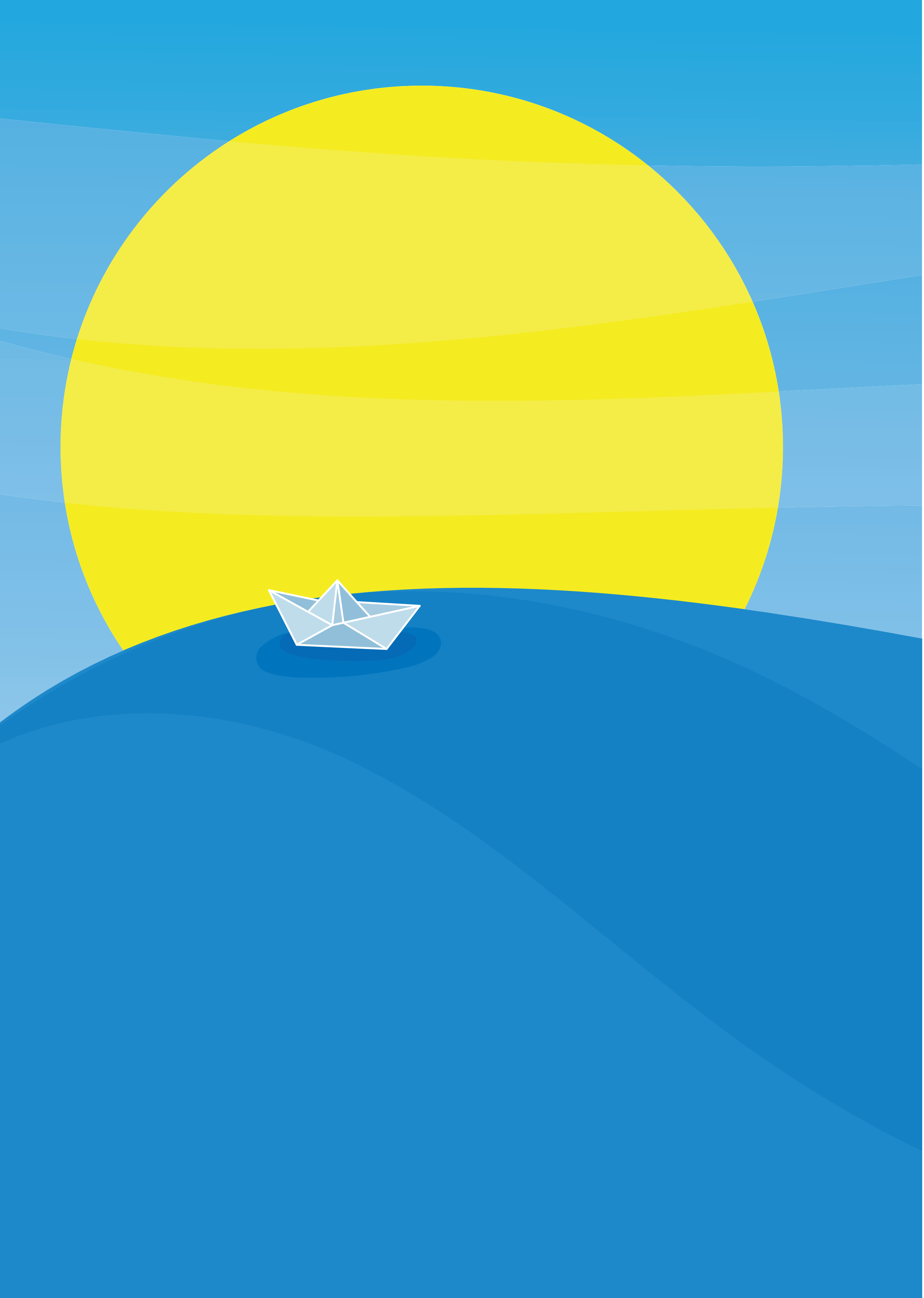


CHAPTER 2

Impact of semantic abilities on word decoding

This chapter is based on:
Van Rijthoven, R., Kleemans, T., Segers, E., & Verhoeven, L. (2017). Beyond the phonological deficit: Semantic abilities contributes indirectly to decoding efficiency in children with dyslexia. *Dyslexia, 24*(4), 309-321. doi:10.1002/dys.1597

Abstract

The present study explored the direct and indirect contribution of semantic abilities to the levels of phonological and orthographic abilities in children with dyslexia. The semantic abilities of fifty-five 9-year-old Dutch children diagnosed with dyslexia were associated with their phonological abilities (phonological awareness, rapid naming, and verbal working memory) and their word decoding and pseudoword decoding efficiency scores. It was found that children's semantic abilities predicted both word decoding efficiency and pseudoword decoding efficiency indirectly via phonological awareness and rapid naming. These results can be explained in terms of a lexical restructuring account of early reading development; strong semantic abilities provide children with dyslexia with a boost to strengthen their phonological skills and naming skills, which indirectly facilitates their reading development.

Introduction

Learning to read is important to become functional literate in today's society. The process of reading involves activation of orthographic, phonological, and semantic features of words (see Coltheart, et al., 2001; Seidenberg & McClelland, 1989). In learning to read, children learn that words constitute of speech sounds that can be represented by letters. By learning the letters and recoding orthographic representations into phonological representations, children become proficient in reading (see Ehri, 2005). Phonological factors are also seen as most critical in predicting early success in reading (Hulme et al., 2005). Research has shown that phonological awareness, rapid automatized naming (Swanson et al., 2003), and working memory (Jongejan et al., 2007) can be seen as important predictors of early word decoding. For children with dyslexia, however, the mapping of orthography to phonology is far from trivial. Many of them experience a phonological deficit that obscures the assignment of phonology to orthographic word representations (Snowling & Göbel, 2010). Research also indicated that phonological awareness, rapid naming, and working memory are generally low in children with dyslexia (Tilanus et al., 2013). Given the presence of a phonological deficit in children with dyslexia, it might well be the case that these children could compensate such a deficit with a strongly developed semantic system. It can be assumed that there is a reciprocal connection between semantic abilities and phonology in the mental lexicon (Li et al., 2004) and that the development of semantic abilities may give a boost to the development of phonological abilities (Van Goch et al., 2014) and thus facilitate the process of learning to read (e.g., Van Bergen et al., 2014). However, the possible beneficial role of semantic abilities in the development of word decoding in children with dyslexia has so far only received scant attention in the literature. Therefore, in the present study, we explored the direct and indirect contribution of semantic abilities to the levels of phonological and orthographic abilities in Dutch children with dyslexia.

Role of semantic abilities in learning to read

Learning to read involves grasping the alphabetic principle that involves the acquisition of mappings between orthography and phonology. This requires that children become aware of the sound structure of their language. In the literature, it has indeed been found that phonological abilities predict children's success in learning to read. To begin with, phonological awareness (i.e., the awareness of spoken sounds in language) has been found to be related to the process of mastering the systematic spelling–sound correspondences and to contribute to accurate and fluent word decoding (Melby-Lervåg et al., 2012). There is also abundant evidence that rapid naming which involves the accurate and efficient storing of detailed phonological or orthographic information, is closely related to word decoding (Georgiou et al., 2012; Norton & Wolf, 2012). And it has also been shown that verbal working memory may constraint the storage of verbal content when excessive demands are being made, as is the case in word decoding (Swanson et al., 1996). In the course of reading development, word decoding becomes faster, and gradually, most words are recognized more or less instantly (Bishop & Snowling, 2004; Nation & Snowling, 2004). Becoming a proficient reader requires having high-quality lexical representations as claimed by the lexical quality hypothesis (Perfetti, 2007). These representations develop by multiple exposures to words that consist of orthographic, phonological, and semantic features (Perfetti & Hart, 2002). For children with dyslexia, however, the acquisition of word decoding is problematic as a consequence of inadequate phonological skills. Already at preliterate age, children at risk for dyslexia have found to be behind in speech decoding (Richardson et al., 2010), phonological awareness, rapid naming, and verbal working memory (Puolakanaho et al., 2007). Their phonological deficit may cause problems in manipulating speech sounds that may hamper the grasping of the alphabetic principle. Moreover, children with dyslexia may stay behind in phonological recoding of written word representations because their phonological lexicon can be considered underspecified (Elbro, 1996; Ramus, 2001).

An important question is how a strong capability in semantic abilities may compensate dyslexic children in reading words and pseudowords. Semantic abilities can, according to the lexical quality hypothesis, be defined as a fuller range of meaning dimensions to discriminate among words in the same semantic field (Perfetti, 2007). Not only vocabulary or the broadness of vocabulary but also the depth of the semantic representations thus may be of importance. The depth of semantic representations is defined as the quality of the meaning network surrounding a word (Nagy & Herman, 1987). Most studies only took the broadness of the semantic lexicon into account and not the depth of the semantic representations (Perfetti & Hart, 2002). Interestingly, the semantic representations of children with dyslexia are quite similar to typically developing children (Nation & Snowling, 1998; Swan & Goswami, 1997), which may provide them with the possibility to use their semantic knowledge as a compensatory mechanism.

Based on the lexical quality hypothesis (Perfetti & Hart, 2002), a direct effect can be expected of semantic abilities on word reading because a better semantic quality of lexical representations may facilitate word identification. And based on the lexical restructuring hypotheses (see Walley et al., 2003), an indirect effect can be expected of semantic abilities on both word and pseudoword reading mediated by phonology. According to this lexical restructuring hypothesis, the development of preliterate phonological abilities in children with dyslexia can be fostered by a strong lexical development. As the numbers of words and their semantic relations increase, a stronger pressure can be hypothesized to make finer phonological distinctions in the mental lexicon. It can thus be assumed that lexical representations start out holistic and become more specified during early and middle childhood (Metsala & Walley, 1998). Indeed, it has been found that children's degree of lexical specificity enhances their phonological awareness (Garlock et al., 2001; Van Goch et al., 2014) and facilitates their decoding skills (Elbro et al., 1998). Following a dual route perspective on reading, it can be hypothesized that a more specified lexicon fosters the process of word decoding and visual word recognition. According to the dual route model (see Coltheart et al., 2001), children learn to assign phonology to new words (or pseudowords) by applying the alphabetical principle. In doing so, they store orthographic, phonological, and semantic knowledge in their mental lexicon. Gradually, they become able to address this stored information in the lexical retrieval of frequently encountered words and in a direct route of visual word recognition (Coltheart, 2006). It can thus be expected that semantic knowledge may foster word decoding indirectly via lexical retrieval (i.e., rapid naming) or directly via word recognition.

Neurocognitive research has indeed evidenced that poor readers rely to a greater extent on their semantic lexicon when it comes to word decoding (Shaywitz et al., 2003). Children with dyslexia may thus compensate for their weak orthographic and phonological representations by using their broad and deeply developed semantic knowledge when combining graphemes and phonemes to a recognizable meaningful word. Because the lexical representations of semantic knowledge and phonological knowledge seem to be reciprocally connected, a broad and deep semantic knowledge can be considered useful when phonological representations are less developed (Li et al., 2004). Behavioural evidence for the role of semantic abilities in word decoding has also been found by Nation and Snowling (2004), who showed that weaker semantic skills related to lower word decoding skills, and Ouellette and Beers (2010) who found semantic skills to predict decoding in Grade 6 and irregular word recognition in Grades 1 and 6. There is also evidence that children with dyslexia compensate for their poor decoding skills by using the semantic context during text reading (Nation & Snowling, 1998). Furthermore, a study of Van Bergen and colleagues (2014) showed verbal IQ (defined by expressive vocabulary, expressive syntax, and comprehension) to be uniquely related to later monosyllabic word decoding in 4-year-old children who go on to develop dyslexia. Besides a direct effect of semantic representations on pseudoword and word decoding, also indirect effects have been shown in the literature. Swanson and colleagues (2003) showed that semantic skills predicted phonological awareness and rapid naming as well as word decoding. In a similar vein, Torppa and colleagues (2010) showed that receptive and productive semantic skills in Scandinavian children at familial risk for dyslexia predicted their word decoding through phonological awareness, letter naming, and inflectional morphology.

The present study

To sum up, it has been made clear that orthography, phonology, and semantic abilities are of main importance for learning to read words. Throughout the grades, children develop full word representations in order to become fluent readers. Although children with dyslexia are in need for more compensation in phonological recoding, it remains unclear for this specific group of readers whether the full semantic lexicon (depth and broadness of the lexicon) could partly compensate for a weak phonological component in building orthographic representations. It is still unclear whether the role of semantic abilities is in assigning phonology to new orthographic representation as tapped with pseudoword reading or in addressing phonology in direct word recognition. An indirect effect of semantic abilities via phonological awareness and rapid naming on word and pseudoword decoding could be predicted in the former case, a direct effect of semantic abilities on word decoding in the latter case. Therefore, in the present study, we investigated the direct and indirect effects of semantic abilities on pseudoword and word decoding within a group of Dutch children with dyslexia, taking into account phonological awareness and rapid naming. In contrast with previous research, in the present study, semantic abilities is defined as much broader than just vocabulary. It is generally known that semantic abilities involves more than vocabulary alone, and especially because the specificity and redundancy of the lexical representations seems to be important (Perfetti & Hart, 2002), a broad operationalization definition of semantic abilities was used, including both lexical knowledge and comprehension skill. Starting from the question to what extent semantic abilities in children with dyslexia would foster their decoding skills, we expected to find pseudoword and word decoding to be both directly and indirectly (via phonological awareness and rapid naming) predicted from semantic knowledge.

Method

Participants

Participants were Dutch children diagnosed with dyslexia who received an in-service reading and/or spelling intervention in a clinic for assessment and intervention for children with learning difficulties. For the purpose of this study, 99 files of Dutch children were collected from the clinic. Due to missing data and different instruments, a group of 55 children (36 boys and 19 girls) with Dutch as their first language remained for this study. For an anticipated medium effect size (in terms of Cohen's f 2) of 0.15 for each path including three predictors (semantic abilities, phonological awareness, and rapid automatized naming), a representative group of 55 participants was needed to have sufficient power (>0.80) at the .05 level (two tailed) according to calculations as recommended by Faul and colleagues (2007).

All children had been referred to a reading clinic by their parents and teachers. Teachers had to prove resistance to treatment (after 10- to 12-week interventions) and constant weak performances for 1.5 years (word reading scores below 10th percentile or below 15th percentile combined with spelling scores below 10th percentile) for these children. All children were diagnosed with severe dyslexia and received in-service reading and/or spelling interventions. The mean age of this group of children during assessment was 8.55 years (*SD* = 1.051). Children were in Grade 2 (*n* = 16), Grade 3 (*n* = 25), Grade 4 (*n* = 10), Grade 5 (*n* = 3), and Grade 6 (*n* = 2). Out of the group of 55 children, 15 children attended the same class an extra year. Parents gave active consent to let their child participate in the present research. Because of the large variation in age, age was included as a covariate in the analyses.

Measures

Reading measures

Pseudoword decoding

Pseudoword decoding was measured by the “Klepel” (Van den Bos et al., 1994). In this task, the child had to read as many meaningless words as possible correctly within a time limit of two minutes. The card contained 116 unrelated pseudowords that had the same structure as meaningful words. Words became more difficult gradually from one syllable (“taaf”) up to five syllables (“nalleroonplinteng”). An efficiency measure (the number of words correctly read within two minutes) was calculated. The reliability of this measure differs per age but is at least .89 (Van den Bos et al., 1994).

Word decoding

Word decoding was measured by the “Brus One Minute Test” (Brus & Voeten, 1973). In this task, the child had to read as many meaningful words correctly as possible within a time limit of one minute. The card contained 116 unrelated words. Words became more difficult gradually from one syllable (“waar” [true]) up to four syllables (“tekortkoming” [shortcoming]). Am efficiency measure (the number of words correctly read within one minute) was calculated. The reliability of this measure differs per age but is at least .87 (Van den Bos et al., 1994).

Precursor measures

Phonological awareness

Phonological awareness was measured by adding the z-scores of two subtests from the “Screening Test for Dyslexia” (Kort et al., 2005b). First, during “Phoneme Deletion”, the child had to omit a phoneme from an orally presented word and speak out the remaining word (e.g., “dak” [roof] minus k [f] is “da” [roo]). Testing was terminated after four consecutive mistakes. The reliability differs per age but is at least .59 (Kort et al., 2005b). Second, during the subtest, “Spoonerism” (Kort et al., 2005b) the child had to switch the first sounds of two words (e.g., “John Lennon” becomes “Lohn Jennon”). Testing was terminated after five consecutive mistakes. The reliability differs per age but is at least .60 (Kort et al., 2005b). In both tests, all correctly formed words were counted.

Rapid automatized naming

Rapid automatized naming was measured by adding the z-scores of two subtests from “Continuous Naming and Reading Words” (Van den Bos & Lutje Spelberg, 2007). First, during “Naming Letters,” the child had to read out loud 50 letters. Second, during “Naming Digits,” the child had to read out loud 50 digits. The child was asked to name these visual stimuli as fast as possible. The time in seconds, needed to finish each subtest, was used for analysis. A low score therefore represents a good performance on this task. The reliability of this measure differs per age but is at least .75 (Van den Bos & Lutje Spelberg, 2007).

Verbal working memory

Verbal working memory was measured using the backward task of the Number Recall subtest from the Wechsler Intelligence Scale for Children (WISC-III^{NL}; Kort et al., 2005a). In this task, the experimenter pronounces sequences of digits that the child was asked to repeat in backward order. Testing was terminated after two consecutive mistakes. The number of correctly recalled sequences was counted. The reliability of this measure differs per age but is at least .50 (Kort et al., 2005a).

Semantic abilities

Semantic abilities were measured by adding the z-scores of four subtests from the WISC-III^{NL} (Kort et al., 2005a). First, during “Information,” the child has to answer verbally asked questions to test their general knowledge about events, objects, places, and people. Based on the manual, the child received zero, one, or two points for each item. Testing was terminated after five consecutive mistakes. All points were counted afterwards. The reliability differs per age but is at least 0.64 (Kort et al., 2005a). Second, during “Similarities,” the child has to name the similarity between two concepts. Based on the manual, the child received zero, one, or two points for each item. Testing was terminated after four consecutive mistakes. All points were counted afterwards. The reliability differs per age but is at least .65 (Kort et al., 2005a). Third, during “Productive vocabulary,” the experimenter pronounces a word and the task of the child was to define the given word. Based on the manual, the child received zero, one, or two points for each item. Testing was terminated after four consecutive mistakes. All points were counted afterwards. The reliability differs per age but is at least .77 (Kort et al., 2005a). Fourth, during “Comprehension,” the experimenter asked questions about social situations or common concepts. Based on the manual, the child received zero, one, or two points for each item. Testing was terminated after four consecutive mistakes. All points were counted afterwards. The reliability differs per age but is at least .73 (Kort et al., 2005a). Kaufman (1975) already showed that these four measures together form a factor named “verbal comprehension.” To confirm this factor within this specific group a principal component analysis with varimax rotation on all subtests of WISC-III^{NL} is added. This showed a four-factor distinction, together explaining 75.79% of variance in intelligence measures. The first factor included semantic abilities (information .810, similarities .807, vocabulary .874, and comprehension .839), the second factor visual spatial abilities (block design .847, visual puzzles .772, incomplete drawings .583, and pictures organization .492), the third factor working memory (digit span forwards .648 and digit span backwards .745), and the fourth factor processing speed (substitution .914 and symbol search .931). To make the impact of all variables equal in this research, factor scores were not included in the analyses.

Perceptual organization

Perceptual organization was measured by adding the z-scores of four subtests from the WISC-III^{NL} (Kort et al., 2005a). First, during “Incomplete drawings,” the child has to name or point at a missing part in a drawing of familiar objects or situations within 30 seconds. Testing was terminated after five consecutive mistakes. The child received one point for each correctly named missing part. All points were counted afterwards. The reliability differs per age but is at least .54 (Kort et al., 2005a). Second, during “Picture arrangement,” the child has to put pictures in the right order to make the story depict right. The child was asked to do this as quickly as possible. Testing was terminated after three consecutive mistakes. The first two items are scored two points at first attempt and one point at second attempt. The other items were given zero, two, three, four or five points based on accuracy and the time the child needs to order the pictures. All points were counted afterwards. The reliability differs per age but is at least .65 (Kort et al., 2005a). Third, during “Block design,” the child had to reconstruct patters of two, four, and later nine blocks shown on a picture. The child was asked to do this as quickly as possible. Testing was terminated after two consecutive mistakes. The first three items are scored two points at first attempt and one point at second attempt. The other items were given four, five, six, or seven points based on accuracy and the time the child needs to reconstruct the pattern. All points were counted afterwards. The reliability differs per age but is at least .71 (Kort et al., 2005a). Fourth, during “Visual puzzles,” the child has to make five puzzles of everyday objects. Testing was terminated after four consecutive mistakes. Each right connection between puzzle pieces was given one point. Extra points were given when less time was needed to make the puzzle with a maximum of ten points. All points were counted afterwards. The reliability differs per age but is at least .40 (Kort et al., 2005a).

Procedure

The current study was based on existing data collected by a clinic for assessment and intervention of children with learning disorders. Between 2009 and 2013, data were filed at this clinic. The following procedures were followed: Assessment started with parents and teacher filling in questionnaires about current problems and child's development. Afterwards, parents were invited for an interview at the clinic. Both the questionnaires and the interview were in order to rule out other explanations for reading and spelling problems. Assessment took place at a clinic for assessment and intervention of children with learning disorders. Parents brought their children to the clinic in Nijmegen (the Netherlands), and MSc-graduated clinicians tested the children individually in quiet rooms. Mostly the assessment took two consecutive mornings from about 9.00 a.m. until 12.00 p.m. including breaks. After assessment, clinical reports were written by the MSc-graduated clinicians. The continuity of quality was guaranteed by supervision of certified clinical health psychologists. The stored files were used for this study.

Results

Table 2.1 presents the descriptive statistics of all standardized measures. Both raw scores and age-related scaled scores are given.

Prior to the analyses, all scores (except for age) were standardized using z-scores. Z-scores were calculated by subtracting the mean raw score from each value and then divided that by the standard deviation. A composite score of these z-scores was computed for phonological awareness, rapid automatized naming, semantic abilities, and perceptual organization. Rapid automatized naming is the only variable in which a negative score means a better performance because rapid automatized naming is expressed in time needed to finish reading letters and digits. In Table 2.2, Pearson correlations are given. All predictor measures were significantly related to word decoding and pseudoword decoding. Furthermore, semantic abilities was found to be significantly related to phonological awareness and rapid automatized naming. Of the covariates, age, and perceptual organization were significantly related to word decoding and pseudoword decoding.

Table 2.1 *Descriptive Statistics for all Participants (n = 55) including Raw Scores and Aage-based Scaled Scores.*

		M	*SD*	Min	Max
Phonological awareness					
Spoonerism	Raw scores	2.93	3.29	0	11
	Scaled scores	7.75	2.21	4	13
Phoneme deletion	Raw scores	8.07	2.40	2	12
	Scaled scores	7.95	2.39	4	15
Rapid automatized naming					
Letter naming	Raw scores	40.58	10.84	24	75
	Scaled scores	5.53	2.58	1	13
Digit naming	Raw scores	36.64	11.07	22	86
	Scaled scores	6.45	2.98	1	12
Working memory					
	Raw scores	4.04	1.36	2	8
Semantic abilities					
Information	Raw scores	13.00	3.66	7	23
	Scaled scores	10.67	2.38	6	17
Similarities	Raw scores	14.60	4.88	5	27
	Scaled scores	12.36	2.90	6	19
Vocabulary	Raw scores	31.05	6.72	19	52
	Scaled scores	11.55	2.42	8	19
Comprehension	Raw scores	20.96	5.69	5	38
	Scaled scores	11.67	2.47	4	19
Pseudoword decoding	Raw scores	19.89	9.91	6	50
	Scaled scores	5.22	1.86	1	8
Word decoding	Raw scores	30.29	13.02	7	62
	Scaled scores	4.51	1.80	1	8

Note. All scaled score population means are 10 and standard deviations are 3. Working memory is only described in terms of means.

Table 2.2 *Pearson Correlations between the Predictor Measures (i.e., Performal IQ Scores, Age, Working Memory, Phonological Awareness, Rapid Automatized Naming, and Semantic abilities) and Criterion Measures (i.e., Pseudoword Decoding and Word Decoding) (n = 55).*

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9**	**10**	**11**	**12**
1. Perceptual organisation	-											
2. Age	.504**	-										
3. Working memory	.131	.229	-									
4. Phonological awareness	.297*	.391**	.175	-								
5. Spoonerism	.330*	.515***	.265	.875***	-							
6. Phoneme deletion	.176	.146	.028	.850***	.489***	-						
7. Rapid automatized naming	-.219	-.446***	.020	-.204	-.160	-.194	-					
8. Letter naming	-.262	-.494***	-.099	-.199	-.189	-.153	.930***	-				
9. Digit naming	-.146	-.367**	.135	-.181	-.109	-.207	.932***	.733***	-			
10. Semantic abilities	.622**	.679***	.141	.357***	.462***	.142	-.365**	-.387**	-.294*	-		
11. Pseudoword decoding	.475**	.645***	.297*	.510***	.556***	.326*	-.480***	-.535***	-.497***	.549***	-	
12. Word decoding	.550**	.807***	.234	.516***	.483***	.394*	-.544***	-.485***	-.408**	.667***	.841***	-

* $p < .05$, ** $p < .01$, *** $p < .001$.

To answer the research questions, two regression based mediation analyses were conducted with the process add-on in SPSS (Hayes, 2013). Bootstrapping was set at 5.000 cycles, as recommended by Hayes (2013). In mediation models, the addition of the direct effect (c') and the indirect effect (ab) form the total effect (c) of a certain independent variable on a dependent variable. The indirect effect (ab) is formed by multiplying the effect of the independent variable on the mediator (a) and the effect of the mediator on the dependent variable (b). A total effect may not reach significance, even when the direct effect is significant (Hayes, 2009), which could be due to a relatively small sample size (Shrout & Bolger, 2002). The final model of this paper includes two statistical models with different dependent variables. In the first model, word decoding was the dependent variable, and in the second model, pseudoword decoding was the dependent variable. In both analyses, verbal working memory, perceptual organization, and age were added as covariates. To ensure that the analyses had enough statistical power, the covariates were added in the models of the dependent variable only. Therefore, the direct and indirect effect do not add up to the total effect. All regression weights can be found in Table 2.3

The results of the first mediation analysis with word decoding as the dependent variable showed no significant direct effect of semantic abilities (c' = 0.0255, *SE* = 0.0248, 95% CI [–0.0316, 0.0825]; *p* = .374) nor a total effect of semantic abilities, (c = 0.0414, *SE* = 0.0319, 95% CI [–0.0226, 0.1055]; *p* = .200). Semantic abilities, however, was significantly related to Phonological awareness (a = 0.1712, *SE* = 0.0615, 95% CI [0.0478, 0.2945]) and Rapid automatized naming (a = –0.1879, *SE* = 0.0657, 95% CI [–0.3197, -0.0560]) and Phonological awareness (b = 0.1099, *SE* = 0.0427, 95% CI [0.0240, 0.1985]) and Rapid automatized naming (b = -0.1238, *SE* = 0.0409, 95% CI [-0.2061, -0.0416]) were significantly related to word decoding. Indirect effects of semantic abilities were found via Phonological awareness (ab = 0.0188, *SE* = 0.0115, 95% CI [0.0037, 0.0524]) and Rapid automatized naming (ab = –0.0233, *SE* = 0.0109, 95% CI [0.0066, 0.0495]). The total indirect effect of semantic abilities was significant (0.0421, *SE* = 0.0173, 95% CI [0.0162, 0.0856]). The relation between semantic abilities and word decoding was partially mediated by Phonological awareness and Rapid automatized naming. The total effect of the model is R^2 = 0.691 (M*SE* = 0.3052, $p < .001$). Age had a significant total effect on word reading (0.0485, *SE* = 0.0086, 95% CI [0.0313, 0.0657]). There were no significant effects of covariates perceptual organization and verbal working memory.

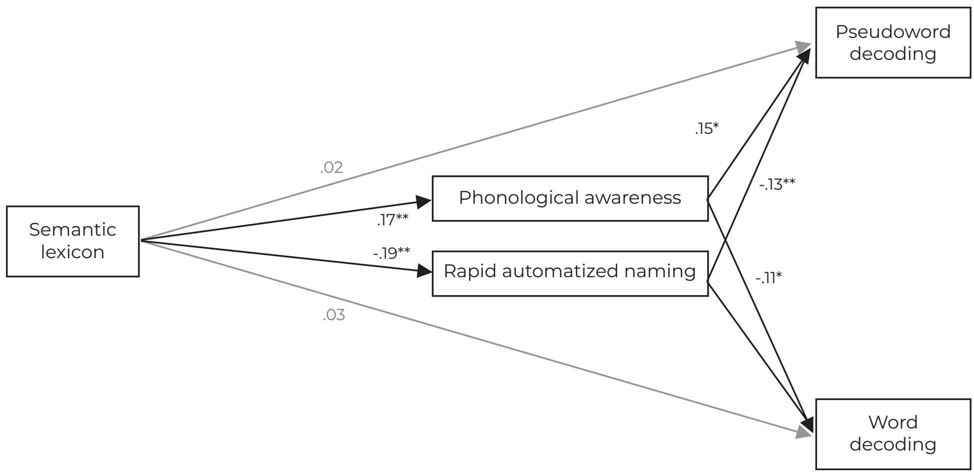
Table 2.3 *Regression Weights of Mediation Analyses for Word Decoding and Pseudoword Decoding.*

Type		*Effect*	*Coeff*	*SE*	*p*	BC 95% CI	
						Lower	Upper
Word decoding							
Direct	(c')	Semantic abilities on word decoding	0.0255	0.0284	.3741	-0.0316	0.0825
Indirect	(a)	Semantic abilities on phonological awareness	0.1712	0.0615	.0074	0.0478	0.2945
	(b)	Phonological awareness on word decoding	0.1099	0.0427	.0132	0.0240	0.1958
	(ab)	Semantic abilities via phonological awareness on word decoding	0.0188	0.0115	-	0.0037	0.0524
	(a)	Semantic abilities on rapid automatized naming	-0.1879	0.0657	.0061	-0.3197	-0.0560
	(b)	Rapid automatized naming on word decoding	-0.1238	0.0409	.0040	-0.2061	-0.0416
	(ab)	Semantic abilities via rapid automatized naming on word decoding	0.0233	0.0109	-	0.0066	0.0495
	(b)	Age on word decoding	0.0373	0.0080	<.0001	0.0211	0.0535
	(b)	Verbal working memory on word decoding	0.0600	0.0679	.3808	-0.076	0.1965
	(b)	Perceptual organisation on word decoding	0.0400	0.0279	.1585	-0.0162	0.0962
Total	(c)	Total effect of semantic abilities	0.0414	0.0319	.2000	-0.0226	0.1055
	(c)	Total effect of age	0.0485	0.0086	<.0001	0.0313	0.0657
	(c)	Total effect of verbal working memory	0.0488	0.0759	.5237	-0.1038	0.2013
	(c)	Total effect of perceptual organisation	0.0407	0.0316	.2043	-0.0228	0.1041
Pseudoword decoding							
Direct	(c')	Semantic abilities on pseudoword decoding	0.0183	0.0389	0.6407	-0.0599	0.0964
Indirect	(a)	Semantic abilities on phonological awareness	0.1712	0.0615	.0074	0.0478	0.2945
	(b)	Phonological awareness on pseudoword decoding	0.1450	0.0586	.0169	0.0272	0.2627
	(ab)	Semantic abilities via phonological awareness on pseudoword decoding	0.0248	0.0165	-	0.0017	0.0697
	(a)	Semantic abilities on rapid automatized naming	-0.1879	0.0657	.0061	-0.3197	-0.0560
	(b)	Rapid automatized naming on pseudoword decoding	-0.1331	0.0561	.0216	-0.2459	-0.0204
	(ab)	Semantic abilities via rapid automatized naming on pseudoword decoding	0.0250	0.0114	-	0.0079	0.0542
	(b)	Age on word decoding	0.0221	0.0110	0.5120	-0.0001	0.0442
	(b)	Verbal working memory on pseudoword decoding	0.1589	0.0930	0.0942	-0.0282	0.3459

Type		*Effect*	*Coeff*	*SE*	*p*	BC 95% CI	
						Lower	Upper
	(b)	Perceptual organisation on pseudoword decoding	0.0440	0.0383	0.2560	-0.0330	0.1211
Total	(c)	Total effect of semantic abilities	0.0371	0.0423	0.3842	-0.0478	0.1220
	(c)	Total effect of age	0.0351	0.0113	0.0033	0.0123	0.0578
	(c)	Total effect of verbal working memory	0.1508	0.1006	0.1402	-0.0513	0.3530
	(c)	Total effect of perceptual organisation	0.0459	0.0419	0.2784	-0.0382	0.1301

The results of the second mediation analysis with pseudoword decoding as the dependent variable showed no significant direct effect of semantic abilities (c' = 0.0183, *SE* = 0.0389, 95% CI [–0.0599, 0.0964]; *p* = .641) nor a total effect of semantic abilities (c = 0.0371, *SE* = 0.0423, 95% CI [–0.0478, 0.1220]; *p* = .384,). Semantic abilities, however, was significantly related to Phonological awareness (a = 0.1712, *SE* = 0.0615, 95% CI [0.0478, 0.2945]) and Rapid automatized naming (a = -0.1879, *SE* = 0.0657, 95% CI [-0.3197, -0.0560]) and Phonological awareness (b = 0.1450, *SE* = 0.0586, 95% CI [0.0272, 0.2627]) and Rapid automatized naming (b = -0.1331, *SE* = 0.0561, 95% CI [-0.2459, -0.0204]) were significantly related to pseudoword decoding. Indirect effects were found via Phonological awareness (ab = 0.0248, *SE* = 0.0165, 95% CI [0.0017, 0.0697]) and Rapid automatized naming (ab = 0.0250, *SE* = 0.0114, 95% CI [0.0079, 0.0542]). The total indirect effect of semantic abilities was significant (0.0498, *SE* = 0.0210, 95% CI [0.0172, 0.0995]). The relation between semantic abilities and word decoding was partially mediated by Phonological Awareness and Rapid automatized naming. The total effect of the model is R^2 = 0.476 (M*SE* = 0.5351, *p* < 0.001). Age did have a significant total effect on pseudoword decoding (0.0351, *SE* = 0.0113, 95% CI [0.0123, 0.0578]). There were no significant effects of covariates perceptual organization or verbal working memory. Figure 2.1 depicts the final models.

Figure 2.1 *Path Diagram for the Predictive Role of the Semantic Knowledge on Pseudoword Decoding, Word Decoding, and the Mediators Phonological Awareness and Rapid Automatized Naming.*



Note: Both significant paths (black) and non-significant paths (grey) and their standardized estimates are displayed.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Conclusions and discussion

The main goal of the present study was to investigate the direct and indirect effect of semantic knowledge on pseudoword and word decoding within a group of Dutch children with dyslexia. It was questioned how semantic knowledge in children with dyslexia predicts pseudoword and word decoding directly and indirectly.

To begin with, significant indirect effects of semantic knowledge were found on both pseudoword decoding efficiency and word decoding efficiency. In line with findings of Torppa and colleagues (2010), we found that children's semantic knowledge has a significant effect on both phonological awareness and rapid naming. Just as found by Metsala (1999), we found that a more specific and redundant lexicon is related to phonological awareness. This indicates that the lexicon could facilitate phonological awareness. Although the relation between semantic knowledge and phonological awareness is generally assumed to be reciprocal (Castles & Coltheart, 2004; Perfetti et al., 1987), in the early stages of reading, semantic processing influences reading development and not vice versa (see Verhoeven et al., 2011). Children with dyslexia are still in their early stages of reading, and thus, these results fit prior research. We also found an effect of semantic knowledge on rapid naming as an index of efficiency in lexical retrieval. Importantly, besides direct effects of semantic abilities on phonological awareness and rapid naming, we also found a significant effect of the latter two abilities on both pseudoword decoding efficiency and word decoding efficiency. In other words, we found a relation between semantic knowledge and word and pseudoword decoding efficiency via phonological awareness and rapid naming. The found indirect effect of semantic abilities via rapid naming is in line with Wolf and colleagues (2016).

However, we found no significant total or direct effect of semantic knowledge on word decoding and pseudoword decoding. This was not expected based on the triangular reading model claiming that orthographic representations are linked to both phonological and semantic representations (Seidenberg & McClelland, 1989). Especially for children with dyslexia, who experience weak orthographic-phonological connections (Wimmer & Schurz, 2010), the use of semantic knowledge could be considered commendable. The finding that there was no impact of broad and deep semantic knowledge on word decoding for children with dyslexia is not in line with previous research (i.e., Van Bergen et al., 2014). The effect of semantic knowledge on word decoding is also not commensurate with the lexical quality hypothesis claiming that proficient reading requires redundant lexicalized word representations (Perfetti & Hart, 2002). It can tentatively be explained from the fact that the children with dyslexia are only in the beginning of their reading development with a primary focus on phonological recoding, which is heavily influenced by phonological awareness and rapid naming, explaining the indirect effect we found of these abilities on children's decoding efficiency.

Of course, the present study can only be seen as a first step in uncovering the role of semantic abilities in dyslexic children's processes of learning to read. It should be acknowledged that the present data were cross-sectional and that causal conclusions regarding relations between semantic abilities and decoding efficiency measures cannot be drawn. It would be informative to know whether typically developing children to a certain extent show an effect of semantic knowledge as well. Future studies following a longitudinal design comparing children with dyslexia and typically developing readers are needed to arrive at final answers regarding the role of lexical semantic abilities in learning to read. A second point to mention is the large variability of age in the sample. Therefore, age is included as a covariate in the analyses regarding the dependent variable. One could argue that age should be included as a covariate in the analyses regarding the independent variables as well. This would lead to underpowered analyses. Therefore, age is not included on all variables; hence, results should be interpreted with caution. More research with more power is necessary to disentangle the effect of age on the model. Furthermore, it should be considered to use measures of receptive and not expressive semantic abilities instead of measures that require word retrieval and verbal formulation because dyslexia and specific language impairment (SLI) are comorbid developmental language disorders (Catts et al., 2005). Besides semantic knowledge also the role of retrieval could be taken into account. A final point to make is that although the results of the factor analysis indicated that the four subtests that measured lexical semantic abilities loaded on one and the same factor, it could be argued that the subtests, similarities, and productive vocabulary, are conceptually more related to semantic abilities as compared with the other two subtests (see Burton et al., 2001; Cohen, 1959). We therefore conducted a secondary analysis with only these two measures (i.e., similarities and productive vocabulary). The overall conclusions remain the same: Semantic abilities were still indirectly related to word decoding and pseudoword reading. The present study leads to implications for future research. It is shown that semantic abilities are indirectly related to word and pseudoword reading, via their relation to phonological awareness and rapid naming. This association could indicate that semantic abilities are a facilitating factor for forming fine-grained phonological and orthographic representations and so indirectly influence reading development. A recent study by Van Gorp and colleagues (2016) has indeed shown that semantic categorization in addition to feedback and motivation in a word decoding training task may yield important effects on decoding efficiency in poor readers in second grade. To find out to what extent the effects are due to semantic categorization, feedback or motivational aspects of the training are object to future research.

Overall, the present findings indicate that the semantic lexicon of children with dyslexia could contribute to pseudoword and word decoding efficiency indirectly. The indirect effects point to the fact that lexical specificity may help dyslexics to become better phonologically aware (see Metsala, 1999) and to become better in lexical retrieval (see Wolf et al., 2016), both of which have a positive impact on decoding efficiency. Furthermore, it fits the lexical restructuring hypothesis in which lexical semantic subsystems could foster the phonological abilities and thereby word and pseudoword reading. Regarding the dual route model, it is possible that the better specified lexicon is the product of the nonlexical route but also partly by semantic development. The finding that there are no direct effects of semantic abilities on decoding measures point to the fact that children with dyslexia do not directly profit from a strong semantic knowledge component in learning to decode words. Based on these results, it seems possible that children with dyslexia compensate their weak ability to form phonological and orthographic representations by use of their semantic abilities as reasoned in the lexical quality hypothesis and lexical restructuring hypothesis. Even though the effect of semantic abilities was small and indirect, these findings show the relevance of a broad and deep semantic knowledge in the reading development of children with dyslexia. Semantic abilities seems to be a variable that should be taken into account in further research regarding reading.

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CHAPTER 3

Response to phonics through spelling intervention

This chapter is based on:
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Abstract

We examined the response to a phonics through spelling intervention for children with dyslexia in word and pseudoword reading efficiency and word spelling. Furthermore, we investigated to what extent the response to the intervention is robust across different cognitive profiles (phonological awareness, rapid automatized naming, and working memory). A group of 54 Dutch children, diagnosed with dyslexia, received a phonics through spelling intervention that combined reading and spelling instruction and practice in a systematic way. An equal amount of time was spent on reading and spelling. Compared with norms within a typically developing population, positive effects were established for word and pseudoword reading efficiency and word spelling from pretest to posttest. The individual variation in phonological awareness, rapid automatized naming, and verbal working memory did not significantly influence the progress in reading and spelling children made during the phonics through spelling intervention. It can thus be concluded that a combined reading and spelling intervention is beneficial for word and pseudoword reading efficiency and word spelling in children with dyslexia notwithstanding their cognitive profiles. Although promising results were found, this study also showed the persistence of spelling, but even more so of reading problems after an intervention among children with dyslexia.

Introduction

Reading and spelling are essential skills in life and contribute to quality of life (Stein et al., 2011). It is thus crucial that all children reach sufficient reading and spelling levels. However, learning to read and spell is not an easy task for all children. To become a proficient reader and speller, an efficient recurrent network of phonological, orthographic, and semantic representations needs to be built (Seidenberg & McClelland, 1989). Previous research has consistently pointed out that bi-directional relationships between phonology and orthography are crucial for the development of both reading and spelling abilities (Bosman & Van Orden, 1997). Children with dyslexia have severe problems in building up these phonology–orthography connections (Lyon et al., 2003), although phonics interventions have been relatively successful in strengthening the connections (for a review, see Galuschka et al., 2014). It is important to note that such interventions have mainly focused on reading (i.e., going from orthography to phonology) rather than reading and spelling combined (i.e., going from phonology to orthography as well, but see Galuschka et al., 2014 and Johnston & Watson, 2006). The effectiveness of a so-called phonics through spelling intervention, aiming to enhance the bi-directional relationships between phonology and orthography, has not yet been demonstrated. In the current study, we therefore examined whether a phonics through spelling intervention benefits both reading and spelling in children with dyslexia and whether such effects are consistent across cognitive profiles.

Problems in learning to read and spell for children with dyslexia

When learning to read, children learn the principle of phonological recoding, that is, to decode words by sounding out graphemes and blending these sounds into words (Castles et al., 2018). With extensive practice, the orthographic and phonological representations and connections between the two get stored in memory. In learning to spell words, the reversed process (i.e., orthographic recoding) occurs. Both phonological and orthographic recoding processes build upon the bi-directional connection between phonological and orthographic representations (Bosman & Van Orden, 1997).

The strength of the bi-directional relationship and the specificity of both phonological and orthographic representations differ among children (Perfetti & Hart, 2002), with words with high-quality representations being read and spelled better than words with lower lexical quality (Perfetti, 2007; Perfetti et al., 2005). Children develop reading and spelling problems when the bi-directional relations between phonological and orthographic representations are less strong (Melby-Lervåg et al., 2012; Wimmer & Mayringer, 2002). This is especially the case for children with dyslexia. These children have missing, inaccurate, or underspecified representations caused by a phonological deficit (Conrad, 2008). As a consequence, these children have large difficulties to read words and pseudowords both accurately and fluently and spell words correctly (Lyon et al., 2003).

Research among typically developing children pointed out that combining reading and spelling during instruction can be beneficial for both learning to read and learning to spell (Conrad, 2008; De Graaff et al., 2009; Ehri, 2000; Ehri & Wilce, 1987; Ellis & Cataldo, 1990; Fitzgerald & Shanahan, 2000; Ise & Schulte-Körne, 2010; Ouellette & Sénéchal, 2008). Such results emphasise the importance of high-quality bi-directional relationships of orthographic representations in learning to read and spell. As a case in point, Ouellette and Sénéchal (2008) found that children in kindergarten who received combined reading and spelling instruction showed a more analytical approach and better integration of phonological and orthographic knowledge, which benefited their reading as well as their spelling development after a four-week training. A transfer effect from training spelling on reading development has also been evidenced (Conrad, 2008; Ehri, 1989; Graham & Hebert, 2011; Ise & Schulte-Körne, 2010; O'Connor et al., 1995; Ouellette et al., 2017), which suggests that the addition of spelling instruction and practice may result in more refined representations as compared to only focusing on reading abilities. For instance, Ehri (1989) found that better spelling leads to more fluent and automatic word identification skills and thus better word reading accuracy due to the necessity of having high-quality representations for spelling. This necessity arises from the fact that spelling is more difficult to learn than reading (Bosman & Van Orden, 1997; Ehri, 1997; O'Connor et al., 1995).

Interventions on reading and spelling

There is a large research base on interventions for struggling readers. A recent meta-analysis by Galuschka and colleagues (2014) pointed out that a phonics intervention is generally most effective, with significant effects on word reading and pseudoword reading with a transfer to spelling levels. However, most phonics interventions focus on reading and do not combine reading and spelling instruction in one intervention. Only a few studies investigated the benefits of a phonics through spelling intervention (Galuschka et al., 2014).

To begin with, Lovett and colleagues (1989) randomly assigned 178 poor-reading children between the ages of 8 and 13 years to phonics instruction with writing activities, a language stimulation program, or a control condition. Both experimental conditions led to improvement in word reading and writing but not in pseudoword reading. The phonics intervention including writing activities, however, showed better generalization of skills to untrained words. In another study, Lovett and colleagues (1990) tested two versions of phonics instruction with writing activities. In a group of 54 disabled readers, a whole-word training was compared to a whole-word training supplemented with phonological and orthographic recoding. Both conditions included writing activities and showed significant effects on word reading accuracy and fluency and word spelling. Pseudoword reading was not included in this study. The training with the whole-word approach showed more transfer to untrained content. Finally, Kirk and Gillon (2009) tested the effectiveness of a training by sorting tasks and spelling with prompts with a control condition among 16 children with spelling problems. The experimental group significantly gained in pseudoword reading and spelling accuracy and was able to generalize their trained skills to new words. No effects were found on word reading.

Two studies examined the benefits of adding spelling activities to a phonics intervention for children with dyslexia in the Netherlands. Tilanus and colleagues (2016) examined a group of 54 children with dyslexia, who had received a 12-week intervention. Approximately one-third of the instruction time was spent on writing activities. Compared to typically developing peers, positive effects were found of this intervention on pseudoword reading accuracy and efficiency and spelling, but not on word reading accuracy or efficiency. Furthermore, Tijms (2011) tested the effectiveness of a computer-based phonics intervention including both reading and spelling activities among 99 children diagnosed with dyslexia. Significant gains were found, and after the intervention word reading accuracy and spelling levels were comparable to the lower bound of normal range.

Robustness of the intervention

Not all children with dyslexia benefit from phonics interventions to the same extent, and individual differences in responsiveness have been reported repeatedly (see, e.g., Galuschka et al., 2014; Singleton, 2009; Snowling & Hayiou-Thomas, 2006; Torgesen, 2006). Attempts have been made to relate the responsiveness to intervention to the cognitive profile of the child. Given the fact that dyslexia can be characterized by an underlying phonological deficit, phonological awareness, rapid automatized naming, and verbal working memory are generally considered cognitive precursor measures that may also predict children's responsiveness to intervention (Shaywitz et al., 2003; Snowling, 1998). In line with the double deficit hypothesis (as described by Wolf & Bowers, 1999), it is argued that phonological awareness and rapid automatized naming can be seen as critical sources of reading impairment (Landerl & Wimmer, 2008).

Prior research on the robustness of response-to-intervention effects showed that decoding accuracy training effects were sustained across individual differences in phonological awareness (Felton, 1993; Tijms, 2011) and that reading fluency training was robust across individual differences in rapid automatized naming training (Heikkilä, 2015). Combining accuracy and fluency training also showed robustness across individual differences in both phonological awareness and rapid automatized naming (Aravena et al., 2016; Tilanus et al., 2016). Responsiveness to intervention may also be dependent on children's verbal working memory. A limited verbal working memory reduces the amount of phonological and orthographic information that can be co-activated during the reading process, especially during the decoding process (Gathercole & Baddeley, 1993; Perez et al., 2012). Hulme (1987), and De Jong (1998) argued that constraints in verbal working memory negatively influence phonological decoding skills since during decoding many segments must be held in memory. However, the effect of verbal working memory on the progress during reading and spelling interventions has received scant attention. Tijms (2011) found verbal working memory to be a significant moderator for reading abilities and not for spelling abilities, whereas Tilanus and colleagues (2016) did not find direct effects of verbal working memory on reading and spelling outcomes.

The present study

From the research conducted so far, it can be concluded that the reading and spelling abilities of children with reading and spelling problems could benefit from the addition of spelling to a phonics intervention. However, the effectiveness of a phonics through spelling intervention in which an equal amount of time is devoted to spelling and reading is still unknown. Given the fact that children with dyslexia have problems in forming strong bi-directional relations between phonology and orthography, a phonics through spelling intervention could indeed enhance the reading and spelling abilities of children with dyslexia. Furthermore, little is known about the robustness of a phonics through spelling intervention in respect of the cognitive profile of the child. The purpose of the present study was, therefore, to measure the responsiveness of a phonics through spelling intervention among Dutch children with dyslexia. It can be hypothesized that an effect of the quality of the bi-directional relationships between phonological and orthographic representations is highly prominent in the case of a transparent orthography like Dutch. In order to find out more about the robustness of this Dutch phonics through spelling intervention, the role of individual differences among children with dyslexia will also be taken into account. Specifically, we addressed the following research questions:

1. What is the effect of a phonics through spelling intervention on pseudoword reading, word reading, and word spelling scores in Dutch children with dyslexia?
2. To what extent are the outcomes of a phonics through spelling intervention robust across different cognitive profiles?

Given the fact that spelling contributes to the deeper knowledge of our sound system and prior research found transfer effects of spelling to reading, we expected that children with dyslexia would show a substantial change in their reading and spelling skills after the phonics through spelling intervention. Second, based on prior research, we expected the phonics through spelling intervention outcomes to be robust across differences in phonological awareness, rapid automatized naming, and verbal working memory.

Method

Participants

Participants were Dutch children diagnosed with dyslexia who received an in-service phonics through spelling intervention in a clinic for assessment and intervention of learning difficulties among children with learning difficulties. For the purpose of this study, 99 files of Dutch children were collected from the clinic. Due to missing data and different instruments, a sample of 54 children (37 boys and 17 girls) with Dutch as their first language was selected for this study.

The mean age of this group of children at the start of the assessment was 8.97 years (*SD* = .96). Children were in grade 2 (*n* = 17), grade 3 (*n* = 24), grade 4 (*n* = 9), grade 5 (*n* = 3), and grade 6 (*n* = 1). Out of the group of 54 children, 17 children attended the same class an extra year. All children had perceptual cognitive capacities within the normal range (*M* = 103.70, *SD* = .15). However, since there was variation in perceptual cognitive capacities, this variable was included as a control variable in the analysis. Parents gave active consent to use the data collected during the intervention for research purposes.

Procedure

The current study was based on existing data collected by a clinic for assessment and intervention for children with learning disorders. Between 2009 and 2013, data were filed in this clinic. All children had been referred to this clinic by their parents and teachers. The assessment and intervention were performed following the standardized Dutch Protocol Dyslexia Diagnostics and Treatment (Blomert, 2006). The following procedures were followed: Assessment started with parents and teacher filling in questionnaires about current problems and the child's development. Afterward parents were invited for an interview at the clinic. Both the questionnaires and the interview were in order to rule out other explanations for reading and spelling problems, such as general learning problems or specific influential events during the child's development with impact on learning progress. Furthermore, by means of the questionnaires teachers had to prove constant weak performances for 1.5 years (word reading scores below 10th percentile or below 15th percentile combined with spelling scores below 10th percentile) for these children notwithstanding systematic and well-defined reading and spelling instruction in the classroom. This should be supplemented with in-class extended instruction time, combined with individual intervention (i.e., remedial teaching) for 10 to 12 weeks. All children were tested during two consecutive mornings (9:00 a.m. – 12:00 p.m. including breaks) by experienced MSc-graduated clinicians. Rapid automatized naming, phonological awareness, verbal working memory, pseudoword decoding, word decoding, spelling, and perceptual cognitive skills were measured. Two or three weeks after the assessment the phonics through spelling intervention started. After the intervention all participants were subjected to the posttest, including pseudoword decoding, word decoding, and spelling measures.

Measures

Outcome measures

Pseudoword decoding

Pseudoword decoding was measured with the Klepel (Van den Bos et al., 1994). Children were asked to read as many meaningless words as possible correctly within a time limit of two minutes. This task consistsed of 116 unrelated pseudowords presented in four rows on one sheet. The words all had the same structure as meaningful words. Words became more difficult gradually from one syllable ("taaf") up to five syllables ("nalleroonplinteng"). An efficiency measure (i.e., total number of words read within two minutes minus number of errors) was calculated. The reliability of this measure differs per age but is at least .89 (Van den Bos et al., 1994). Pseudoword decoding was measured before and after the intervention.

Word decoding

Word decoding was measured with the Brus One Minute Test (Brus & Voeten, 1973). Children were asked to read as many meaningful words correctly as possible within a time limit of 1 minute. This task consists of 116 unrelated words presented in four rows on one sheet. Words became more difficult gradually from one syllable ("waar" [true]) up to four syllables ("tekortkoming" [shortcoming]). An efficiency measure (i.e., total number of read words minus number of errors) was calculated. The reliability of this measure differs per age but is at least .87 (Van den Bos et al., 1994). Word decoding was measured before and after the intervention.

Word spelling

Word spelling was measured with the PI word dictation (Geelhoed & Reitsma, 2000). In this task children were asked to write single words correctly. The dictation consisted of 135 words, divided into 9 blocks of 15 words. First a sentence was read aloud and the target word was repeated. The test was terminated when a child failed to write at least eight words correctly in one block. The number of correctly written words was counted. The reliability of this measure differs per age but is at least .91 (Geelhoed & Reitsma, 2000). Word spelling was measured before and after the intervention.

Predictor measures

Phonological awareness

Two subtests from the Screening Test for Dyslexia were used. First, during "Phoneme Deletion" (Kort et al., 2005), children were asked to omit a phoneme from an orally presented word and speak out the remaining word (e.g., "dak" [roof] minus "k" [f] is "da" [roo]). Testing was terminated after four consecutive mistakes. Second, during the subtest "Spoonerism" (Kort et al., 2005), children had to switch the first sounds of two words (e.g., "John Lennon" becomes "Lohn Jennon"). Testing was terminated after five consecutive mistakes. The reliability differs per age but is at least .60 (Kort et al., 2005). In both tests, all correctly formed words were counted. A composite score was calculated by adding z-scores of both subtests.

Rapid automatized naming

Rapid automatized naming was measured using two subtests of Continuous Naming and Reading Words (van den Bos et al., 2010). First, during "Naming Letters," children had to read out loud 50 letters. Second, during "Naming Digits" they were asked to read out loud 50 digits. Children were asked to name these visual stimuli as quickly as possible. The time in seconds needed to finish each subtest was used for analysis. A low score therefore represented a good performance. The reliability of this measure differs per age but is at least .75 (van den Bos & Lutje Spelberg, 2010). A composite score was calculated by adding z-scores of both subtests.

Verbal working memory

Verbal working memory was measured using the backward task of the Number Recall subtest from the Wechsler Intelligence Scale for Children-III (WISC-III^{NL}) (Kort et al., 2005). In this task, the experimenter pronounces sequences of digits and the child was asked to repeat in backward order. Testing was terminated after two consecutive mistakes. The number of correctly recalled sequences was counted. The reliability of this measure differs per age but is at least .50 (Kort et al., 2005).

Perceptual cognitive skills

Perceptual cognitive skills were measured by adding the z-scores of four subtests from the WISC- III^{NL} (Kort et al., 2005). First, during "Incomplete drawings," the child was asked to name or point at a missing part in a drawing of familiar objects or situations within 30 seconds. Testing was terminated after five consecutive mistakes. The child received one point for each correctly named missing part. All points were counted afterward. The reliability differs per age but is at least .54 (Kort et al., 2005).

Second, during “Picture arrangement”, the child has to put pictures in the right order to make the story depict right. The child was asked to do this as quickly as possible. Testing was terminated after three consecutive mistakes. The first two items were scored two points at first attempt and one point at second attempt. The other items were given zero, two, three, four, or five points based on accuracy and the time the child needs to order the pictures. The last item was given one point when the order was reversed. All points were counted afterward. The reliability differs per age but is at least .65 (Kort et al., 2005). Third, during “Block design,” the child had to reconstruct patters of two, four, and later nine blocks shown on a picture. The child was asked to do this as quickly as possible. Testing was terminated after two consecutive mistakes. The first three items were scored two points at first attempt and one point at second attempt. The other items were given four, five, six, or seven points based on accuracy and the time the child needs to reconstruct the pattern. All points were counted afterward. The reliability differs per age but is at least .71 (Kort et al., 2005). Fourth, during “Visual puzzles” the child has to make five puzzles of everyday objects. Testing was terminated after four consecutive mistakes. Each right connection between puzzle pieces was given one point. Extra points were given when less time was needed to make the puzzle, with a maximum of ten points. All points were counted afterward. The reliability differs per age but is at least .40 (Kort et al., 2005).

Phonics through spelling intervention

The aim of the phonics through spelling intervention was to reach a functional level of technical reading (given the age) and spelling (given the class) by means of combining reading and writing into one intervention. The intervention meets the criteria of the standardized Dutch Protocol Dyslexia Diagnostics and Treatment (Blomert, 2006). Children had a weekly 45-minute session with a clinician. The mean length of the intervention was 27.06 weeks (*SD* = 4.79). Variation in the length of the intervention occurred due to variation in time needed to acquire the 80%-accuracy levels as described below. During these sessions, the clinician tailored the intervention as much as possible to each child’s needs. Explicit direct instruction, guided exercises, and feedback were given according to each child’s needs. Approximately half of the time was spent on reading activities and the other half of the time was spent on spelling activities. The continuity of quality during assessment and intervention was guaranteed by supervision of certified clinical health psychologists. The intervention included three parts:

(1) Grapheme–phoneme correspondence (GPC)

Both reading and spelling started with practice of GPC. The GPCs a child found difficult were identified and practiced using mnemonic cards. When the child read or wrote all

GPCs correctly, the child was asked to accelerate by decreasing the time a flashcard was shown and accelerate the speed of letter dictation. In the end, the child had to name every letter in one second. All GPCs, including combinations of letters that were associated with phonemes, were presented on a mnemonic card and divided into categories (e.g., vowels that sound long vs. vowels that sound short).

(2) The alphabetical principle in writing and reading (accuracy and efficiency)

The next phase of intervention was the use of letter knowledge in reading and writing words. At first, children learned to write words using a four-step strategy: repetition of the auditory offered word, dividing the word into individual phonemes, writing the individual graphemes one-by-one until the word was finished, and finally checking the written word by reading it out loud. In the beginning, children had to write simple words (e.g., CVC, CVVC), but difficulty gradually increased (e.g., CCVVV, CCVVVC, CCCVCC). When children mastered these levels, the same five-step strategy was used but now dividing/writing in syllables instead of individual phonemes.

At the same time, reading words was practiced by naming words using flashcards. Depending on their level of reading ability, children were asked to read the individual letters or syllables of the word and then sound out the word or directly sound out the word. At first, only accuracy was trained and later on also efficiency was trained. During the intervention, the difficulty of words on the flashcards gradually increased based on the child's reading level. The trained words re-appeared in reading texts. The text was read repeatedly to stimulate accuracy and efficiency. Feedback was given on accuracy and later also on efficiency. When word reading became more difficult, text reading shifted to higher levels as well.

(3) Rules and exceptions

Dutch is a rather transparent language, but still rules and exceptions need to be learned to write and read words (mostly polysyllabic words) correctly. In spelling four main rules were taught. First, the writing of words that end on the phoneme /t/ was learned. In Dutch these words can be written with "t" or "d" on the end of the word (e.g., hond [dog], boot [ship]). By making a word plural it is possible to hear a /t/ or a /d/ (e.g., honden [dogs], boten [ships]). Whatever consonant is heard in the plural form must be written in the singular word as well. The second category concerns words with /gt/, which can be written as "gt" or "cht" (e.g., zaagt [saws], lucht [air]). Whenever a short sound vowel is placed before /gt/, then a "cht" needs to be written (lucht [air]). The third and fourth rules were combined because for both rules words need to be divided into syllables. When a syllable ends with a long vowel this is written short (/raa-men/ → ra-men [windows]), but when it ends with a short vowel the next consonant is doubled (/ki-pen/ → kippen [chickens]).

In this phase of the intervention, children also read polysyllabic words and thus needed to understand that the third and fourth spelling rules also apply to reading. The word 'ramen' shows a short vowel but it needs to be read as a long vowel (/raa-men/) and when a double consonant is sighted the vowel can be read short as well, but the consonant must be read only once (/ki-pen/). Additional rules for spelling and reading were taught according to each child's needs.

In order to rehearse the above-mentioned spelling and reading knowledge children had to do some home exercises both for reading as well as spelling. Parents were asked to train four times a week during 15 minutes with prescribed exercises. Parents kept a log, provided by the clinician. Based on this log, the clinician could move forward or give more attention to certain topics. When a child reached an accuracy of 80% during practice (read or write 80% of the words correctly) and improved significant in their fluency (more fluent compared to the first time words were read) the clinician moved on to the next topic or phase of intervention. Therefore, variation in the length of the program is present.

Analytic approach

All outcome measures were measured before and after the intervention and both pre- and posttest scores were standardized compared to norm-based peers using percentile scores at the time of testing. We calculated the individual mean change per session (both with raw and percentile scores) by subtracting pre- from posttest scores. Following Gollwitzer and colleagues (2014) change scores are reliable if two requirements are met. First, standard deviations must differ between measurement occasions. Second, there needs to be a non-zero variation in observed difference scores in order to define the reliability. In order to rule out the effects of variation in the length of the intervention, the individual change score was divided by the number of sessions the intervention for each individual lasted. Working with change scores implied that the differences in individual pretest scores were not taken into account. Pretest scores were included as a control variable to control for variation.

Results

Descriptive statistics

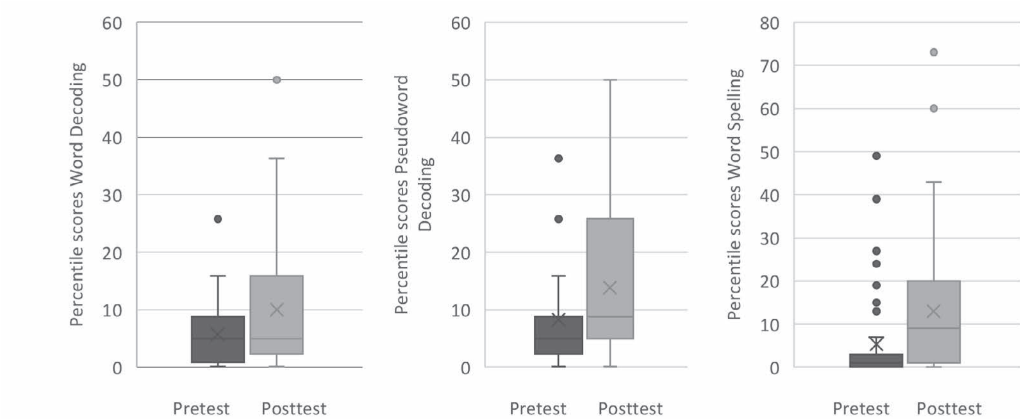
Table 3.1 presents the descriptive statistics (means, standard deviations, and range) of all study measures. Both pre- and posttest scores are given of all outcome measures in raw scores and percentile scores. These percentiles scores are based on norms within the typically developing population. At the start of the intervention the mean scores were below the 10th percentile on pseudoword reading, word reading, and word spelling, while afterward these mean scores were above the 10th percentile on all three measures. Furthermore, raw scores and age-based standardized scores are reported for all the predictor measures. Finally, the change scores and change scores per session were calculated. Both requirements as reported by Gollwitzer and colleagues (2014) were met since the standard deviations had increased after the intervention and the differences scores were all positive and thus non-zero. Reading and spelling boxplots before and after the phonics through spelling intervention can be seen in Figure 3.1.

Table 3.1 *Descriptive Statistics for all Participants in Raw and Percentile or Age based Standardized Scores.*

	Raw scores					**Percentile scores**				
	n	***M***	**SD**	**Min**	**Max**	***n***	***M***	**SD**	**Min**	**Max**
Pseudoword decoding										
Pretest	44	18.77	8.74	6	38	44	8.36	8.46	.10	36.30
Posttest	44	28.48	11.59	4	58	44	13.58	11.80	.10	50.00
Difference scores	44	9.70	8.21	-5	38	44	5.21	8.80	-9.90	41.20
Change per session	44	0.39	0.33	-.16	1.41	44	0.21	0.36	-0.38	1.65
Word decoding										
Pretest	53	29.15	13.26	2	62	53	5.76	6.34	.10	25.80
Posttest	53	40.19	14.15	10	47	53	10.02	11.06	.10	50.00
Difference scores	53	11.23	0.86	-3	30	53	4.29	9.04	-10.90	34.10
Change per session	53	0.42	0.23	-.11	1.20	53	0.16	0.34	-0.42	1.31
Word spelling										
Pretest	53	43.02	24.47	5	105	53	5.34	10.41	0	49
Posttest	53	71.66	25.13	7	125	53	13.00	15.06	0	73
Difference scores	53	28.64	1.61	0	58	53	7.66	16.41	-25.00	66.00
Change per session	53	1.08	0.44	0	2.23	53	0.26	0.57	-1.09	1.83
						Age based standardized scores				
Phonological awareness										
Spoonerism	54	2.78	3.27	0	11	54	7.78	2.20	4	13
Phoneme deletion	54	7.96	2.36	2	12	54	7.91	2.33	4	15
Rapid automatized naming										
Letter naming	54	41.43	10.82	24	75	54	5.44	2.59	1	13
Digit naming	54	37.37	11.16	22	86	54	6.33	3.00	1	12
Verbal working memory	54	3.93	1.29	2	8	-	-	-	-	-
Perceptual cognitive skills										
Picture completion	54	18.24	2.98	10	23	54	10.87	2.77	3	16
Block design	54	38.61	11.66	6	57	54	10.56	3.32	2	18
Picture arrangement	54	25.28	9.07	7	44	54	10.48	2.89	3	17
Object assembly	54	25.94	6.06	10	35	54	10.11	2.77	4	15

Correlations among all study variables are presented in Table 3.2. As can be seen, phonological awareness was significantly correlated with word decoding posttest percentile scores, and word spelling posttest percentile scores. Rapid automatized naming correlated significantly with word decoding pretest and posttest percentile scores, whereas verbal working memory did not correlate significantly with any criterion measure. With respect to the covariates, both perceptual cognitive skills and spelling pretest scores were significantly related to spelling posttest percentile scores.

Figure 3.1. *Boxplots of Pretest and Posttest Scores of Word Decoding, Pseudoword Decoding, and Word Spelling.*



Phonics through spelling intervention effects

First, the effect of the intervention was established by determining response to intervention for each child. Based on the normal distribution and the correction for time, typically developing children would have the same percentile score at pre- and posttest. Positive mean change scores per session among the children with dyslexia therefore would indicate a response to intervention. Table 3.1 presents the descriptive statistics for the percentile scores and the change scores for all dependent variables. The mean change scores are positive for all dependent measures.

Paired-sample *t*-tests, using Holm–Bonferroni correction (Holm, 1979), were used to test whether a change was significant. Holm–Bonferroni procedure was used to adjust the critical p-value to control for the Type 1 error (see Abdi, 2010). Pseudoword posttest percentile scores were significantly higher than pretest percentile scores (t (43) = -3.927, adjusted p = .017, d = 0.51). Similar positive effects were found for posttest versus pretest percentile scores of word reading (t (52) = -3.453, adjusted p = .025, d = 0.47) and word spelling (t (52) = -3.137, adjusted p = .050, d = 0.59). Pretest and posttest differences are depicted in boxplots in Figure 3.1. Out of all children, 49.1% were no longer among the lowest 10% for spelling. For pseudoword reading this was 26.1% and for word reading 29.6%.

Table 3.2 *Pearson Correlations between the Predictor Measures (i.e., Length of Intervention, Perceptual Cognitive Skills, Age, Working Memory, Phonological Awareness, and Rapid Automatized Naming) and Criterion Measures (i.e., Percentiles Scores of Pseudoword Decoding Pretest/Posttest, Word Decoding Pretest/Posttest, and Spelling Pretest/Posttest).*

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**
1. Length of intervention	-											
2. Perceptual cognitive skills	.277*	-										
3. Age	.108	.445**	-									
4. Phonological awareness	.066	.257	.333*	-								
5. Rapid automatized naming	-.136	-.182	-.425**	-.214	-							
6. Verbal working memory	-.287*	.083	.123	.099	.040	-						
7. Pseudoword decoding pretest	-.004	.105	.032	.185	-.225	.094	-					
8. Pseudoword decoding posttest	-.102	-.132	-.168	.168	-.257	.152	.668**	-				
9. Word decoding pretest	.010	.078	.085	.191	-.298*	-.068	.590**	.523*	-			
10. Word decoding posttest	.070	.034	.199	.312*	-.334*	.108	.490**	.584*	.587**	-		
11. Word spelling pretest	.200	.067	-.080	-.032	.099	.186	.078	.079	-.036	.017	-	
12. Word spelling posttest	.370**	.474**	.224	.385**	-.209	.162	.294*	.210	.146	.262	.365**	-

* $p < .05$. ** $p < .01$. *** $p < .001$.

Robustness of the intervention

Second, the robustness for variation in individual cognitive profiles of a phonics through spelling intervention in a rather transparent orthography was examined by multiple linear regressions. Table 3.1 presents the descriptive statistics for both raw and percentile scores of the individual change per session. In the multiple linear regressions, for all outcome measures percentile scores were used to control for age, as the children in this study vary in age.

We performed three multiple linear regression analyses (one for each outcome variable). Variables were added in three steps. The predictor variables (i.e., phonological awareness, rapid automatized naming, verbal working memory) were entered in Step 1, followed by perceptual cognitive skills in Step 2 to control for variation in perceptual cognitive skills. Finally, in Step 3, pretest percentile scores were entered to see variation at the start of the intervention predicted the mean change per session during the intervention.

No significant effects of the three main precursors (phonological awareness, rapid automatized naming, and verbal working memory) were found on spelling and pseudoword and word reading. In other words, the change per session could not be predicted from individual variation in precursor measures, and the intervention seems therefore robust to variation in the cognitive profiles. The control variables perceptual cognitive skills and pretest scores did not influence the mean change per session for reading. However, for spelling, this was the case. First, the higher the scores on perceptual cognitive skills, the larger the change per session on spelling. Second, the lower the pretest percentile score, the larger the change per session on spelling. Table 3.3 depicts the results.

Table 3.3 *Summary of Multiple Linear Regression.*

		Pseudoword reading		Word reading		Word spelling	
		Adj. R^2	***B***	**Adj. R^2**	***B***	**Adj. R^2**	***B***
Step 1	(Constant)	-.051	.208***	.048	.155***	.130*	.266***
	Phonological awareness		-.016		.035		.089
	Rapid automatized naming		-.025		-.024		-.083
	Verbal working memory		.022		.069		.011
Step 2	(Constant)	.009	.194***	.048	.155***	.182**	.266***
	Phonological awareness		-.010		.041		.070
	Rapid automatized naming		-.033		-.028		-.071
	Verbal working memory		.046		.071		.001
	Perceptual cognitive skills		-.045		-.020		.063
Step 3	(Constant)	-.009	.226***	.032	.173***	.431***	.414***
	Phonological awareness		-.008		.042		.065
	Rapid automatized naming		-.036		-.031		-.034
	Verbal working memory		.046		.069		.051
	Perceptual cognitive skills		-.043		-.020		.077**
	Pretest scores		-.004		-.003		-.028***

*$p < .05$. **$p < .01$. ***$p < .001$.

Conclusions and discussion

The present study investigated the effect of a phonics through spelling intervention in children with dyslexia. Two research questions were addressed. The first question was about the changes in pseudoword reading, word reading, and word spelling scores in Dutch children with dyslexia after a phonics through spelling intervention. The second research question addressed whether the phonics through spelling intervention is robust to individual variation in cognitive profiles consisting of phonological awareness, rapid automatized naming, and verbal working memory in a transparent orthography.

With respect to the first research question, it was found that on average children with dyslexia responded to the phonics through spelling intervention; their standardized scores (i.e., scores that were based on typically developing peers) on pseudoword reading, word reading, and word spelling significantly improved as compared to their corresponding pretest scores. The goal of the intervention was to elevate the children to a higher level of spelling and reading performances. Elevating these children from the lowest 10% group is an important step. As mentioned in the results, out of all children 49.1% were no longer among the lowest 10% for spelling. For pseudoword reading this was 26.1% and for word reading 29.6%. A substantial group of children thus remains in the lowest 10%, which highlights the resistance to treatment among children with dyslexia (e.g., Alexander & Slinger-Constant, 2004; Galuschka et al., 2014; Tilanus et al., 2019; Torgesen, 2006). However, the positive effects also show that gains can be made. This is in line with previous findings about the effectiveness of phonics interventions (e.g., Galuschka et al., 2014) and the combination of both reading and spelling in instructions among typically developing children (Conrad, 2008; Ehri & Wilce, 1987; Ellis & Cataldo, 1990), children with reading and spelling problems (Kirk & Gillon, 2009; Lovett et al., 1989, 1990; Ouellette & Sénéchal, 2008), and children diagnosed with dyslexia (Tijms, 2011; Tilanus et al., 2016). The fact that we found positive effects on both spelling and reading (word or pseudoword reading) supports the hypothesis that combining spelling and reading in one intervention is beneficial for reading and spelling development of children with dyslexia. It shows that a focus of the intervention on the bi-directional relation between orthographic and phonological representations has a positive impact on both reading and spelling development (Ouellette & Sénéchal, 2008). The positive outcomes of this phonics through spelling intervention should be evaluated against positive effects on word spelling and rather inconsistent findings of reading-focused interventions on pseudoword and word reading (Kirk & Gillon, 2009; Lovett et al., 1989, 1990; Tijms, 2011; Tilanus et al., 2016). In contrast, our study showed that a phonics through spelling intervention that devoted time equally to reading and spelling instruction has positive effects on spelling as well as on both pseudoword and word reading. It is evidenced that a combined reading and spelling instruction helps building strong bi-directional relations between phonology and orthography and thereby benefits reading and spelling development.

With respect to the second research question, it was shown that the results of the intervention on word reading, pseudoword reading, and spelling after a phonics through spelling intervention were robust to variation in cognitive profiles (e.g., phonological awareness, rapid automatized naming, and verbal working memory). In other words, the phonics through spelling intervention on average appears to work notwithstanding the variation in cognitive-linguistic profiles within the group of children with dyslexia. These findings are in line with other studies demonstrating the robustness of reading interventions focusing on decoding accuracy training for phonological awareness (Felton, 1993; Tijms, 2011), fluency training for rapid automatized naming (Heikkilä, 2015), and the combination of both decoding accuracy and fluency into one training for phonological awareness, rapid automatized naming (Aravena et al., 2016; Tilanus et al., 2016), and verbal working memory (Tilanus et al., 2016).

It is interesting to note that the variation in perceptual cognitive skills and pretest scores did not influence the pseudoword or word reading change scores. Both control variables had small but significant effects on spelling change scores. The positive effect of perceptual cognitive skills found on spelling is in line with findings among typically developing children (Landerl & Wimmer, 2008). The negative effect of spelling pretest scores on the change in spelling scores after a phonics through spelling intervention could indicate a small but significant reverse Matthew effect. This is in line with findings from Aarnoutse and colleagues (2001), who found that low performers in spelling benefit most from instruction. It is possible that the children with lower spelling scores at pretest had more trouble building up a strong and bi-directional network of phonological and orthographic representations by themselves. The phonics through spelling intervention may have helped them to build this network and thereby overcome some of the problems.

The unique character of the present study is the relatively large amount of time spent on spelling in order to strengthen the bi-directional relation between phonological and orthographic representations as described by Bosman and Van Orden (1997). Although children in this study significantly improved and many were no longer among the weakest 10% in word reading and spelling, it is important to note that most children remain weak readers and spellers compared to typically developing controls and large variation in reading and spelling levels is present even after the intervention. Interestingly, posttest scores, and not pretest scores for word decoding and word spelling were found to be related to phonological awareness that is seen as a prime indicator of a phonological deficit in children with dyslexia (Shaywitz et al., 2003; Snowling, 1998). It can tentatively be concluded that the phonics through spelling intervention helped children with dyslexia to overcome their reading and spelling problems up to the level of their genetically disposed phonological deficit.

Some limitations should be acknowledged at this point along with directions for future research. To begin with, although the positive effects of the phonics through spelling intervention are based on standardized norms (i.e., comparisons with typically developing peers), the results should be interpreted carefully as we did not include control groups in our study. Our study shows on average promising results for children with dyslexia after a phonics through spelling intervention. More research is necessary to find out whether these are due to the addition of spelling to the intervention. Despite these promising results, the majority of the children remain in the lowest 10%, particularly for pseudoword and word reading. More research is needed to find out what causes the differences in growth during the intervention. Future studies should consider larger samples sizes and control conditions that focus on reading solely and spelling solely. For studies combining reading and spelling in a phonics through spelling intervention, it is important to report the amount of time spent on reading or spelling separately and variations in spelling approaches that mirror phonics approaches (e.g., analytical versus synthetic approaches).

To conclude, the present findings show that phonics through spelling interventions help children with dyslexia to improve their pseudoword reading, word reading, and spelling levels. On average, the intervention is effective, notwithstanding children's individual cognitive profiles. Perceptual cognitive skills and pretest scores predicted the change in word spelling during the intervention. Although promising results were found, this study also showed the persistence of spelling, but even more so of reading problems after an intervention among children with dyslexia.

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CHAPTER 4

Role of semantic abilities in a phonics through spelling intervention

This chapter is based on:
Van Rijthoven, R., Kleemans, T., Segers, E., & Verhoeven, L. (2021). Semantic abilities impacts response to phonics through spelling intervention in children with dyslexia. *Annals of Dyslexia*, 1-20. doi:10.1007/s11881-021-00233-1

Abstract

We examined the response to a phonics through spelling intervention in 52 children with dyslexia by analyzing their phonological, morphological, and orthographic spelling errors both before and after the intervention and additionally, their spelling errors before the intervention were compared with those of 105 typically developing spellers. A possible compensatory role of semantic abilities on the intervention effects was also investigated. Results showed that before the intervention, children with dyslexia and the typically developing children both mostly made morphological errors, followed by orthographic and phonological errors. Within each category, children with dyslexia made more errors than the typically developing children, with differences being largest for phonological errors. Children with dyslexia with better developed semantic representations turned out to make fewer phonological, morphological, and orthographic errors compared with children with dyslexia with less developed semantic representations. The intervention for children with dyslexia led to a reduction of all error types, mostly of the orthographic errors. In addition, semantic abilities was related to the decline in phonological, morphological, and orthographic spelling errors. This study implicates that semantic stimulation could benefit the spelling development of children at risk for or with dyslexia.

Introduction

The spelling of phonologically transparent words is rather straightforward. Starting from the phonemic segmentation of a word, the speller applies phoneme-grapheme correspondence rules to arrive at the correct spelling (Vanderswalmen et al., 2010). For words that are phonologically less transparent, the speller may use a strategy to search for analogy with similar spellings of known words, building on previously acquired phonological and orthographic representations (Allen, 1992). Research shows that children with dyslexia have severe problems in building up these representations (Lyon et al., 2003), which can be explained by their phonological deficit (Conrad, 2008; Göbel & Snowling, 2010). Consequently, children with dyslexia make more phonological errors in reading as well as in spelling compared to typically developing children (e.g., Bourassa et al., 2006). In addition, they also make more orthographic and morphological spelling errors. This can be explained from the fact that orthographic and morphological spelling builds upon the phonological base (Nunes et al., 1997). An overall delay in spelling development in children with dyslexia showing a phonological deficit that persists into adolescence can thus be expected (see, e.g., Bourassa & Treiman, 2003). Given that variation in semantic abilities has previously been shown to impact reading (Nation & Snowling, 2004; Torppa et al., 2010; Van Bergen et al., 2014) and spelling ability (Ouellette, 2010; Tainturier & Rapp, 2001), it might well be the case that children with dyslexia may compensate their low spelling outcomes through semantic abilities. However, semantic abilities has not yet been included as a predictor in responsiveness to intervention studies. Therefore, in the present study, the impact of semantic abilities on a response to phonics through spelling intervention in children with dyslexia was examined.

Comparison of learning to spell for children with and without dyslexia

In alphabetic writing systems, learning to spell starts with the segmentation of spoken words into singular sounds, followed by phoneme-to-grapheme mapping and word synthesis (Vanderswalmen et al., 2010). This so-called phonetic strategy helps to build up bi-directional connections between phonological and orthographic representations (Bosman & van Orden, 1997). Strong and bi-directional connections could facilitate a self-teaching mechanism (Share, 1995) to foster spelling development (Burt & Tate, 2002).

Learning to spell, however, requires more than one-to-one phoneme-grapheme mapping. After mastering this phonetic strategy, children encounter words that are orthographically more complex. In this phase, word spelling inconsistencies need to be learned in order to become a skilled speller (Ehri, 2000; Treiman, 2018). Specific knowledge of morphological and orthographic patterns is then connected to already existing semantic representations, so that analogies of common words can be used in the spelling of uncommon words (Allen, 1992; Treiman et al., 1994). The accumulating knowledge of morphological and orthographic patterns further strengthens the quality of lexical representations. Indeed, it has been found that high-quality phonological, orthographic, and semantic representations lead to better spelling levels (Perfetti, 2007). Building up high-quality phonological and orthographic representations is demanding for all beginning spellers (as described by Cassar et al., 2005). However, for children with dyslexia, learning to spell words correctly is even more challenging (Lyon et al., 2003), due to a phonological deficit (Conrad, 2008; Göbel & Snowling, 2010). This deficit makes it difficult to learn and retrieve phonological information from long-term memory (Cassar et al., 2005), resulting in more phonological, morphological, and orthographic spelling errors as compared to typically developing children (Bourassa & Treiman, 2003; Bourassa et al., 2006; Cassar et al., 2005).

The phonological deficit is an important predictive factor for spelling development (Wimmer & Mayringer, 2002). However, as proposed by the phonological-core variable differences model by Stanovich (1988), along with the core phonological deficit, other variables influence the spelling development as well. This model posits that all poor readers have a phonological deficit, but that additional cognitive factors are important for their reading and spelling skills. The triangular framework (Seidenberg & McClelland, 1989) highlights the importance of high-quality semantic representations for learning to read and spell. In line with this model, it can be assumed that variation in semantic abilities could partly compensate for the phonological deficit, especially since the semantic abilities of children with dyslexia are quite similar to those of typically developing children (Nation & Snowling, 1998). Phonological and semantic skills influence reading development from its earliest stages and influence each other as well (e.g., Laing & Hulme, 1999). However, Nation and Snowling (2004) showed that within the typically developing readers, broader language skills (also verbal production and comprehension) beyond phonology make important contributions to word recognition development. Prior research regarding reading indeed showed the benefits of well-developed semantic representations (e.g., Nation & Snowling, 2004; Torppa et al., 2010) and suggested a possible importance of semantic representations for spelling as well (Ouellette, 2010; Ouellette & Fraser, 2009). It remains, however, unclear to what extent variation in semantic ability impacts phonological versus orthographic spelling of children with dyslexia on top of phonological abilities.

Analysis of spelling errors

Only few studies addressed the distribution of different types of spelling errors (e.g., Bourassa & Treiman, 2003) and none predicted spelling errors from individual differences in cognitive factors. One way of addressing phonological and orthographic errors separately is to analyze and categorize spelling errors. Spelling error analyses and the comparisons between typically developing spellers and spellers with dyslexia are mostly based on post hoc error classifications. The errors are subdivided into three broad categories in order to define the source of the errors: phonological, morphological, and orthographic errors (see Moats, 1995; Sawyer et al., 1999; Tops et al., 2014; Vanderswalmen et al., 2010). Morphological and orthographic errors represent the morphological and orthographic patterns that are part of the orthographic spelling development (Allen, 1992). In phonological errors, a difference occurs between the pronunciation of the written word and the spoken target word. In morphological errors, words maintain the proper pronunciation but are misspelled based on language-specific grammatical rules. In orthographic errors, words also maintain the proper pronunciation but are misspelled based on orthographic conventions or based on the original language a word is from (see Appendix A).

Previous research that categorized spelling errors into these categories concluded that children with dyslexia proportionally made the same mistakes, but in higher numbers compared to typically developing children (Bourassa & Treiman, 2003; Bourassa et al., 2006). As a case in point, Bourassa and Treiman (2003) found that both typically developing children and children with dyslexia made mostly linguistically motivated errors. Errors made by children with dyslexia with an average age of 11 years were comparable with mistakes of typically developing children that were on average 3.5 years younger. This is, however, not just a temporarily delay or slow development, but a delay that persists in later life. Indeed, Tops and colleagues (2014) showed that students with dyslexia in higher education, despite their ongoing effort, still made more spelling errors than their peers without dyslexia. However, relative differences between all three error types were not studied yet in children, since Bourassa and Treiman (2003) and Bourassa and colleagues (2006) did not include all three error types.

Interventions for spelling development

The weak spelling performances of children with dyslexia compared to typically developing children have serious consequences for their general development at school. For instance, when one is still struggling with spelling correctly, working memory cannot be fully used to write down a story in a developed manner (Wakely et al., 2006). This influences text production fluency and quality (Berninger & Swanson, 1994; McCutchen, 2000). Early intervention is needed in order to give these children the same opportunities in life. These interventions are a good way of studying the spelling development of children with dyslexia.

In such interventions, it is recommended to include and explicitly teach phonological, morphological, and orthographic awareness of word forms, their parts, and their interrelationships (Berninger et al., 2008; Galuschka et al., 2020). As concluded by Cassar and colleagues (2005), children with dyslexia need direct assistance to develop their spelling skills by improving both the phonological and orthographic representations. Skilled spelling requires a solid base of grapheme-phoneme translation, which enables the formation of strong bi-directional relations between phonological and orthographic representations. Next, a combination of instruction and experience in both reading and spelling can help to learn the increasingly complex and specific orthographic spelling by learning morphological and orthographic patterns (Caravolas et al., 2001). This further enhances the quality of the relation between phonological and orthographic representations and includes semantic features as well (Perfetti & Hart, 2002).

A specific form of intervention that combines the above described principles is the phonics through spelling intervention. Phonics interventions are in general effective in enhancing spelling (and reading) development in typically developing children, as well as for children with dyslexia (Galuschka et al., 2014). A phonics through spelling intervention includes more time for instruction and practice in spelling compared to other phonics interventions. By doing so, the intervention enhances both reading and spelling levels, probably because of the high-quality network of phonological, orthographic, and semantic representations that are formed during the intervention (Van Rijthoven et al., 2020). However, results of phonics interventions on spelling have only been expressed in the number of words written correctly, whereas comparing spelling error profiles before and after the intervention could give new insights in the phonological and orthographic spelling development due to the intervention.

Despite the fact that children with dyslexia have shared problems, large individual differences were found in the progress during intervention (e.g., Galuschka et al., 2014). Individual differences during intervention were mainly caused by a phonological deficit (see Snowling, 1998; Tilanus et al., 2019). However, no distinction was made between phonological and orthographic spelling and semantic abilities was not included as a predictor.

The present study

Previous research showed that children with dyslexia make more spelling errors compared to typically developing children. In order to enhance the possibilities of children with dyslexia early in life, it is important to gain more insight in the relative differences between spelling error patterns these children show both before and after an intervention and to what extent the number and distribution of errors is related to children's semantic abilities. In the present study, the following research questions were asked:

1. (a) To what extent do children with dyslexia differ from typically developing children in phonological and orthographic spelling?

(b) What is the role of semantic abilities in predicting the phonological and orthographic spelling of children with dyslexia?

2. (a) To what extent can phonological and orthographic spelling abilities of children with dyslexia be trained through a phonics through spelling intervention?

   (b) What is the role of semantic abilities in predicting the development of phonological and orthographic spelling in children with dyslexia due to a phonics through spelling intervention?

Regarding the first research question, firstly, we expected children with dyslexia to make more but not proportionally different errors. Second, we expected orthographic spelling to be more difficult than phonological spelling for both children with dyslexia and typically developing children. Third, we expected semantic abilities to be a compensatory factor for children with dyslexia across error types.

Regarding the second research question, we expected a decline in the number of errors in all categories with no relative differences between the proportion of errors due to the intervention. Furthermore, we expected a decline in the number of errors across the three types to be predicted by the children's level of semantic abilities.

Method

Participants

Participants were children diagnosed with dyslexia (34 boys, 18 girls) and typically developing children (52 boys, 53 girls). All participants spoke Dutch as their primary language and all parents gave active consent to use the collected data for research purposes.

The children with dyslexia were diagnosed between 2009 and 2013 following the protocol by Blomert (2006), which is in line with the definition of dyslexia of the International Dyslexia Association (2002). The Dutch protocol for diagnosis of dyslexia (Blomert, 2006) states that teachers have to prove persistent reading problems (resistance to treatment) and severity (weak performances on word reading and spelling during one and a half school years). In the subsequent diagnosis, a phonological deficit needs to be evidenced and other explanations of reading or spelling problems excluded by a certified clinical psychologist. After formally being diagnosed with dyslexia, children received an in-service phonic through spelling intervention in a clinic for assessment and intervention for children with learning difficulties. The mean age of this group of children at the start of the assessment was 8.97 years (SD = .94). Children were in grade 2 (n = 17), grade 3 (n = 23), grade 4 (n = 9), grade 5 (n = 2), and grade 6 (n = 1). All children had semantic abilities within the normal range both in total scores (M = 108.35, SD = 12.18) and standardized subtest scores ($M_{information}$ = 10.50, $SD_{information}$ = 2.42, $M_{simularities}$ = 12.25, $SD_{simularities}$ = 2.83, $M_{vocabulary}$ = 11.31, $SD_{vocabulary}$ = 2.32, $M_{comprehension}$ = 11.58, $SD_{comprehension}$ = 2.41).

The mean age of the children in the control group was 8.88 years (*SD* = .89). Children were in grade 2 (*n* = 25), grade 3 (*n* = 52), and grade 4 (*n* = 28). All children had semantic abilities within the normal range both in total scores (*M* = 101.67, *SD* = 13.84) and standardized subtest scores ($M_{information}$ = 10.40, $SD_{information}$ = 2.63, $M_{simularities}$ = 10.98, $\mathrm{SD}_{simularities}$ = 2.81, $M_{vocabulary}$ = 10.46, $SD_{vocabulary}$ = 2.82, $M_{comprehension}$ = 9.34, $SD_{comprehension}$ = 2.81). The fact that both groups scored within the normal range on the four measures of the semantic ability seems to converge with the aptitude-achievement discrepancy model that defined dyslexia as a discrepancy between rather normal intelligence and weak reading scores (Fletcher et al., 2007).

Procedure

With respect to the recruitment of the control group, six schools for mainstream primary education throughout the Netherlands were asked by letter and telephone to participate in the present study. When a school agreed to participate, parents gave active consent to let their child participate in the present study.

With respect to the group of children with dyslexia, the data from the current study was based on existing data collected by a clinic for assessment and intervention of children with learning disorders. All children were tested between 2009 and 2013 in two consecutive mornings by clinicians on rapid automatized naming, phonological awareness, verbal working memory, pseudoword decoding, word decoding, spelling, and semantic abilities. Two or three weeks after the assessment, the phonics through spelling intervention started. After the intervention, all participants were subjected to the posttest, including pseudoword decoding, word decoding, and spelling measures. All children from the control group were tested once, during one school day.

Measures

Outcome measure

Spelling

Spelling was measured with the standardized “PI word dictation” (Geelhoed & Reitsma, 1999). In this task, children were asked to write single Dutch words correctly. The dictation consisted of 135 words, divided into 9 blocks of 15 words. First, a sentence was read aloud and afterwards, the target word was repeated. The test was terminated when a child failed to write at least eight words correctly within one block. The number of correctly written words was counted. There were two versions available of the test (version A and version B). The reliability of both version A and version B differs per age but is at least .90 (Geelhoed & Reitsma, 1999).

Predictor measures

Phonological awareness

Two subtests from the "Screening Test for Dyslexia" (Kort et al., 2005a) were used. First, during "Phoneme Deletion," children were asked to omit a phoneme from an orally presented word and speak out the remaining word (e.g., "dak" [roof] minus "k" [f] is "da" [roo]). Testing was terminated after four consecutive mistakes. Second, during the subtest "Spoonerism," children had to switch the first sounds of two words (e.g., "John Lennon" becomes "Lohn Jennon"). Testing was terminated after five consecutive mistakes. The reliability differs per age but is at least .60. A composite score was calculated by adding z-scores of both subtests.

Rapid automatized naming

Rapid automatized naming was measured using two subtests of "Continuous Naming and Reading Words" (van den Bos & Lutje Spelberg, 2010). During "Naming Letters," children had to read out loud 50 letters. During "Naming Digits," they were asked to read out loud 50 digits. Children were asked to name these visual stimuli as quickly as possible. The time in seconds needed to finish each subtest was used for analysis, which means that a higher score reflects a weaker performance on RAN. The reliability of this measure differs per age but is at least .75. A composite score was calculated by adding z-scores of both subtests.

Verbal working memory

Verbal working memory was measured using the backward task of the Number Recall subtest from the Wechsler Intelligence Scale for Children-III (WISC-III^{NL}) (Kort et al., 2005b). In this task, the experimenter pronounces sequences of digits that the child was asked to repeat in backward order. Testing was terminated after two consecutive mistakes. The number of correctly recalled sequences was counted. The reliability of this measure differs per age but is at least .50.

Semantic abilities

Semantic abilities were measured by adding the z-scores of four subtests from the WISC-III^{NL} (Kort et al., 2005b). Based on the manual, the child received zero, one, or two points for each item. Testing was terminated after four or five (Information) consecutive mistakes. The reliability differs per age but is between .64 and .77 (Kort et al., 2005b).

First, during "Information," the child has to answer verbally asked questions to test their general knowledge about events, objects, places, and people. Secondly, during "Similarities," the child has to name the similarity between two concepts. Thirdly, during "Productive vocabulary," the experimenter pronounces a word and the task of the child was to define the given word. Fourthly, during "Comprehension," the experimenter asked questions about social situations or common concepts. Kaufman (1975) already showed that these four measures together form a factor named "verbal comprehension," which was also the case in the current sample (Van Rijthoven et al., 2018).

Spelling error classification

The PI word dictation consisted of 135 words. However, for most children, testing was terminated earlier. We therefore selected the first four blocks (60 words). All possible types of errors within these 60 words were listed and labeled (e.g., phoneme addition, end d/t, ei/ij). These errors were divided into three categories: phonological, morphological, and orthographic errors following Tops and colleagues (2014), Vanderswalmen and colleagues (2010), and Worthy and Viise (1996), see Appendix A. Some types of errors could not be classified exclusively into phonological, morphological, or orthographic errors. Words containing these types of errors were removed from the dataset, see Appendix B (i.e., 21.66% (version A) and 18.33% (version B)). After the removal of the above-mentioned words, the total number of possible errors was calculated based on the descriptions of the total number of possible errors within each category. This was done for each version of the PI word dictation (versions A and B) to correct for any differences between the two versions.

Next, the dictation tasks of all participants were screened on the number and type of errors made by the child. Following Tops and colleagues (2014), the error classification was based on the end product and not on the strategy used by the child. For each child with dyslexia, two dictations were screened (pre- and posttest). For typically developing children, a single dictation was screened (all version A). The interrater reliability of the two MSc students who did the screening was good: Cohen's kappa is .84 (A-version) and .88 (B-version).

For each dictation task, all errors were entered in a dataset in which each error was assigned to the type of error. One word could contain multiple errors following the descriptions in Appendix A. In case of early termination of the task (after eight errors in a block of 15 words), all possible errors in non-written words were entered in the dataset based on the assumption that the upcoming words would be too difficult for the child. This is following procedures of other tests such as the WISC-III^{NL} (Kort et al., 2005a) or the PPVT (Dunn & Dunn, 1997). In the end, the total number of phonological, morphological, and orthographic errors was calculated by adding the types of errors as these have been classified in Appendix A. Finally, the percentage of errors for each classification was calculated based on the total number of possible errors for each category per version.

Phonics through spelling intervention

A phonics through spelling intervention aimed to reach a functional level of technical reading and spelling by means of combining reading and writing in one intervention following the protocol by Blomert (2006). Unique to a phonics through spelling intervention is that during the intervention, both reading and spelling instruction and exercises were equally balanced in terms of time spent on each topic (50–50). This is rather unique as most studies include less or even no spelling instruction or exercises. Children had a weekly 45-min session with a clinician. The mean length of the intervention was 27.04 weeks (*SD* = 4.93). Variation in the length of the intervention occurred due to variation in the post-intervention assessment schedule (for instance due to holidays or personal circumstances). Furthermore, variation in the length of the intervention occurred due to variation in time needed to acquire 80%-accuracy levels and improved fluency levels as described below. During the sessions, the clinician tailored the intervention as much as possible to each child's needs. Explicit direct instruction, guided exercises, and feedback were given according to each child's needs. Approximately half of the time was spent on reading activities and the other half of the time was spent on spelling activities. The continuity of quality during assessment and intervention was guaranteed by supervision of certified clinical health psychologists. The intervention included two stages:

1. Phonological spelling

The intervention started with practice of the phonological base of reading and spelling due to learning the grapheme-phoneme correspondences (GPCs). After learning the GPCs, children learned to use this letter knowledge in reading and writing words and sentences/texts by using an explicit strategy. When children mastered the basic levels, children learned to read and write words based on syllables as well. Accuracy was trained first, followed by efficiency and words and sentences/texts increased in difficulty. Feedback was given on accuracy and later also on efficiency.

2. Orthographic spelling

Dutch is a rather transparent language, but still morphological rules and orthographic patterns need to be learned to write and read words (mostly polysyllabic words) correctly. The morphological rules and orthographic patterns can be found in Appendix A and were taught according to each child's needs.

In order to rehearse the above-mentioned spelling and reading knowledge, children had to do home exercises for reading and spelling. Parents were asked to train four times a week during 15 minutes with prescribed exercises. All parents have confirmed that this has been complied with. Parents reflected on the home exercises in a day-to-day log. When a child reached an accuracy of 80% during practice (read or write 80% of the words correctly) and improved significant in their fluency (more fluent compared to the first time words were read), the clinician moved on to the next topic of intervention. This formative testing was sustained throughout the entire intervention. Therefore, variation in the length of the program is present.

Results

Individual differences in phonological and orthographic spelling

Research question 1a was about the differences between children with dyslexia and typically developing children regarding their phonological and orthographic spelling. Table 4.1 presents the descriptive statistics.

To compare children with dyslexia and typically developing children, we performed t-tests for independent samples with Holm-Bonferroni correction (Holm, 1979). Regarding the outcome measures, children with dyslexia scored below typically developing children in the total number of words written correctly in the dictation task ($t(155) = -10.011$, $p < .001$, $d = 1.66$) and made higher percentages of errors in all three categories (Phonological errors $t(51) = 4.562$, $p < .001$, $d = 0.89$; Morphological errors $t(65) = 7.589$, $p < .001$, $d = 1.41$; Orthographic errors $t(51) = 5.416$, $p < .001$, $d = 1.05$). Regarding the predictive measures children with dyslexia scored weaker compared to typically developing children on phonological awareness measures (Spoonerism $t(154) = -7.249$, $p < .001$, $d = 0.98$; Phoneme deletion $t(78) = -5.483$, $p < .001$, $d = 1.24$), rapid automatized naming (letter naming $t(155) = 5.939$, $p < .001$, $d = 1.00$, digit naming $t(71) = 5.623$, $p < .001$, $d = 1.02$), and verbal working memory ($t(125) = -2.757$, $p = .007$, $d = 0.45$). With regard to semantic abilities, the groups scored equally on information ($t(155) = 0.111$, $p = .911$, $d = 0.02$) and vocabulary ($t(155) = -1.775$, $p = .080$, $d = 0.31$), whereas children with dyslexia outperformed typically developing children on similarities ($t(155) = 2.611$, $p = .010$, $d = 0.57$) and comprehension ($t(155) = 4.271$, $p < .001$, $d = 0.72$).

Next, differences in distribution of errors within each group were studied using ANOVA with Errortype (phonological errors, morphologic errors, and orthographical errors) as within subject factor and group (typically developing children, children with dyslexia) as between subject factor. Mauchly's test indicated that the assumption of sphericity had been violated for the main effects of Errortype, χ^2 (2) = 368.098, $p < .001$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (*e* = .53 for Error type). There was a main effect of Errortype, $F(1.048, 162.440) = 213.914$, $p < .001$, η^2_p = .580, as well as an interaction between Errortype and Group, $F(1, 155) = 25.245$, p = <.001, η^2_p = .140. Children with dyslexia made more phonological (t (51) = 4.562, $p < .001$, d = 0.89), morphological (t(65) = 7.589, $p < .001$, d = 1.41), and orthographic errors (t (51) = 5.416, $p < .001$, d = 1.05) than typically developing children. The interaction suggests that this difference tended to be more pronounced in the phonological errors. Indeed, planned contrasts revealed that the difference between the two groups is significant for phonological and orthographic errors ($F(1,155) = 78.42$, $p < .001$), phonological and morphological errors ($F(1,155) = 78.415$, $p < .001$) and morphological and orthographic errors ($F(1,155) = 17.22$, p = <.001.): both groups made most morphological errors, followed by orthographic errors and phonological errors).

Table 4.1 *Descriptive Statistics for Children with Dyslexia at Pretest (n = 52) and Typically Developing Children (n = 105).*

		Children with Dyslexia		Typically developing Children	
		M	*SD*	*M*	SD
Outcome measures					
Word Spelling pretest	Raw scores	43.15	23.54	80.23	20.95
Phonological errors	Raw scores	103.21	160.67	1.98	2.50
	Percentages	16.28	25.22	0.32	0.41
Morphological errors	Raw scores	6.77	4.37	1.88	2.14
	Percentages	40.47	25.64	11.72	13.36
Orthographic errors	Raw scores	17.44	22.17	1.00	1.61
	Percentages	20.96	26.18	1.27	2.04
Predictor measures					
Phonological awareness					
Spoonerism	Raw scores	2.80	3.35	6.99	3.40
Phoneme deletion	Raw scores	7.96	2.35	9.99	1.74
Rapid automatized naming					
Letter naming	Raw scores	41.63	10.944	31.00	10.37
Digit naming	Raw scores	37.79	11.26	28.21	6.98
Verbal working memory	Raw scores	3.92	1.31	4.59	1.65
Semantic abilities					
Information	Raw scores	12.58	3.27	12.64	3.23
Similarities	Raw scores	14.27	2.42	12.49	3.68
Vocabulary	Raw scores	30.23	6.14	28.22	6.94
Comprehension	Raw scores	20.60	5.52	16.60	5.62

Table 4.2 *Pearson Correlations between the Outcome Measures (i.e., Word Spelling, Phonological errors, Morphological errors, Orthographic errors) and Predictor Measures (i.e., Phonological awareness, Rapid automatized naming, Verbal working memory, and Semantic abilities). Below the Diagonal: Children with Dyslexia (n = 52); Above the Diagonal: Typically Developing Children (n = 105).*

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**
1. Word spelling raw scores pretest	-	-.585**	-.747**	-.617**	.610**	-.418**	.426**	.563**	-	-	-	-
2. Percentages phonological errors	-.768**	-	.392**	.370**	-.491**	.360**	-.146	-.343**	-	-	-	-
3. Percentages morphological errors	-.907**	.839**	-	.564**	-.519**	.241*	-.227*	-.451**	-	-	-	-
4. Percentages orthographic errors	-.810**	.992**	.857**	-	-.337**	.323**	-.242*	-.283**	-	-	-	-
5. Phonological awareness	.305*	-.245	-.293*	-.263	-	-.255**	.317**	.528**	-	-	-	-
6. Rapid automatized naming	-.378**	.239	.390	.256	-.212	-	-.231*	-.318**	-	-	-	-
7. Verbal working memory	.294*	-.230	-.247	-.235	.088	.040	-	.410**	-	-	-	-
8. Semantic abilities	.652**	-.456**	-.665**	-.491**	.345*	-.359**	.085	-	-	-	-	-
9. Change per session phonological errors	.720**	-.893**	-.808**	-.878**	.315*	-.250	.275	.526**	-	-	-	-
10. Change per session morphological errors	.627**	-.598**	-.776**	-.580**	.093	-.185	.201	.421**	.731**	-	-	-
11. Change per session orthographic errors	.740**	-.879**	-.812**	-.875**	.325*	-.290	.248	.537**	.990**	.713**	-	-
12. Change per session spelling percentiles	-.291*	-.211	-.287	-.243	.305*	-.305*	.027	.363**	.292*	.236	.303*	-

$^*p < .05$. $^{**}p < .01$ $^{***}p < .001$

Predicting individual differences in phonological and orthographic spelling

Research question 1b was about the role of semantic abilities in predicting the phonological and orthographic spelling of children with dyslexia. To answer this question, hierarchical regression analyses were conducted on all three outcome measures (i.e., phonological errors, morphological errors, and orthographic errors). Given that we had a control group that was matched on age, we chose to use raw scores instead of standardized scores as it would allow us to compare impact of each measure. In step 1, phonological awareness, rapid automatized naming, and verbal working memory were entered, followed by semantic abilities in step 2. Semantic abilities was added separately to see the unique contribution of semantic abilities beyond phonological awareness, rapid automatized naming, and verbal working memory. Correlations between all used measures are presented in Table 4.2.

The results of the analyses (see Table 4.3) showed that rapid naming and verbal working memory predicted morphological errors (Step 2). In Step 2 the effect of rapid naming on morphological errors was no longer present. Higher scores on semantic abilities resulted in fewer phonological, morphological, and orthographic errors and higher scores on verbal working memory resulted in fewer morphological errors.

Table 4.3 *Cognitive Predictors of Spelling Errors in Children with dyslexia (n = 52).*

		Phonological errors		**Morphological errors**		**Orthographic errors**	
		ΔR^2	**b**	ΔR^2	**b**	ΔR^2	**b**
Step 1		.151		.268**		.168*	
	Phonological awareness		-2.711		-2.965		-3.045
	Rapid automatized naming		2.738		4.751**		3.031
	Verbal working memory		-7.083		-7.986*		-7.467
Step 2		.123**		.275***		.143**	
	Phonological awareness		-1.071		-0.478		-1.208
	Rapid automatized naming		1.194		2.411		1.302
	Verbal working memory		-6.312		-6.816*		-6.602
	Semantic abilities		-2.803**		-4.250***		-3.140**
Total R^2_{adj}		.211**		.503***		.250**	

*$p < .05$. **$p < .01$ ***$p < .001$

To check whether age had any impact on the results, we reran the hierarchical regression analysis including age in step 1 and the predictor measures in steps 2 and 3; results remained the same.

Change in spelling errors due to intervention in children with dyslexia

Research question 2a focused on the extent to which children with dyslexia develop their phonological and orthographic spelling due to a phonics through spelling intervention.

We first calculated the change per session by subtracting the number of phonological, morphological, and orthographical errors at pre- and posttest. Following Gollwitzer and colleagues (2014), change scores are reliable when standard deviations differ between measurement occasions and there needs to be a non-zero variation in observed difference scores. Our data met these requirements. In order to rule out the effects of variation in length of the intervention and to ensure the analyses had enough statistical power, the individual change score was divided by the number of sessions the intervention for each individual lasted. Paired t-tests with Holm-Bonferroni correction (Holm, 1979) were computed to test the differences between pre- and posttest on overall spelling performance and each type of spelling error, respectively. Results showed an increase in overall spelling scores as well as a decrease in all three error types after intervention (see Table 4.4). Regarding the relative differences in change per session, results showed significant differences between phonological and morphological (t(45) = 4.159, p = .<001, d = 0.46) and morphological and orthographic errors(t(45) = -3.098, p = .003, d = 0.35), and phonological and orthographic errors ((t(45) = 4.613, p < .001, d = 0.10). The change per session is highest for morphologic errors, followed by orthographical and lastly phonological errors.

Table 4.4 *Descriptive Statistics from both Pre- and Posttest on al Dependent Measures, the Results on the T-tests for Paired Samples, Cohen's d, and the Change per Session.*

	Pretest (n = 52)		**Posttest (n = 46)**		**Difference scores (t-tests)**		**Change per session**	
	M	***SD***	***M***	***SD***	***t***	***d***	***M***	***SD***
Word spelling percentiles	5.40	10.50	13.25	15.10	3.41***	0.60	.26	0.57
Percentage of phonological errors	16.27	25.22	1.96	11.07	-4.34***	0.73	-.62	0.98
Percentage of morphological errors	40.47	25.64	13.61	16.34	-8.10***	1.25	-1.05	0.90
Percentage of orthographic errors	20.96	26.18	3.85	12.85	-4.95***	0.82	-.72	0.99

*p < .05. **p < .01 ***p < .001

Predicting individual differences in change scores in children with dyslexia

Finally, research question 2b focused on the predictive role of semantic abilities on the phonological and orthographic spelling development of children with dyslexia due to a phonics through spelling intervention. This question was answered by conducting three hierarchical regression analyses (i.e., one analysis for each change score in error type). For each analysis, the predictor variables (i.e., phonological awareness, rapid automatized naming, and verbal working memory) were entered in step 1, followed by semantic abilities in step 2 to see what the unique contribution of semantic abilities is beyond phonological awareness, rapid automatized naming, and verbal working memory. In step 1, no variables significantly predicted any change score, although the model was significant for phonological and orthographic errors. In step 2, semantic abilities was a positive predictor for all three change scores: the better the semantic abilities, the higher the change scores in phonological, morphological and orthographic errors (see Table 4.5).

We again checked whether age had any impact on the results and reran the analysis including age in step 1; results remained similar.

Table 4.5 *Cognitive Predictors of the Change in Spelling Errors during the Interventions (n = 46).*

		Change in phonological errors		**Change in morphological errors**		**Change in orthographic errors**	
		ΔR^2	**b**	ΔR^2	**b**	ΔR^2	**b**
Step 1		.204*		.086		.213*	
	Phonological awareness		0.142		0.017		0.146
	Rapid automatized naming		-0.109		-0.091		-0.131
	Verbal working memory		0.338		0.254		0.305
Step 2		.152**		.149**		.154**	
	Phonological awareness		0.059		-0.058		0.062
	Rapid automatized naming		-0.055		-0.042		-0.076
	Verbal working memory		0.266		0.189		0.232
	Semantic abilities		0.124**		0.113**		0.126**
Total R^2_{adj}		.292**		.235**		.367**	

*p < .05. **p < .01 ***p < .001

Conclusions and discussion

The present study investigated the phonological and orthographic spelling development of children with dyslexia by analyzing phonological, morphological, and orthographic spelling errors both before and after a phonics through spelling intervention. The predictive role of semantic abilities for children with dyslexia was studied as an addition to the phonological core deficit.

In line with the first hypothesis, children with dyslexia made more phonological, morphological, and orthographic errors compared to typically developing children. These results confirm previous research (Bourassa & Treiman, 2003; Bourassa et al., 2006; Cassar et al., 2005).

In accordance with our second hypothesis, we found that orthographic spelling is more difficult for all spellers. This finding confirmed that more specific knowledge of rules and orthographic patterns is necessary for orthographic spelling (see Allen, 1992). Both children with dyslexia and typically developing children made proportionally most morphological errors, followed by orthographic and phonological errors. In addition, when comparing the relative differences between children with dyslexia and typically developing children, results showed that children with dyslexia differed most from typically developing children on phonological errors compared to morphological and orthographic errors. The fact that children with dyslexia struggle more than typically developing children with phonological errors follows from their phonological deficit, which prevents children with dyslexia from building strong bi-directional connections between phonological and orthographic representations (Cassar et al., 2005; Snowling, 1998).

In compliance with our third hypothesis, we found that for children with dyslexia morphological errors were negatively associated with verbal working memory and phonological, morphological, and orthographic errors were negatively associated with their level of semantic abilities. The impact of verbal working memory on morphological errors is also highlighted in the Morphological Pathways Framework, suggesting that additional working memory is needed in these cases (Levesque et al., 2021). The importance of semantic abilities for both phonological and orthographic spelling is in line with the lexical quality hypothesis (Perfetti, 2007); semantic abilities could be seen as a compensatory factor for both phonological and orthographic spelling. We showed that semantic abilities is not only important for reading (Nation & Snowling, 2004) but for phonological and orthographic spelling as well. This is in line with the connectionist model of Plaut and colleagues (1996) in which literacy development was described in terms of a division of labour between interacting phonological and semantic pathways. Variation in both phonological and semantic processing could be related to individual differences in literacy development, whereas children with dyslexia rely on contributions from the semantic pathway because of their poorly developed phonological pathway (Nation & Snowling, 1998; Snowling, 2000). However, longitudinal studies are necessary to understand the complex interplay between phonological and semantic abilities as been indicated by Laing and Hulme (1999).

With regard to our fourth hypothesis, we found a decline in the error percentages in all three error categories after a phonics through spelling intervention. The change per session (decline in error percentages) was highest for morphological errors, followed by orthographic errors and lowest for phonological errors. The relative differences in the percentages of errors between the three categories stayed the same: children with dyslexia still made relatively most morphological errors, followed by orthographic errors and lastly phonological errors (based on percentages of the total number of possible errors in that category). These results are all in line with the spelling improvements that were found after interventions including phonics, morphological, or orthographic instruction (Galuschka et al., 2020) and illustrate that phonics through spelling interventions have a positive effect on both phonological and orthographic spelling development.

Consistent with our fifth hypothesis, we found that for children with dyslexia, the decline in phonological, morphological, and orthographic errors during the phonics through spelling intervention were associated with their level of semantic abilities. Semantic abilities influence the spelling development over time and together with the above-mentioned findings, this led to the conclusion that children with better semantic abilities do not only perform better in spelling, in general, but gain more during a phonics through spelling intervention as well.

The present study can be seen as a first step in uncovering the development of phonological and orthographic spelling and the role of semantic abilities in this spelling development of children with dyslexia. Some limitations should be acknowledged at this point along with directions of future research. First, results should be interpreted with caution as children could make more phonological errors compared to morphological and orthographic errors. Although we used a standardized Dutch dictation task, it is recommended for future research to consider dictations tasks in which errors will be more evenly distributed among these three categories and in which higher levels are included as well. This way, the control group will show more normally distributed scores without floor effects. Future research could find out whether the predictive role of semantic abilities for spelling errors is specific for children with dyslexia or not. Second, we only followed the children with dyslexia over time and did not incorporate a (randomized) control group to evaluate the effects of the intervention. In future research, this latter group could also be followed over time in order to find out whether the effect of semantic abilities on the spelling development over time is typically for children with dyslexia. Follow-up studies could include both skill-based and word-based effects of semantic abilities in order to find out which benefits children most. Third, future research could consider to include the actual time spent on each spelling error category during the intervention in order to see how this influenced the spelling error decline. Fourth, although this study checked for the amount and frequency of the homework that comes with the intervention, there could be an effect of home environment on the change due to intervention, for instance, due to differences in socio-economic status. Follow-up studies focusing on the influence of the home environment are recommended.

It can be concluded that in general, orthographic spelling is more difficult than phonological spelling, but that children with dyslexia differ far more from typically developing children in the proportion of phonological errors compared to the difference in the proportion of morphological and orthographic errors. This is in line with their phonological deficit and implies that children with dyslexia need an intervention that stimulates both phonological and orthographic spelling development, but especially phonological errors since the differences with typically developing children are biggest. This study contributes to the existing literature by demonstrating that children with dyslexia with strong semantic representations, appear to make fewer phonological, morphological, and orthographic spelling errors, compared to children with dyslexia with less developed semantic representations and children with dyslexia with better developed verbal working memory make fewer morphological errors compared to children with dyslexia with better developed verbal working memory. Our study shows that a phonics through spelling intervention benefits both phonological and orthographic spelling development quite evenly among children with dyslexia but that there is a positive additional effect of semantic abilities on the progress during the intervention as well. Promising effects of integrating semantic abilities in spelling interventions were found before (Ouellette, 2010; Ouellette & Fraser, 2009). Therefore, it is recommended to stimulate the semantic development of children that are at risk for dyslexia at an early stage and throughout their school carrier in order to help them build strong semantic networks to compensate in their spelling development. Furthermore, semantic abilities could be stimulated during interventions as well in order to stimulate spelling development even further.

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Appendixes

Appendix A. *Classification of Errors in Phonological, Morphological and Orthographic Errors and corresponding Error Descriptions.*

Phonological Errors	
Type of Error	*Explanation, Examples and total Error Calculation*
Phoneme addition	The addition of one or more graphemes per place (e.g., zons [sun] instead of zon [sun])
Phoneme deletion	The deletion of a grapheme (e.g., zo [so] instead of zon [sun]).
Long vowel in closed syllable swap	A long vowel in a closed syllable is written as a short vowel (e.g., ram [ram] instead of raam [window]) or as another long vowel (e.g., room [cream] instead of 'raam' [window]).
Long vowel in open syllable swap	A long vowel in an open syllable is swapped for the wrong vowel (e.g., ro-men [skimming] instead of ramen [windows]).
Short vowel swap	A short vowel is swapped for the wrong vowel (e.g., rum [rum] instead of ram [ram]).
Two-character vowels swap	A two-character vowel (e.g., ie) is swapped for the wrong two-character vowel, (e.g., 'puis' [no Dutch meaning] instead of poes [cat]) or written incorrectly (e.g., 'peos' [no Dutch meaning] instead of poes [cat]).
Consonant swap	A consonant is swapped for the wrong consonant (e.g., poek [no Dutch meaning] instead of 'poes' [cat]).

Morphological Errors	
Type of Error	*Explanation, Examples and total Error calculation*
end d/t	When words end with a /t/ it can be written with 't' or 'd' on the end of the word (e.g., hond [dog], boot [ship]). By making a word plural it is possible to hear a 't' or a 'd' (e.g., hon*d*en [dogs], bo*t*en [ships]). Whatever consonant is heard in the plural form must be written in the singular word as well. Errors: write a 't' instead of a 'd' or viceversa (e.g., hont instead of hond).
open syllables long vowel	When a syllable ends with a long vowel this is written short (raa-men must be written as ra-men [windows]) Errors: write a long vowel (e.g., boomen instead of bomen [trees]).
gt/cht	Words with /gt/, which can be written as 'gt' or 'cht' (e.g., zaagt [sweeps], lucht [air]). Whenever a short sound vowel is placed before /gt/, then a 'cht' needs to be written (l*u*cht). There are three exceptions: ligt (lays down), legt (put), zegt (says). Errors: write a 'gt' instead of 'cht' (e.g., vrugt instead of vrucht) or viceversa (veecht instead of veegt) or make mistakes in exception words. (e.g., zecht instead of zegt).

Orthographic Errors	
Type of Error	*Explanation and Examples*
aai/ooi/oei	The letterclusters aai/ooi/oei are pronounced as aaj/ooj/oej. Errors: write the j instead of the i.
eeuw/ieuw/uw	The letterclusters eeuw/ieuw/uw are pronounced as iw/iew/uuw, for instance in leeuw (lion), nieuw (new) and duw (push). Errors: writings like 'leew' instead of 'leeuw'.
i/ie/y	The sound /ie/ can be writing in three ways. The two-character vowel 'ie' and 'y' are always pronounced like 'ie', for instance in 'gieter' (watering can) and 'systeem' (system). The letter 'i' is pronounced like 'ie' or 'i' depending on the word, for instance 'liter' (/lietur/) and dieper (/diepur/, deeper). It needs to be learned by heart whether to write the 'ie', 'i' or 'y' in case of an /ie/. Errors: writings like 'lieter'/'lyter' instead of 'liter'.
g/ch	The sound /g/ (not followed by a 't' as in the gt/cht rule) can be written in two ways; 'g' or 'ch'. It needs to be learned by heart whether to write the 'g'/'ch'. Errors: writings like 'zach' (no Dutch meaning) instead of 'zag' (saw).
c/k/s	The sound /k/ can be written as 'k' or 'c' and the sound /s/ can be written as 's' or 'c'. It needs to be learned by heart whether to write the 'k'/'c' and 's'/'c'. Errors: writings like 'creeft' (lobster) instead of 'kreeft' (lobster).
f/v and s/z	Although there is a difference in sounds the 'f' and 'v' and 's'and 'z' sound alike, for instance in fiets (bike) and vlag (flag). For many children this is therefore an orthographic category. Errors: writings like 'viets' instead of 'fiets' (bike) or 'see' instead of 'zee' (sea).
ou/au/ouw/auw and ei/ij	The sound /au/ can be writing in four ways; 'au'/'ou'/'auw'/'ouw', and /ij/ as 'ij'or 'ei'. For instance in 'saus' (sauce), 'kous' (stocking), 'rauw' (raw) or 'mouw' (sleeve). It needs to be learned by heart which letter combination to write. Errors: writings like 'sous' instead of 'saus' (sauce) 'or trijn' instead of 'trein' (train).
Schwa	A reduced vowel in unstressed syllables that in Dutch is pronounced like /u/. It may be written using any of the following letters: 'e', as in muren (walls) 'i', as in grapp*i*g (funny) 'ij', as in moeil*ij*k (difficult) The schwa-parts of words need to be learned by heart. Errors: writings like 'grappug'/'grappeg' instead of 'grappig' (funny).

Appendix B. *Removed Types of Errors.*

Type of error	*Explanation, Examples and total Error Calculation*
Tone discol-oration	The letters 'r' and 'l' can discolorate the tone of certain grapheme or grapheme-clusters such as ee, oo, eu, ij and ei. For instance, 'veel' (a lot of) sounds like /vil/ with a slightly long stretched short vowel /i/, Errors: mostly the tone discoloration is not recognized and the short vowels are written down. For instance, 'vil' instead of 'veel'. Deleted because it could be classified as both morphological as orthographic.
Adhesive letters	In certain parts in the Netherlands a schwa is added in between two consonants in the letterclusters with 'r' (-rg/-rp/-rm/-rk/-rf) and with 'l' (-lg/-lp/-lm/-lk/-lf). For instance, the word 'tulp' (tulip) is pronounce /tulup/. A schwa is added between two consonants. Errors: the schwa is sometimes added in the written word, for instance 'tulup' instead of 'tulp'. Deleted because it could be classified as both morphological as orthographic or phonological error.
-ng/-nk	The grapheme-combination '-ng' and '-nk' are difficult because the sound is different from the known grapheme's 'n', 'g' and 'k'. The 'ng' forms a new sound and de 'nk' is pronounced like 'ngk'. The sound and grapheme-combination have to be known by heart. Errors: mostly the 'ng' is written like 'n' for instance 'krin' instead of 'kring' (circle). The 'nk' is mostly written like 'ngk' for instance in 'flingk' instead of 'flink' (brave). Deleted because some schools treat it as a grapheme-phoneme correspondence whereas others see it as an orthographic word to remember.

CHAPTER 5

Compensatory role of verbal learning and consolidation in reading and spelling

This chapter is based on:
Van Rijthoven, R., Kleemans, T., Segers, E., & Verhoeven, L. (2022). Compensatory role of verbal learning and consolidation in reading and spelling of children with dyslexia. *Annals of Dyslexia*, 1-26. doi:10.1007/s11881-022-00264-2

Abstract

The present study investigated the compensatory role of verbal learning and consolidation in reading and spelling of children with (*n* = 54) and without dyslexia (*n* = 36) and the role of verbal learning (learning new verbal information) and consolidation (remember the learned information over time) on the response to a phonics through spelling intervention of children with dyslexia. We also took phonological awareness, rapid automatized naming, verbal working memory, and semantic abilities into account. Results showed that children with dyslexia performed better in verbal learning and equal in verbal consolidation compared to typically developing peers. Regression analyses revealed that verbal learning did not predict reading but did predict spelling ability, across both groups; verbal consolidation did not predict reading, nor spelling. Furthermore, neither verbal learning nor verbal consolidation were related to responsiveness to a phonics through spelling intervention in children with dyslexia. Verbal learning may thus be seen as a compensatory mechanism for spelling before the intervention for children with dyslexia, but is beneficial for typically developing children as well.

Introduction

In learning to read, children learn to integrate orthographic, phonological, and semantic codes into highly specified and redundant lexical representations (Perfetti, 2007). After having cracked the alphabetic code, they need to speed up their visual word decoding and spelling with ongoing practice (Ehri, 2005). Brain studies showed that during fluent reading, typically developing children show activation in the posterior regions, while poor readers tend to show underactivation (Paulesu et al., 2001; Shaywitz et al., 2002). This underactivation could hinder the building of an efficient connection between orthographic and phonological codes, and thus can be linked to the phonological deficit that is associated with dyslexia (Göbel & Snowling, 2010; Shaywitz et al., 2003). However, poor readers may compensate for their reading and spelling problems by using their ability for verbal learning. In learning new verbal information, both the verbal learning (learning through rehearsals) and consolidation of the learned material (recall over time) are important and independent processes (Helmstaedter et al., 1997). A higher verbal learning capacity enables the learning of new phonological information, which may enhance the phonological network. This, in turn, may support reading and spelling development. So far, behavioural research into this possibly compensatory role of verbal learning in children with dyslexia is limited and mostly lacking control variables and a typically reading control group. In addition, the impact of verbal learning and consolidation on responsiveness to intervention has not been tested. Therefore, in the present study, the impact of verbal learning and verbal consolidation on reading and spelling before and after a phonics intervention were examined.

Reading and spelling in children with dyslexia

Already at a young age, children start to develop their spoken language. According to Levelt and colleagues (1999) this development starts with the formation of semantic representations (which word refers to which object), which are connected to phonological representations (words contain separate phonological segments). The formation of semantic and phonological representations can be seen as the foundation on which further reading and spelling development builds (Shaywitz et al., 2003). Literacy development continues when children learn to read by recoding graphemes into sounds and blend these sounds into spoken words. At the same time children learn to spell words by dividing a spoken word into separate sounds and write the corresponding graphemes. In the beginning, children read and spell slowly. Later, reading and spelling gets faster and more fluent. According to the lexical quality hypothesis, this is the consequence of the formation of phonological, semantic, and orthographic representations and bi-directional relations between these representations during reading and spelling (Perfetti, 2007). The specificity and redundancy of the representations determine reading and spelling levels (Perfetti, 2007). Children with dyslexia are hindered in building a high-quality network by their phonological deficit; they show problems in the detection, segmentation, and manipulation of individual sounds in words (Beitchman & Young, 1997). These abilities are, at least to a large extent, dependent on the quality of the underlying phonological representations (Goswami, 2000), which can be underspecified and sometimes missing (Conrad, 2008; Göbel & Snowling, 2010). As a consequence, children may experience difficulties in reading words accurately and fluently and in spelling words correctly (Lyon et al., 2003).

Multiple neuroimaging studies found that children with dyslexia show relative underactivation in the posterior regions and relative overactivation in the anterior regions during rhyme decision tasks of both real words and pseudowords (e.g., Hoeft et al., 2007; Shaywitz et al., 2003). The posterior region of the brain is known for the integration of visual codes, phonological structures and the phonological retrieval that enables fluent reading (Price & Friston, 1997) and has found to be associated with the phonological deficit of children with dyslexia (Brunswick et al., 1999). The anterior region of the brain is known for different aspects of language processing, making efficient processing of language possible (Bookheimer, 2002), such as the encoding of new memories, the retrieval and selection of declarative and procedural knowledge (Buckner et al., 2001; Ullman, 2004), and for memorization of verbal information (Smith & Jonides, 1999).

Based on neuroimaging studies, Kearns and colleagues (2019) as well as Hoeft and colleagues (2011) suggested that children with dyslexia may use different pathways to read as compared to typically developing peers in an attempt to overcome dysfunctions in the posterior regions. The overactivation in the anterior regions could point to a compensation for the weak relationship between phonological and orthographic representations. One possible source of compensation associated with this region is the ability to learn and remember verbally presented information. Verbal learning is a way of expanding the phonological representations and thus the lexical specificity of words. As verbal learning adds new phonological information to the child's lexicon (and therefore more specificity and redundancy) it could facilitate reading and spelling (in line with the lexical restructuring hypothesis by Metsala & Walley (2008)). Children who learn verbal information more easily may be able to form more and better specified semantic and phonological representations, which helps to recognize words while reading parts of it. Better ability to learn verbal information may thus indirectly compensate for the lack of strong and bi-directional phonological and orthographic representations. In other words, the ability to learn and remember words could expand the lexical quality as described by Perfetti (2007).

Role of verbal learning and consolidation in reading and spelling

Throughout the years, a lot of reseach has been done on memory-related functions among children with dyslexia, with verbal working memory receiving most attention. Previous research showed that children with dyslexia have verbal working memory problems, which are related to deficiencies in their literacy development (Kastamoniti et al., 2018). To be more specific, problems in verbal working memory lead to unstable representations and thus inefficient activation of the semantic features of words (Lukatela et al., 1998). Therefore, working memory is also related to semantic development (Gathercole, 1995). In the case of unstable phonological representations, repetition and rehearsal could lead to better outcomes as these processes stimulate the specificity of the lexicon. However, as verbal working memory itself can only store and retrieve phonological information for a limited amount of time, it has been suggested that stimulating the specificity of the lexicon itself lies not so much in the verbal working memory system, but in the storage of phonological information in long-term memory (e.g., Elbro & Jensen, 2005; Mayringer and Wimmer, 2000).

Two processes that are involved in acquiring and storing verbal information in long-term memory are verbal learning and consolidation. Verbal learning can be seen as a process of maintaining as much verbal information as possible in working memory for a short period (Kibby, 2009) with the help of repetition and rehearsal to store the verbal information properly (Van Strien, 1999). Research regarding the role of verbal learning showed that school-aged 6 to 13-year-old children with dyslexia learn verbal information less efficiently compared to controls in paired associate learning (Elbro & Jensen, 2005; Litt & Nation, 2014; Mayringer & Wimmer, 2000; Messbauer & De Jong, 2003; 2006, Wang et al., 2017) and verbal list learning (Kibby, 2009; Kramer et al., 2000; Tijms, 2004; Van Strien, 1999). Only Kibby (2009) found no differences in verbal learning ability between 9 to 13-year-old children with dyslexia and typically developing controls. Research on verbal learning tasks showed that children with dyslexia between 6 and 13-years old indeed benefit from rehearsal and external updating, although they profit less from it than controls (Elbro & Jensen, 2005; Kibby, 2009; Kramer et al., 2000; Litt & Nation, 2014; Mayringer & Wimmer, 2000; Messbauer & De Jong, 2003, 2006; Wang et al, 2017). It can be concluded that children with dyslexia may have a less efficient rehearsal and encoding mechanism, which may limit the acquisition of higher quality representations of already known words (Elbro & Jensen, 2005).

After learning, new verbal material needs to be remembered over time. This is called verbal consolidation. The consolidation of this information in 8 to 13-year-old children with dyslexia is comparable with controls of the same age (Kibby, 2009; Kramer et al., 2000; Messbauer & De Jong, 2003; Van Strien, 1999;) and the same reading age (2 years younger) (Elbro & Jensen, 2005). Tijms (2004) concluded that inaccurate phonological representations could interfere with the semantic processing and thus with the acquisition of verbal material. However, once a deeper semantic level is activated, no further problems appear to be encountered and consolidation of verbal information can take place as usual. As differences were found in verbal learning and in a single case also in consolidation, these differences could be a possible cause for reading and spelling problems. However, only a few studies related verbal learning and consolidation to reading and spelling. First, some studies found that visual-verbal paired-associated learning was related to reading outcomes among typically developing children varying in age between 6 and 12-years old (Hulme et al., 2007; Litt et al., 2013; Warmington & Hulme, 2012; Windfuhr & Snowling, 2001). Second, Kibby (2009) found non-significant small partial correlations between verbal list learning and reading for 9 to 13-year-old children with dyslexia. The relations were also non-significant for typically developing children. Third, Tijms (2004) found that, among 11-year-olds with dyslexia, verbal list learning as part of a factor 'phonological memory' together with digit span and interference was weakly but significantly related to reading and spelling. According to Tijms (2004), these tasks were taken together as they share the encoding of the phonological characteristics of information. More serious phonological memory deficits were found to be accompanied by weaker reading and spelling levels. It was concluded that children with dyslexia have problems in the acquisition of verbal material, but when verbal material is acquired consolidation of verbal information takes place as usual. All studies just described operationalized verbal learning as the end result of learning (the total number of words remembered in the last trial) instead of looking at the learning potential by means of the learning curve of each child as has been done by Kramer and colleagues (2000) and Van Strien (1999). By comparing all four mentioned studies, it can be concluded that differences were observed with respect to operationalization of verbal learning and age of participants. So far, no study linked the learning curve as described by Van Strien (1999) and Kibby (2009) to reading and spelling outcomes.

Prior studies showed that children with dyslexia benefit most from phonics interventions for reading compared to reading fluency trainings, phonemic awareness instructions, reading comprehension trainings, auditory trainings, medical treatments and coloured overlays or lenses (Galuschka et al., 2014). For spelling, it was found that phonics, morphological and orthographic interventions are all effective in treating spelling of children with dyslexia (Galuschka et al., 2020). Furthermore, prior studies showed that brain activation in the posterior region is more alike typically developing peers after such an intervention (Shaywitz et al., 2003; Simos et al., 2002). However, large individual differences in response to intervention were reported (Galuschka et al., 2014; 2020). Following our line of reasoning, the ability to learn and maintain verbal information could be related to variation in responsiveness. Better verbal learning and consolidation may help to develop better specified lexical representations and improve reading and spelling development.

Given the fact that dyslexia can be characterized by an underlying phonological deficit, phonological awareness, rapid automatized naming, and verbal working memory are generally considered cognitive precursor measures that predict literacy development (Shaywitz et al., 2003; Snowling, 1998). In order to determine the unique contribution of verbal learning and consolidation to reading and spelling before and after an intervention these measures need to be included. Furthermore, variation in semantic abilities has previously been shown to impact reading (Nation & Snowling, 2004; Torppa et al., 2010) and spelling ability (Ouellette, 2010; Tainturier & Rapp, 2001) and should, therefore, be included as well. Out of the studies that included list learning tasks Kibby (2009) did not include control variables and Tijms (2004) included phonological awareness seperately and verbal working memory was included in the factor 'phonological memory' together with verbal learning. Rapid automatized naming and semantic abilities were not included. As a consequence, the unique contribution of verbal learning and consolidation is still unknown. In order to find out whether this impact is typical for children with dyslexia, control groups are necessary. However, Tijms (2004) did not include a control group and so it is still unknown whether the reported effects are unique for children with dyslexia.

The debate on the compensatory role of verbal learning can at best be called inconclusive. First of all, verbal learning is interpreted differently across studies. The studies that related verbal learning to reading and spelling interpreted verbal learning and consolidation as a static measure in which the end result counts (e.g., Tijms, 2004), whereas both verbal learning and consolidation can be considered dynamic processes in which the learning curve is an important indicator of the ability to learn and withhold verbal information (e.g., Kramer et al., 2000). To the best of our knowledge, no prior study examined the relation between the dynamic aspect of verbal learning or consolidation and reading and spelling outcomes. Second, prior studies relating verbal learning and consolidation to reading and spelling included few or no control variables and no control group. In order to understand the unique contribution of verbal learning and verbal consolidation, studies need to include other relevant control variables (such as phonological awareness, rapid automatized naming, verbal working memory and semantic abilities). In order to find out if the effects of verbal learning or consolidation are typical for children with dyslexia a control group with typically developing peers needs to be included as well. Third, no study so far examined verbal learning and consolidation in relation to response to intervention. Individual variation in the dynamics of the task might also have an impact on the intervention.

The present study

The present study investigated the compensatory role of verbal learning and consolidation in reading and spelling of children with (n = 54) and without dyslexia (n = 36). Additionally, the role of verbal learning and consolidation on the response to a phonics through spelling intervention of children with dyslexia was examined in order to find out whether expanding the specificity and redundancy of the (phonological) lexicon helps children with dyslexia. Verbal learning was measured by a list learning task in which children were verbally presented with a list of 15 meaningful words. Immediately after hearing the words, the children were asked to recall as many words as possible in a random order. The same list was presented five times in a row and each time the child had to name as many of the presented words as possible. Following Van Strien and colleagues (2008), the result of the first trial is seen as an index of immediate memory span and the change in performance over the five trials as a measure of verbal learning. After a 30-minute delay, children were asked to name all the words they remembered. The outcome was called the verbal consolidation. We first studied the similarities and differences in verbal learning and consolidation between children with dyslexia and typically developing children. Next, we examined the relation between the individual differences in verbal learning and consolidation of both groups and their reading and spelling outcomes (before the intervention) by means of regression analyses, controlling for phonological awareness, rapid automatized naming, verbal working memory, and semantic abilities. Furthermore, we examined the relation between verbal learning and consolidation and the response to intervention among children with dyslexia again with regression analyses and inclusion of the prementioned control variables.

The present study investigated the extent to which verbal learning and consolidation predict reading and spelling levels and intervention outcomes in children with dyslexia. Based on the lexical quality hypothesis (see Perfetti, 2007), we expected that better verbal learning and consolidation are related to better reading and spelling outcomes, even more so for children with dyslexia (see Shaywitz et al., 2003). Furthermore, we expected that better verbal learning and consolidation are positively related to responsiveness to intervention in children with dyslexia due to the enhancement of lexical representations as well.

Method

Participants

Participants were children diagnosed with developmental dyslexia (37 boys, 17 girls) and typically developing children (12 boys, 24 girls). All participants spoke Dutch as their first language and all parents gave active consent to use the collected data for research purposes.

The Dutch children with dyslexia were diagnosed and received an in-service phonics through spelling intervention in a clinic for assessment and intervention for children with learning difficulties. The mean age of the children with dyslexia at the start of the assessment was 8.65 years (*SD* = 1.07). Children were in grade 2 (*n* = 12), grade 3 (*n* = 24), grade 4 (*n* = 11), grade 5 (*n* = 5), and grade 6 (*n* = 2). Ten children attended the same class an extra year. All children had semantic abilities within the normal range (Mean of the total standardized score of four subtests that were added to measure semantic abilities = 109.26, *SD* = 13.11).

The mean age of the children in the control group was 8.66 years (*SD* = .88). Children were in grade 2 (*n* = 10), grade 3 (*n* = 17), and grade 4 (*n* = 9). Two children attended the same class an extra year. All children had semantic abilities within the normal range (Mean total standardized score of four subtests forming semantic abilities = 105.00, *SD* = 14.20).

Measures

Outcome measures

Pseudoword decoding

Pseudoword decoding was measured with the *'Klepel Test'* (Van den Bos et al., 1994). Children were asked to read as many meaningless words as possible correctly within a time limit of two minutes. This task consisted of 116 pseudowords presented in four rows on one sheet. The words all had a legal phonological structure of Dutch words. Words became more difficult gradually from one syllable ('taaf') up to five syllables ('nalleroonplinteng'). An efficiency measures (i.e., total number of words read within two minutes minus number of errors) were calculated. Test scores were standardized by comparing them to norm-based peers with help of the manual of the tests. The parallel test-retest reliability of this measure differs per age but is at least .89 (Van den Bos et al., 1994).

Word decoding

Word decoding was measured with the *'Brus One Minute Test'* (Brus, & Voeten, 2010). In this word reading fluency test, children were asked to read as many meaningful words correctly as possible within a time limit of one minute. This task consisted of 116 unrelated words presented in four rows on one sheet. Words became more difficult gradually from one syllable ('waar' [true]) up to four syllables ('tekortkoming' [shortcoming]). An efficiency measure (i.e., total number of read words minus number of errors) was calculated. Test scores were standardized by comparing them to norm-based peers with help of the manual of the tests. The parallel test-retest reliability of this measure differs per age but is at least .87 (Van den Bos et al, 1994).

Spelling

Spelling was measured with the standardized 'PI word dictation' (Geelhoed & Reitsma, 1999). In this task children were asked to write single Dutch words correctly. The dictation consisted of 135 words, divided into nine blocks of fifteen words. First a sentence including the target word was read aloud and afterwards the target word was repeated. The test was terminated when a child failed to write at least eight out of fifteen words per block correctly in one block. The number of correctly written words was counted. Test scores were standardized by comparing them to norm-based peers with help of the manual of the tests. There were two versions available of the test (version A and version B). The internal consistency reliability of this measure differs per age but is at least .91 (Geelhoed, & Reitsma, 1999).

Predictor measures

Verbal learning

Verbal learning was measured by the '15 words test for children' (Kingsma, & Van den Burg, 2005), the Dutch adaptation of the Rey Auditory Verbal Learning Test (Rey, 1941). The experimenter verbally presented the child with a list of 15 meaningful and mono- and bisyllabic words. A list of the words can be found in Appendix A. Immediately after hearing the words, the child was asked to recall as many words as possible in a random order. The same list was presented five times in a row and each time the child had to name as many of the presented words as possible. Each trial the number of correct named words was noted. Following Van Strien et al. (1999), the result of the first trial can be seen as an Index of immediate memory span (Intercept) and the change in performance over the five trials (Slope) can be seen as a measure of verbal learning. The parallel test-retest reliability of this measure is .70 (Van den Burg & Kingsma, 1999).

Verbal consolidation

Verbal consolidation was measured by the '15 words test for children' (Kingsma, & Van den Burg, 2005), the Dutch adaptation of the Rey Auditory Verbal Learning Test (Rey, 1941). After finishing the five trials there was a 30-minute delay in which non-verbal tasks were administered. After this 30-minute delay the children were asked to name all the words they remembered, which represents the Verbal consolidation. The reliability of this measure is .62 (Kingsma, & Van den Burg, 2005).

Control measures

Phonological awareness

Two subtests from the 'Screening Test for Dyslexia' (Kort et al., 2005a) were used. First, during 'Phoneme Deletion' children were asked to omit a phoneme from an orally presented word and speak out the remaining word (e.g., ‘da*k*’ [roof] minus ‘*k*’ [f] is ‘da’ [roo]). Testing was terminated after four consecutive mistakes. Second, during the subtest ‘*Spoonerism*’ children had to switch the first sounds of two words (e.g., ‘*J*ohn *L*ennon’ becomes ‘*L*ohn *J*ennon’). In both tests, all correctly formed words were counted. The test-retest reliability differs per age but is at least .60 (Kort et al., 2005a).

Rapid automatized naming

RAN was measured using two subtests of ‘Continuous Naming and Reading Words’ (Van den Bos & Lutje Spelberg, 2007). During *‘Naming Letters’* children had to read out loud 50 letters. During *‘Naming Digits’* they were asked to read out loud 50 digits. Children were asked to name these visual stimuli as quickly as possible. The time in seconds needed to finish each subtest was used for analysis, and thus, a higher score expressed a weaker performance on RAN. The (split half) reliability of this measure differs per age but is at least .75 (Van den Bos & Lutje Spelberg, 2007).

Verbal working memory

Verbal working memory was measured using the backward task of the Number Recall subtest from the Wechsler Intelligence Scale for Children-III (WISC-III^{NL}) (Kort et al., 2005b). In this task, the experimenter pronounces sequences of digits that the child was asked to repeat in backward order. Testing was terminated after two consecutive mistakes. The number of correctly recalled sequences was counted. The (split half) reliability of this measure differs per age but is at least .50 (Kort et al., 2005b).

Semantic abilities

Semantic abilities were measured by adding the z-scores of four subtests from the WISC-III^{NL} (Kort et al., 2005b). Based on the manual, the child received zero, one, or two points for each item. Testing was terminated after four or five (Information) consecutive mistakes. The (split half) reliability differs per age but is between .64 and .77 (Kort et al., 2005b). First, during *‘Information’,* the child has to answer verbally asked questions to test their general knowledge about events, objects, places, and people. Secondly, during *‘Similarities’,* the child has to name the similarity between two concepts. Thirdly, during *‘Productive vocabulary’,* the experimenter pronounces a word and the task of the child was to define the given word. Fourthly, during *‘Comprehension’,* the experimenter asked questions about social situations or common concepts. Kaufman (1975) already showed that these four measures together form a factor named ‘verbal comprehension’, which is also the case in the current sample (Van Rijthoven et al., 2018).

Procedure

For the purpose of this study, 99 files of Dutch children were collected from a clinic for assessment and intervention for children with learning difficulties. Due to missing data and different instruments a sample of 54 children with Dutch as their first language remained for this study. The children were diagnosed with dyslexia following the protocol by Blomert (2006), which is line with the definition of dyslexia of the International Dyslexia Association (2002). The Dutch protocol for diagnosis of developmental dyslexia (Blomert, 2006) states that teachers have to prove resistance to treatment and weak performances on word reading and spelling during one and a half school year. In the subsequent diagnosis, a phonological deficit needs to be evidenced and other explanations of reading or spelling problems need to be excluded by a certified clinical psychologist. After assessment all children diagnosed with dyslexia received an in-service phonic through spelling intervention in a clinic for assessment and intervention for children with learning difficulties. All children were tested between 2009 and 2013 in two consecutive mornings by clinicians on above mentioned measures. For semantic abilities and verbal working memory, a few raw scores were missing (2-4 per variable). Furthermore, spelling dictation of one child was missing. Two or three weeks after the assessment the phonics through spelling intervention started for 52 children. After the intervention all participants were subjected to the posttest, including pseudoword decoding, word decoding, and spelling measures. Eight children were not tested for pseudoword decoding at posttest.

For the current study, data from a control group was included. Data from the control group was gathered at a primary school in the east of the Netherlands. Parents were informed about the purpose of the study by means of a letter and flyer with a link to an online consent form. In the flyer, it has been described we were hoping to get permission to test the verbal learning ability and reading and spelling levels along with some control variables in order to study differences and similarities between children with dyslexia and typically developing children in their abilities and the relation between these abilities. In total, 36 parents gave permission for their child to participate. Children from the control group were tested by graduate students, during two mornings within two weeks. The graduate students received a training by one of the authors. Tests were performed in two blocks (Block A and Block B). The blocks were randomized over the two days. However, the test order within the blocks was fixed. Block A included measures for spelling, verbal learning, word reading, pseudoword reading, rapid automatized naming and verbal consolidation. Block B included the measures for phonological awareness and the five subtests of the WISC-III^{NL}. Both blocks lasted about 45 minutes and took place in a quiet room within the school of the children. Children were picked up from the classroom for participation. All outcome variables were standardized by comparing them to norm-based peers with help of the manual of the tests. The raw scores (total number of words correctly written or read) were converted into percentile scores (a score of for instance 35 meant that 35% of the children scored at or below the child in question). A higher score meant a better performance on the task. For the predictor measures z-scores (based on raw scores) were used to standardize all measures. From the z-scores of the measures phonological awareness, rapid automatized naming, and semantic abilities a composite score was computed.

Phonics through spelling intervention

A phonics through spelling intervention aimed to reach a functional level of technical reading and spelling by means of combining reading and writing in one intervention following the protocol by Blomert (2006). Unique to a phonics through spelling intervention is that 50% of the amount of time available during the intervention is spent on spelling while most studies include less or sometimes no word spelling. Children had a weekly 45-minute session with a clinician. The mean length of the intervention was 27.27 weeks (*SD*=4.88). Variation in the length of the intervention occurred due to variation in the post-intervention assessment schedule (for instance due to holidays or personal circumstances). Furthermore, variation in the length of the intervention occurred due to variation in time needed to acquire 80%-accuracy levels and improved fluency levels as described below. During the sessions, the clinician tailored the intervention as much as possible to each child's needs. Explicit direct instruction, guided exercises, and feedback were given according to each child's needs. The continuity of quality during assessment and intervention was guaranteed by supervision of certified clinical health psychologists. The intervention included two stages:

1) Phonological spelling

The intervention started with practice of the phonological base of reading and spelling due to learning the grapheme-phoneme-correspondences (GPC). After learning the GPCs, children learned to use this letter knowledge in reading and writing words and sentences/texts by using an explicit strategy. When children mastered the basic levels, children learned to read and write words based on syllables as well. Accuracy was trained first, followed by efficiency and words and sentences/texts increased in difficulty. Feedback was given on accuracy and later also on efficiency.

2) Orthographic spelling

Dutch is a rather transparent language, but still morphological rules and orthographic patterns need to be learned to write and read words (mostly polysyllabic words) correctly. The morphological rules and orthographic patterns were taught according to each child's needs.

In order to rehearse the above-mentioned spelling and reading knowledge children had to do home exercises for reading and spelling. Parents were asked to train four times a week during 15 minutes with prescribed exercises. All parents have confirmed that this has been complied with. Parents reflected on the home exercises in a day-to-day logbook. When a child reached an accuracy of 80% during practice (read or write 80% of the words correctly) and improved significantly in their fluency (more fluent compared to the first time words were read) the clinician moved on to the next topic of intervention. This formative testing was sustained throughout the entire intervention. Therefore, variation in the length of the program is present.

Analytic approach

By means of regression analyses intercept and slope of the five trials of the 15 words test were calculated for each participant to quantify verbal learning. To check whether groups differed on verbal learning and consolidation, two Repeated Measures ANOVA's were conducted. To answer the research question and maintain enough statistical power, in total twelve separate hierarchical regressions were conducted; four for each outcome measure (i.e., word decoding, pseudoword decoding, and spelling). The first and second set of hierarchical regressions tested the effect of verbal learning on the outcome measure before and after the intervention, the third and fourth set of hierarchical regressions tested the effect of verbal consolidation on the outcome measures before and after the intervention. In all cases, relations were tested without control variables first and later control variables were added separately. Based on the fact that verbal learning and verbal consolidation are separate processes (Helmstaedter et al., 1997) we assumed that analyzing the effects of these factors separately would be a good way to maintain enough power as in the case of the response to intervention only 52 participants were present. In line with Harris (1985), who reported that analysis should include an absolute minimum of ten participants per predictor, this meant we could include five predictors at most. In order to express the response to intervention, the individual mean change between pre- and posttest (with percentile scores) was calculated by subtracting pre- from posttest scores. Following Gollwitzer and colleagues (2014), change scores are reliable if two requirements are met. First, standard deviation must differ between measurement occasions. Second, there needs to be a non-zero variation in observed difference scores in order to define the reliability. In order to rule out the effects of variation in length of the intervention, the individual change score was divided by the number of sessions the intervention for each individual lasted. Working with change scores implied that the differences in individual pretest scores were not taken into account. Pretest scores were included as a control variable to control for variation.

Results

Descriptive statistics for all measures are presented in Table 5.1. To compare children with dyslexia and typically developing children, we performed *t*-tests for independent samples with Holm-Bonferroni correction (Holm, 1979). Children with dyslexia scored below typically developing children on all outcome measures and on predictor measures phonological awareness measures (except the raw scores of phoneme deletion) and rapid naming measures (except the raw scores of letter naming). No differences were found in verbal working memory or semantic abilities. Regarding verbal learning, t-tests showed no group differences at trial 1, but significant differences at trials 2 to 5, with lower scores for the typically developing children. The total score over five trials differed, but the scaled score, intercept, and slope over five trials did not differ significantly. Finally, no differences were found regarding verbal consolidation. Correlations between all used measures are presented in Table 5.2.

Table 5.1 *Descriptive Statistics for Children with Dyslexia at Pretest and Typically Developing Children.*

		Children with dyslexia		Typically developing children		Holm-bonferroni corrected t-tests	
		M	***SD***	***M***	***SD***	***t***	***d***
Outcome measures							
Word decoding	Raw scores	31.37	13.23	51.94	18.69	-5.72***	1.27
	Percentiles	5.51	5.61	45.06	33.43	-7.03***	1.65
Pseudoword decoding	Raw scores	20.61	10.05	46.11	21.42	-6.67***	1.52
	Percentiles	8.39	8.09	51.86	31.33	-8.15***	1.90
Spelling	Raw scores	49.96	28.31	72.97	24.38	-3.98**	0.90
	Percentiles	7.74	14.50	62.11	33.88	-9.08***	2.06
Predictor measures							
Phonological awareness							
Spoonerism	Raw scores	3.07	3.27	6.42	3.78	-4.47***	0.95
	Scaled scores	7.80	2.13	10.25	2.90	-4.35**	0.96
Phoneme deletion	Raw scores	8.02	2.38	9.50	2.04	-3.07	0.67
	Scaled scores	7.67	2.33	9.89	2.72	-4.14**	0.88
Rapid automatized naming							
Letter naming	Raw scores	39.85	9.25	35.67	10.93	1.96	0.41
	Scaled scores	5.43	2.32	8.44	3.73	-4.33**	0.97
Digit naming	Raw scores	36.26	10.00	29.14	5.68	4.23**	0.88
	Scaled scores	6.33	2.89	9.94	3.11	-5.64***	1.20
Verbal working memory							
Digit span backwards	Raw scores	4.14	1.37	5.42	2.61	-2.68	0.61
Semantic abilities							
Information	Raw scores	13.35	3.84	12.44	2.32	1.37	0.29
	Scaled scores	10.78	2.40	10.89	2.33	-0.22	0.05
Similarities	Raw scores	14.60	5.14	11.89	3.85	2.82	0.60
	Scaled scores	12.30	3.14	10.89	3.16	2.08	0.45
Vocabulary	Raw scores	31.44	7.14	28.22	6.58	2.15	0.60
	Scaled scores	11.56	2.51	10.22	2.89	1.11	0.24
Comprehension	Raw scores	20.94	5.88	18.00	4.65	2.51	0.55
	Scaled scores	11.54	2.57	10.50	2.50	1.90	0.41
Verbal learning							
Trial 1	Raw scores	4.74	1.39	4.67	1.33	0.25	0.05
Trial 2	Raw scores	7.41	2.02	6.06	1.94	3.16*	0.68
Trial 3	Raw scores	8.59	1.95	7.08	2.09	3.50*	0.75
Trial 4	Raw scores	9.54	2.08	7.83	2.59	3.45*	0.73
Trial 5	Raw scores	10.35	1.96	8.53	2.60	3.79**	0.79

		Children with dyslexia		Typically developing children		Holm-bonferroni corrected t-tests	
		M	***SD***	***M***	***SD***	***t***	***d***
Total score over five trials	Raw scores	40.63	7.49	34.17	8.47	3.80**	0.81
	Scaled scores	4.83	2.81	3.61	2.50	2.11	0.46
Intercept trial 1-5	Based on raw scores	5.46	1.51	4.93	1.55	1.59	0.35
Slope trial 1-5	Based on raw scores	1.34	0.48	1.53	3.73	-0.38	0.07
Verbal consolidation							
Delayed recall (trial 6)	Raw scores	8.50	2.34	7.92	2.60	1.11	0.23
	Scaled scores based on age	4.56	2.48	4.14	2.52	0.78	0.16
	Scaled scores based on total score	4.69	2.88	5.42	2.87	-1.18	0.25

*$p < .05$. **$p < .01$ ***$p < .001$

Table 5.2 *Pearson Correlations between the Outcome Measures and Predictor. Below the Diagonal: Children with Dyslexia; Above the Diagonal: Typically Developing Children.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Word decoding	-	.923**	.749**	.496**	-.326	.261	.380*	.398*	-.260	-.272	-.205	-	-	-
2. Pseudoword decoding	.592**	-	.649**	.473**	-.409**	.266	.374*	.321	-.314	-.263	-.202	-	-	-
3. Spelling	-.069	.137	-	.310	-.099	.329	.265	.340*	.070	-.100	.033	-	-	-
4. Phonological awareness	.202	.221	.211	-	-.085	.180	.464**	.101	-.150	-.093	-.113	-	-	-
5. Rapid automatized naming	-.402**	-.250	.004	-.279*	-	-.069	-.379*	-.350*	.234	.109	-.047	-	-	-
6. Verbal working memory	.007	.167	.432**	.160	.133	-	.237	.024	-.071	-.252	.081	-	-	-
7. Semantic abilities	.152	.150	.054	.392**	-.363**	.101	-	.384*	-.146	.093	.234	-	-	-
8. Intercept 15wt	.550	-.034	.081	.281*	-.184	.122	.315*	-	-.420*	.140	.234	-	-	-
9. Slope 15wt	-.115	-.075	.058	.149	-.066	-.090	.095	-.327*	-	.363*	.236	-	-	-
10. Trial 5	-.014	-.068	.057	.252	-.280*	.022	.350*	.379**	.668**	-	.741**	-		
11. Verbal consolidation (trial 6)	.157	.077	.055	.202	-.367**	.097	.450**	.551**	.135	.557**	-	-	-	-
12. Word decoding change per session	.065	.195	.267	.123	-.195	.196	..034	.058	-.043	-.011	-.031	-	-	-
13. Pseudoword decoding change per session	.161	-.107	.018	-.074	-.147	.084	-.161	.015	-.031	.044	.128	.344*	-	-
14. Spelling change per session	.304*	.251	-.330*	.357*	-.188	.035	.450**	.174	-.034	.069	.272	-.122	-.154	-

*$p < .05$. **$p < .01$ ***$p < .001$

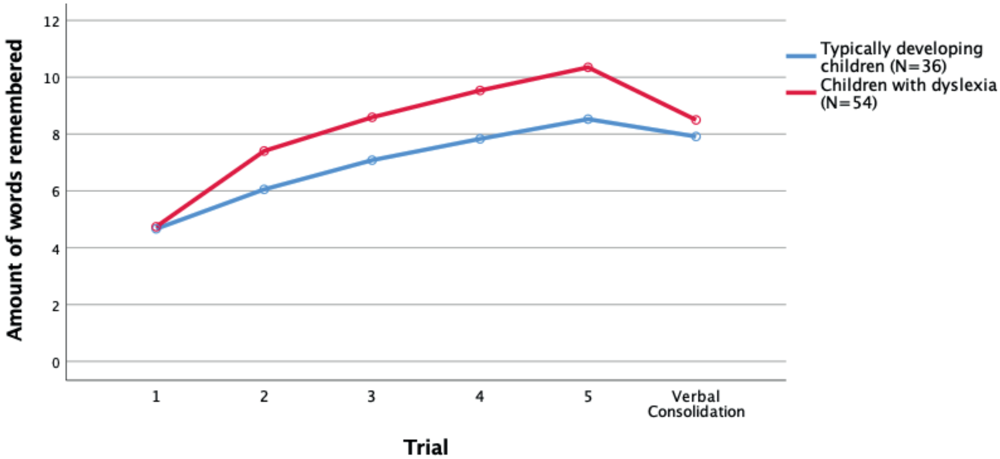
Note. The change per session is calculated by subtracting pre- from posttest scores and devide the outcome by the number of sessions the intervention lasted.

Differences in verbal learning and consolidation

Before answering the research question, we checked for group differences by conducting two general linear model repeated measure analyses. Firstly, we studied the difference between children with dyslexia and typically developing children in their verbal learning over the five trials. Verbal learning was the within subject factor (the five consecutive trials) and Group (children with dyslexia versus typically developing children) was the between subjects' factor. Mauchly's test indicated that the assumption of sphericity has been violated for the main effects of verbal learning, χ^2 (9) = 25.167, p = .003. Therefore, degrees of freedom were corrected using Huyn-Feldt estimates of sphericity (e = .85 for verbal learning). Results showed that there was a main effect of Verbal learning, F(3.65, 320.77) = 154.136, p < .001, η^2_p = .637, Group F(1, 88) = 14.468, p < .001, η^2_p = .141, as well as an interaction between Verbal learning and Group, F(3.645, 320.77) = 5.592, p < .001, η^2_p = .060. While based on the Holm-Bonferroni corrected t-test (see Table 5.1) the groups did not differ at T1 (p = .802), the Holm-Bonferroni corrected t-test showed significant differences at all subsequent trials (p = .002), due to a higher growth for the group with dyslexia between T1 and T2 (p < .001).

Secondly, we studied the difference between children with dyslexia and typically developing children in verbal consolidation (the number of words remembered at T6). The number of Words remembered was the within subject factor (fifth trial and verbal consolidation/T6) and Group (children with dyslexia versus typically developing children) was the between subjects' factor. There was a main effect of Words remembered, F(1, 88) = 33.386, p < .001, η^2_p = .275, a main effect of Group F(1, 88) = 6.930, p = .010, η^2_p = .073, as well as an interaction Words remembered x Group, F(1, 88) = 8.473, p = .005, η^2_p = .088. All children forgot words over time but children with dyslexia forgot more words compared to typically developing children. Based on the Holm-Bonferroni corrected t-test (see Table 5.1), children with dyslexia seem to remember significantly more words at trial 5 compared to the typically developing children (p < .001) and at the moment of verbal consolidation (i.e., T6) there seems to be no difference in the number of remembered words over time (p = .271). Results are depicted in Figure 5.1.

Figure 5.1 *Group Average Words Remembered from Trial 1-5 and Delayed Recall for Children with Dyslexia (n = 54) and Typically Developing Children (n = 36).*



Predicting reading and spelling by verbal learning and consolidation

To answer the first part of the research question, regarding the effect of verbal learning and consolidation on reading and spelling outcomes before the intervention, six hierarchical regression analyses were conducted. Three hierarchical regression analyses were performed to test the effect of verbal learning on word decoding, pseudoword decoding, and spelling followed by three hierarchical regression analysis to test the effect of verbal consolidation using the same outcome measures. In the first set of three hierarchical regression analyses, Group was entered in Step 1 (typically developing children = 0, children with dyslexia = 1), followed by the intercept and the slope of verbal learning (trial 1-5) in Step 2. In Step 3, finally, the corresponding interaction terms between Group and the predictor measures were included to test whether the effects of the predictors are stronger for one of both groups. In the second set of three hierarchical regression analyses Trial 5 and Verbal Consolidation were entered in Step 2.

The results (see Table 5.3) showed that Group was a significant predictor for all three outcome measures. Children with dyslexia read and spelled fewer words correctly (Step 1). Adding Step 2 to the model, resulted in a significant improvement for all three dependent variables. In Step 2, Group predicted again all outcome measures. Furthermore, Slope predicted Pseudoword Decoding and Intercept predicted Spelling: a less steep slope indicated higher pseudoword decoding scores and a higher intercept indicated higher spelling scores. Better verbal learning appears to be associated with lower pseudoword decoding scores. A higher immediate memory span appears to result in better spelling skills. Step 3 was a significant improvement of the model for spelling, but not for word and pseudoword decoding. Intercept, Slope, and the GroupxIntercept interaction were all significant predictors of Spelling. A steeper slope and a higher intercept were related to higher spelling scores. The effect of the Intercept is larger for one of both groups. To be more precise, as can be seen in Table 5.2, especially for typically developing children, a higher intercept is related to higher spelling scores. This shows that typically developing children seem to benefit more from their immediate memory span capacity in learning to spell compared to children with dyslexia.

In order to check if the found effects remain present when controlling for the severity of the reading and spelling problems (phonological awareness, rapid naming, and verbal working memory) and semantic abilities, these variables were added separately in Step 2 and 3 of each hierarchical regression analyses. The effect of Slope on Pseudoword decoding and the effect of Intercept on Spelling remained significant in Step 2 for each predictive variable. This indicated that despite the severity of the reading and spelling problems or the semantic abilities of children the higher verbal learning rates still predict lower scores in pseudoword decoding and that a higher immediate memory span still predicts higher spelling scores. Step 3 was no longer a significant improvement when adding these variables with the exception of Phonological awareness. When adding Phonological awareness, Step 3 became significant for Word decoding and Pseudoword decoding as well, showing significant effects of Intercept and the GroupxIntercept interaction on Word decoding and no significant effects of Intercept or Slope for Pseudoword decoding. The immediate memory span appeared to be associated with word reading and spelling performances for all children but even more so for typically developing children.

The results of the second set of three hierarchical regression analyses, regarding the effect of Trial 5 and Verbal consolidation (see Table 5.4) showed that group was a significant predictor for all three outcome measures (Step 1). Children with dyslexia read and spell fewer words correctly (Step 1). Step 2 and Step 3 were both not leading to a significant improvement of the model. As a result, Trial 5 and Verbal consolidation were both not significantly associated to reading and spelling after controlling for group.

Table 5.3 *The Role of Verbal Learning (e.g., Slope T1-T5) in Predicting Percentile Scores of Word Decoding, Pseudoword Decoding, and Spelling Pretest in Children with Dyslexia and Typically Developing Children, Controlled for Immediate Recall; and Cohen's* f^2.

		Word decoding pretest			**Pseudoword decoding pretest**			**Spelling pretest**		
		ΔR^2	f^2	*b*	ΔR^2	f^2	*b*	ΔR^2	f^2	*b*
Step 1		.453***	0.828		.519***	1.079		.554***	1.242	
	Group			-0.673***			-0.720***			-0.744***
Step 2		.056**	0.114		.048*	0.111		.031*	0.072	
	Group			-0.704***			-0.740***			-0.771***
	Intercept (T1-T5)			0.152			0.075			0.181*
	Slope (T1-T5)			-0.143			-0.185*			0.098
Step 3		.033	0.072		.015	0.036		.031*	0.081	
	Group			-0.055			-0.317			-0.165
	Intercept (T1-T5)			0.403**			0.241			0.421**
	Slope (T1-T5)			-0.082			-0.146			0.155*
	Group x Intercept (T1-T5)			-0.747*			-0.494			-0.714*
	Group x Slope (T1-T5)			-0.004			0.005			0.012
Total R^2_{adj}		.515			.557			.592*		

*$p < .05$. **$p < .01$ ***$p < .001$

Table 5.4 *The Role of Verbal Consolidation (e.g., trial 6) in Predicting Percentile Scores of Word Decoding, Pseudoword Decoding, and Spelling Pretest in Children with Dyslexia and Typically Developing Children, Controlled for Trial 5 (e.g., Intercept); and Cohen's f^2.*

		Word decoding pretest			Pseudoword decoding pretest			Spelling pretest		
		ΔR^2	f^2	b	ΔR^2	f^2	b	ΔR^2	f^2	b
Step 1		.453***	0.828		.519***	1.079		.554***	1.242	
	Group			-.673***			-0.720***			-0.744***
Step 2		.022	0.042		.019	0.041		.005	0.009	
	Group			-.611***			-0.662***			-0.718***
	Intercept (Trial 5)			-.171			-0.161			-0.093
	Verbal consolidation (Trial 6)			.020			0.019			0.082
Step 3		.018	0.036		.012	0.027		.008	0.018	
	Group			-1.193***			-1.141***			-0.893**
	Intercept (Trial 5)			-.284			-0.245			-0.241
	Verbal consolidation (Trial 6)			-.008			-0.016			0.210
	Group x Intercept (Trial 5)			.552			0.423			0.575
	Group x Verbal Consolidation (Trial 6)			.106			0.118			-0.364
Total R^2_{adj}		.463			.524			.540		

*$p < .05$. **$p < .01$ ***$p < .001$

Finally, it is important to mention that when we added phonological awareness, rapid automatized naming, verbal working memory or semantic abilities separately in Step 2, combined with a corresponding interaction term with group in Step 3, the effects of Trial 5 and Verbal consolidation did not change and remained non-significant.

Predicting response to intervention by verbal learning and consolidation

To answer the second part of the research question, regarding the impact of verbal learning and consolidation on the response to a phonics through spelling intervention, we again conducted six hierarchical regression analyses. The same procedure was followed as in predicting reading and spelling outcomes, but with different outcome measures (i.e., change per session for word decoding, pseudoword decoding, and spelling). The descriptive statistics of these outcome measures are presented in Table 5.5. In the analyses, pretest was included as a control variable.

The results (see Table 5.6 and 5.7) showed an effect of pretest on spelling, but no significant effects of verbal learning or consolidation on each of the outcome measures: Verbal learning and consolidation were not significantly linked to progress made in a phonics through spelling intervention.

Table 5.5 *Descriptive Statistics of Outcome Measures (Raw and Percentile) including Pre- and Posttest Scores as well as Change Scores and Change per Session.*

	Raw scores		Percentile scores	
	M	***SD***	***M***	***SD***
Word decoding				
Pretest	31.37	13.23	5.51	5.61
Posttest	41.04	14.74	9.70	11.20
Change scores	10.29	6.35	4.16	9.18
Change per session	0.38	0.23	0.15	0.34
Pseudoword decoding				
Pretest	20.61	10.05	8.39	8.09
Posttest	29.36	12.28	12.63	11.74
Change scores	9.59	9.05	4.36	8.92
Change per session	0.38	0.34	0.18	0.34
Spelling				
Pretest	49.96	28.30	7.74	14.50
Posttest	75.20	27.47	22.00	20.54
Change scores	27.39	11.44	8.71	17.36
Change per session	1.02	0.43	0.30	0.62

Note. The change scores are calculated by subtracting pre- from posttest scores. The change per session was calculated by deviding the change scores by the number of sessions the intervention lasted.

Table 5.6 *The Role of Verbal Learning (e.g., Slope T1-T5) in Predicting Change per Session of Word Decoding, Pseudoword Decoding, and Spelling Posttest in Children with Dyslexia, Controlled for Immediate Recall (e.g., Intercept T1-T5); and Cohen's f^2.*

		Change per session Word decoding			Change per session Pseudoword decoding			Change per session Spelling		
		ΔR^2	f^2	*b*	ΔR^2	f^2	*b*	ΔR^2	f^2	*b*
Step 1		.004	0.004		.001*	0.001		.031	0.032	
	Intercept (T1-T5)			0.049			-0.007			0.182
	Slope (T1-T5)			-0.027			-0.029			0.025
Step 2		.003	0.003		.012	0.012		.100*	0.516	
	Intercept (T1-T5)			0.046			<0.001			0.154
	Slope (T1-T5)			-0.021			-0.041			0.023
	Pretest			0.059			0.111			-0.317*
Total R^2_{adj}		-.055			-.061			-.075*		

*$p < .05$. **$p < .01$ ***$p < .001$

Table 5.7 *The Role of Verbal Consolidation (e.g., Trial 6) in Predicting Change per Session of Word Decoding, Pseudoword Decoding, and Spelling Posttest in Children with Dyslexia, Controlled for Trial 5 (e.g., Intercept); and Cohen's f^2.*

		Change per session Word decoding			Change per session Pseudoword decoding			Change per session Spelling		
		ΔR^2	f^2	*b*	ΔR^2	f^2	*b*	ΔR^2	f^2	*b*
Step 1		.001	0.001		.018	0.018		.087	0.095	
	Intercept (Trial 5)			0.009			-0.050			-0.139
	Verbal consolidation (Trial 6)			-0.36			0.158			0.354*
Step 2		.005	0.005		.013	0.013		.070	0.083	
	Intercept (Trial 5)			0.021			-0.067			-0.121
	Verbal consolidation (Trial 6)			-0.056			0.170			0.275
	Pretest			0.075			-0.116			-0.274
Total R^2_{adj}		-.056			-.041			.103		

*$p < .05$. **$p < .01$ ***$p < .001$

Conclusions and discussion

The present study investigated the extent to which verbal learning and consolidation predict reading and spelling levels and intervention outcomes in children with dyslexia. It was found that verbal learning was not related to reading, whereas it was related to spelling. Furthermore, verbal consolidation was found not to be related to reading nor spelling outcomes. Immediate memory span was related to word decoding when controlling for phonological awareness and it was positively related to spelling skills notwithstanding individual differences in the included cognitive factors, i.e., phonological awareness, rapid automatized naming, verbal working memory, and semantic abilities. The influence of the immediate memory span (number of words remembered in the first trial) on word decoding and spelling was found for all children, but it was even stronger for typically developing children. No compensatory role of verbal consolidation on spelling was found and both verbal learning and consolidation did not improve the response to a phonics through spelling intervention.

Prior to answering our research questions, we compared verbal learning and consolidation of children with dyslexia and their typically developing controls. Both groups performed equally on the immediate memory span. Children with dyslexia performed better in verbal learning but they remembered fewer words correctly over time compared to typically developing children. The verbal consolidation (words remembered at trial 6) was equal to typically developing children as children with dyslexia forgot more words over time between trial 5 and 6. In line with Kramer and colleagues (2000), both groups started by remembering the same number of words after the first learning trial (immediate memory span). In our study, children with dyslexia with a mean age of 8.65 years outperformed typically developing children in verbal learning during subsequent trials (trial 2-5), whereas Kramer and colleagues (2000) and Van Strien (1999) found typically developing children around 8- to 13-years-old to outperform children with dyslexia, and Kibby (2009) found no differences among children aged 9- to 13-years-old. Our finding that children with dyslexia declined more over time than typically developing children contrasts previous findings of similar declines in words remembered by both groups (e.g., Kibby, 2009). This could have multiple explanations. Firstly, it could be due to the fact that children with dyslexia in our study were slightly younger than in previous studies on list learning. Younger children practice word attack strategies like rehearsal of words excessively in school and especially children with dyslexia need these strategies as they have to update information constantly due to their problems in verbal working memory (Puolakanaho et al., 2007). Since children with dyslexia rely more on alternative pathways to learn to read (e.g., Kearns et al., 2019), verbal learning could be a source of compensation for younger children with dyslexia. Secondly, differences between studies could also indicate that differences between the two groups were rather small and therefore somewhat unstable. Thirdly, different learning strategies that were taught to children in their schools could explain the contradicting results.

Our first research question was whether verbal learning and consolidation predict reading and spelling in children with dyslexia compared to controls. We expected verbal learning and consolidation to be associated with reading and spelling outcomes, even more so in children with dyslexia (see Shaywitz et al., 2003). We found that verbal learning was not related to word reading, negatively related to pseudoword reading for children with dyslexia (this negative relation disappeared when controlling for phonological awareness), and positively related to spelling for both children with dyslexia and typically developing children. The effects were small to medium. Furthermore, no compensatory role of verbal consolidation was found.

The finding that verbal learning was negatively related to pseudoword reading could indicate that especially children with decoding problems train and use their verbal learning ability in an attempt to overcome these problems. Pseudoword reading is in the end a task that requires decoding skills mostly. The fact that this negative effect disappeared when we added phonological awareness to the model indicates that these decoding difficulties are phonologically based. The fact that verbal learning did not positively influence children's reading contrasts findings by Tijms (2004) but the positive influence of verbal learning on spelling levels among children with dyslexia is in line with findings by Tijms (2004). In addition, we showed the unique influence of verbal learning on spelling in both children with dyslexia and typically developing peers. Overall, the results fit the idea that better verbal learning may support the specificity and redundancy of the phonological lexicon and therefore stimulates literacy development (Shaywitz et al., 2003), but shows that the effect is limited to spelling only. This can be explained by the fact that spelling relies more on phonological representations compared to reading (Landerl & Wimmer, 2008). This outcome seems to be in line with the statistical-learning perspective on spelling development, which emphasises that the spelling of children reflects the input to which children have been exposed. This input is filtered through their learning mechanisms (Pollo et al., 2007). Children with stronger verbal learning abilities (their learning mechanism) can learn more from exposure to verbal input, which benefits their spelling.

The results showed no compensatory role of verbal consolidation. This is in line with the conclusion of Tijms (2004) who concluded that once a deeper semantic level is activated, no further problems appear to be encountered and consolidation of verbal information can take place as normal. It could also be due to the fact that verbal consolidation is closely related to automaticity (Manoach & Stickgold, 2009). Indeed, in our study we found rapid automatized naming to be associated to verbal consolidation for children with dyslexia. It is interesting to note that the above described results hold even when phonological awareness, rapid automatized naming, verbal working memory, and semantics abilities are included in the analysis. Only the addition of phonological awareness changed the results slightly, as the negative effect of verbal learning on pseudoword decoding was no longer significant and immediate memory span appeared to predict word reading.

The second research question was on the compensatory role of verbal learning and consolidation on response to intervention among children with dyslexia. While we expected that better verbal learning and consolidation would be positively related to responsiveness to intervention in children with dyslexia due to the enhancement of semantic and phonological representations, we did not find such a relation. After intervention, children are better able to integrate visual codes, phonological structures and the phonological retrieval, which enables them to read more fluently (Price & Friston, 1997; Simos et al., 2002). We may thus speculate that a tailored intervention diminishes the need for compensation for weaker spelling abilities via verbal learning.

This study adds to already existing literature by relating the dynamic process of verbal learning and consolidation to reading and spelling outcomes of children with and without dyslexia and study the impact on response to intervention as well. Some limitations should be acknowledged at this point along with directions of future research. Firstly, although we used a standardized Dutch test for verbal learning and consolidation, this measure of verbal learning contains high-frequency words and could, therefore, also be interpreted as the reactivation of word representations clustered together instead of learning new words and withhold this cluster instead of actual consolidation of new words. Therefore, it would be recommended to include tasks in which new words need to be learned as well (e.g., Elbro & Jensen, 2005). Second, we followed the children with dyslexia over time without incorporating a (randomized) control group to evaluate the effects of the intervention. The latter group could be included in future research in order to find out if within the typically developing group verbal learning and consolidation does not influence the change due to intervention as well. Third, we did not control for the socio-economic status or parental educational level. As prior studies showed that socio-economic status of parents predicts semantic growth (Romeo et al., 2018) this could have influenced our results. We recommend future research to include this variable in their analyses. Fourth, control measures can be refined by choosing a verbal working memory test with higher reliability and by adding a measure for morphological awareness, which is also addressed in the intervention. Fifth, differences in verbal learning could also be related to school related factors such as the learning strategies that children are being taught at different schools. Future research could include schoolbound learning strategies in order to rule out the possibility that this caused the found differences. Finally, this study included a rather small sample. Although we calculated a priori that we should have enough statistical power to conduct the analyses, effect sizes in terms of Cohen's f^2 in the regression analyses were relatively small. Therefore, the results should be interpreted with caution. Follow-up studies with larger sample sizes are recommended.

To conclude, the present findings showed that verbal learning is positively related to spelling skills for all children. Furthermore, the immediate memory span had a positive influence on spelling and word decoding of children with dyslexia and even more so for their typically developing peers. Moreover, both verbal learning and consolidation were not related to reading and spelling outcomes after a phonics through spelling intervention. The present findings also show that even before an intervention, verbal learning may facilitate spelling. Therefore, it can be recommended to monitor the verbal learning capacity of all children and not just children with dyslexia during their early spelling development. In a similar vein it is evidenced that, since younger children seem to rely on their phonological and semantic representations, spelling strategies like oral word repeating also may benefit spelling development.

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Appendixes

Appendix A. *Test Items from the 15 Words Test per Version.*

Version A (*n* = 88)	**Version B (*n* = 1)**	**Version C (*n* = 1)**
Gordijn [curtain]	Konijn [rabbit]	Soldaat [soldier]
Vogel [bird]	Veter [shoelace]	Gieter [watering can]
Potlood [pencil]	Papier [paper]	Ballon [ballon]
Bril [glasses]	Keuken [kitchen]	Pijp [pipe]
Winkel [shop]	Schip [ship]	Kleuter [toddler]
Spons [sponge]	Bal [ball]	Wind [wind]
Rivier [river]	Sprookje [fairy-tale]	Verf [paint]
Kleur [colour]	Fruit [fruit]	Toren [tower]
Fluit [flute]	Post [post]	Ketting [chain]
Plant [plant]	Gezicht [face]	Voet [foot]
Koffie [coffee]	Rommel [rubbish]	Schuur [shed/barn]
Stoel [chair]	Broek [trousers]	Poes [cat/puss]
Trommel [drum]	Tent [tent]	Spiegel [mirror]
Schoen [shoe]	Stoep [doorstep/sidewalk]	Roos [rose]
Lucht [air/sky]	Lamp [lamp]	Lip [lip]

Note. *n* expressed the total number of participants that made version A, B or C.

CHAPTER 6

General discussion

In order to become a proficient reader and speller, an efficient recurrent network of phonological, orthographic, and semantic representations needs to be built (Seidenberg & McClelland, 1989). According to the lexical quality hypothesis word representations can be characterized by two dimensions: specificity and redundancy. Lexical specificity refers to the degree to which words are specified phonologically, semantically, and orthographically. Redundancy refers to the extent that lexical representations can be retrieved from memory; lexically and/or sublexically (Perfetti, 2007). Children with dyslexia stay behind in their reading and spelling development and there seems to be consensus that multiple factors combine and/or interact to cause difficulties in learning to read and spell (Catts et al., 2017; McGrath et al, 2020; O'Brien & Yeatman, 2021; Pennington, 2006; Protopapas, 2019; Van Bergen, 2014b). For most children with dyslexia, the phonological deficit underlies reading and spelling problems (Lyon et al., 2003; Snowling & Hulme, 2021) by causing inaccurate and underspecified phonological pathways (Conrad, 2008; Nation & Snowling, 2004). However, not only weaknesses but also strengths may be related to reading and spelling outcomes (Catts & Petscher, 2020) and are important to build on when compensating weaknesses (Protopapas, 2019). When phonological representations are weak, other parts of the triangular framework (Seidenberg & McClelland, 1989) could become more important and relative strengths in semantic and orthographic representations could be sources of compensation for these weaker phonological representations. Although prior research mentioned the possible compensatory role of semantic abilities on reading (e.g., Duff et al., 2015; Gijsel, 2007; Haft et al., 2016; Hulme et al., 2010; Torppa et al., 2010) and spelling (e.g., Ouellette, 2010) and the possible compensatory role of stimulating orthographic representations on learning to spell and read (e.g., Conrad, 2008), these factors received scant attention in research so far among children with the actual diagnosis of dyslexia. In contrast with previous research, in the present thesis, semantic abilities are defined as much broader than just vocabulary. It is generally known that semantic abilities involve more than vocabulary alone, especially because the specificity and redundancy of the lexical representations can be considered important (Perfetti & Hart, 2002). Therefore, the aim of this dissertation was to study these two possible sources of compensation for phonological shortcomings and thereby the reading and spelling problems of children with dyslexia in the Netherlands. The first research question was to what extent deep and broad semantic abilities compensate for a phonological deficit in reading and spelling development in children with dyslexia. The second research question was to what extent a phonics through spelling intervention could benefit reading and spelling development of children with dyslexia with varying cognitive and linguistic profiles.

Compensatory role of semantic abilities

Regarding the first research question, results of the current dissertation showed that within a group of children with dyslexia, semantic abilities are indirectly related to reading efficiency and directly to the number of spelling errors. It was found in chapter 2 that within a group of children with dyslexia, semantic abilities were related to both word decoding efficiency and pseudoword decoding efficiency indirectly via phonological awareness and rapid naming. Strong semantic abilities seem to provide children with dyslexia with a boost to strengthen their phonological skills and rapid naming skills, which in turn facilitate their reading abilities. Furthermore, in Chapter 4, better verbal working memory was found to be related to fewer morphological errors and on top of that higher scores on semantic abilities were related to fewer phonological, morphological and orthographic spelling errors among children with dyslexia. Children with better verbal working memory made fewer morphological errors and children with stronger semantic abilities are thus relatively better in spelling accuracy than children with less well-developed semantic abilities. In addition to the possible impact of semantic abilities, the relation between verbal learning and reading and spelling outcomes was studied in chapter 5. Verbal learning can be seen as a dynamic assessment of semantic abilities. Results showed that verbal learning was not related to reading but it was related to spelling skills. Children that were able to learn more verbally presented words due to repetition performed better on spelling. Verbal consolidation was not related to reading, nor spelling. The ability to maintain verbally presented words in memory showed no impact on reading and spelling.

The aforementioned results indicate that lexical specificity (in this case semantic specificity) may help children with dyslexia to improve their phonological awareness (see Metsala, 1999) and to become better at lexical retrieval (see Wolf et al., 2016), which, in turn, may have a positive impact on decoding efficiency. As described in the lexical restructuring hypothesis, well-developed semantic representations also stimulate growth of phonological representations (Metsala & Walley, 1998). This is in line with the suggestions that semantic abilities help to circumvent phonological decoding deficits as mentioned by Haft et al. (2016) and is in line with findings by Van Viersen et al (2018) who found that (early) semantic abilities are at the base of preliteracy and word decoding skills. Prior research also found the reverse effect in which deficits in the semantic development are associated with later reading development as well (Van Viersen et al. (2017). The absence of a direct relation between semantic abilities and word decoding efficiency is neither in line with previous research (Van Bergen et al., 2014a) nor with the lexical quality hypothesis (Perfetti & Hart, 2002). Finding indirect and not direct relations of semantic abilities on reading efficiency could be due to the fact that the children with dyslexia in the current thesis are in the early stages of their reading development with a primary focus on phonological recoding, which is heavily influenced by phonological awareness and rapid naming. Besides the indirect relation of semantic abilities on reading, we found a direct relation of semantic abilities on both phonological and orthographic processes in spelling. It turns out that the phonology-orthography connection, that is necessary for spelling, may benefit from a strong base of semantic representations as described in the triangular framework (Seidenberg & McClelland, 1989). These results are in line with other studies that found beneficial effects of semantic abilities on learning to spell (see Ouellette, 2010; Ouellette & Fraser, 2009). The beneficial effect of semantic abilities is in line with the lexical restructuring hypothesis and the stimulating effect of well-developed semantic representations on phonological representations.

When we approach semantic abilities in a more dynamic assessment via verbal learning, similar outcomes were evidenced. We did not find relationships between verbal learning and reading but did find a direct positive relationships between verbal learning and spelling. The finding that verbal learning was not related to reading contrasts findings by Tijms (2004) but the positive influence of verbal learning on spelling levels among children with dyslexia is in line with findings by Tijms (2004) and also to results from chapter 4. In addition to the findings of Tijms (2004), we found that the influence of verbal learning on spelling is not unique for children with dyslexia, but also applies to typically developing children. Overall, the results fit the idea that better verbal learning may support the specificity and redundancy of the phonological lexicon and therefore stimulates literacy development (Shaywitz et al., 2003), but shows that the effect is limited to spelling only. This can be explained by the fact that spelling relies more on phonological representations compared to reading (Landerl & Wimmer, 2008). The results showed no compensatory role of verbal consolidation. This could be because verbal consolidation is closely related to automaticity (Manoach & Stickgold, 2009). Indeed, we found rapid automatized naming to be associated with verbal consolidation for children with dyslexia.

These findings show the relevance of a broad and deep semantic network in the reading and spelling development of children with dyslexia. In addition, it was shown that a dynamic assessment of verbal learning could be a useful instrument to find out more about compensatory mechanism for spelling development of children with and without dyslexia. Semantic abilities and the ability to learn verbal information could thus be seen as strengths that could help all children, but especially children with dyslexia to perform relatively better in reading and spelling. This is in line with the Multifactorial causal model of dyslexia (e.g., Catts et al., 2017) indicating that both weaknesses and strengths may predict reading and spelling levels (Astle & Fletcher-Martin, 2020). Although the found effects were small (and in one case indirect), these results underline the division of labour between interacting phonological and semantic pathways as described in the triangular reading and spelling framework (Seidenberg & McClelland, 1989). Variation in both phonological and semantic processing seems to be related to individual differences in literacy development, whereas children with dyslexia rely on contributions from the semantic pathway because of their poorly developed phonological pathway (Conrad, 2008; Nation & Snowling, 2004). With regard to our first research question we can conclude that semantic abilities indeed can be seen as a possibly compensatory factor for reading and spelling, but it should be noted that children with dyslexia remain weak in reading and spelling.

Compensatory phonics through spelling intervention

Regarding the second research question, results of the present dissertation indicate that stimulating the orthographic representations with a phonics through spelling intervention is beneficial for children with dyslexia. In chapter 3, we found that a phonics through spelling intervention benefits word and pseudoword reading efficiency and word spelling in children with dyslexia. Children with dyslexia gained more on all three measures compared to norm-based peers. In addition, chapter 4 showed that children with dyslexia make fewer phonological, morphological, and orthographic errors throughout the phonics through spelling intervention, with the biggest reduction of orthographic spelling (morphological and orthographic errors). A phonics through spelling intervention thus facilitates both phonological and orthographic processes of spelling. In order to gain more insight in the effects of relative strengths and weaknesses of cognitive abilities of children with dyslexia, we also related cognitive precursors to the response to intervention. In chapter 3, it was found that phonological awareness, rapid automatized naming, and verbal working memory did not influence children's reading and spelling progress in the phonics through spelling intervention. Semantic representations as a cognitive factor, however, seemed to influence the spelling results, as was found in chapter 4. To be more specific, children with dyslexia with well-developed semantic abilities representations made fewer phonological, morphological, and orthographic errors throughout the intervention compared to children with dyslexia with less developed semantic representations. This means that children with broad and deep semantic networks are able to benefit more from the phonics through spelling intervention when focusing on spelling errors. Finally, Chapter 5 showed that verbal learning and consolidation are both not related to the progress children made during the phonics through spelling intervention. The learning curve of verbally presented words and the ability to maintain these words in memory for a longer period was not related to reading and spelling outcomes during the phonics through spelling intervention.

A unique feature of the phonics through spelling intervention in the current thesis is the relatively large amount of time spent on spelling in order to strengthen the bi-directional relationship between phonology and orthography. The intervention turned out to be beneficial for reading and spelling for children with dyslexia, which is in line with previous findings on the effectiveness of phonics interventions (e.g., Galuschka et al., 2014) and programs emphasising both reading and spelling among typically developing children (Conrad, 2008; Ehri & Wilce, 1987, Ellis & Cataldo, 1990). The reduction of all of the examined categories of spelling errors is in line with improvements that were found after interventions focusing on phonics, morphological, or orthographic instruction (Galuschka et al., 2020) and illustrates that phonics through spelling interventions may have a positive effect on both phonological and orthographic aspects of spelling development. The positive outcomes of this phonics through spelling intervention should be evaluated against positive effects on word spelling and rather inconsistent findings of reading-focused interventions, focusing on pseudoword and word reading (Kirk & Gillon, 2009; Lovett et al., 1989, 1990; Tijms, 2011; Tilanus et al., 2016). In contrast, our results showed that a phonics through spelling intervention is beneficial for spelling as well as for both pseudoword and word reading. It is evidenced that a combined emphasis on reading and spelling instruction helps building strong bi-directional relations between phonology and orthography and thus benefits reading and spelling development, probably because the phonology-orthography relation is stimulated to a bigger extent as spelling is more difficult than reading (Bosman & Van Orden, 1997). Although children in this study significantly improved, and many of them were no longer among the weakest 10% in word reading and spelling, it is important to note that after the intervention, most children remained weak readers and spellers compared to typically developing controls with substantial inter-individual variation in reading and spelling levels.

Our results provide more insight in the influence of relative strengths and weaknesses of children on response to intervention. Phonological abilities (i.e., phonological awareness, rapid automatized naming, and verbal working memory) were not related to response to phonics through spelling intervention of children with dyslexia. This is in line with findings from other studies demonstrating the robustness of reading interventions that improve decoding accuracy notwithstanding the levels of phonological awareness (Felton, 1993; Tijms, 2011), rapid automatized naming (Heikkilä, 2015), or by improving both decoding accuracy and fluency notwithstanding their levels of phonological awareness, rapid automatized naming (Aravena et al., 2016; Tilanus et al., 2016), or verbal working memory (Tilanus et al., 2016). It turns out that, although most of these phonological abilities influence word and pseudoword reading and spelling before the intervention, there was no additional influence on response to intervention. This could indicate that the intervention is so well tailored to the child's needs that the phonological differences could not influence the impact of the intervention. However, we did find a relationship between phonological awareness (a prime indicator of the phonological deficit, see Shaywitz et al., 2003) and posttest scores. It could be the case that the phonics through spelling intervention helped children with dyslexia to overcome their reading and spelling problems up to the level of their genetically disposed phonological deficit. This could indicate that children with dyslexia have room for improvement despite the severity of their phonological deficit, but after the intervention, children with the weakest phonological abilities (i.e., the most severe phonological deficit) remain the weakest readers and spellers. The only factor that was found to influence the response to intervention of spelling (more specifically the decline in spelling errors) was semantic abilities. Earlier studies showed promising effects of integrating semantic abilities in spelling interventions (Ouellette, 2010; Ouellette & Fraser, 2009) and this study adds to this literature by showing the positive relationship between pre-existing semantic representations and spelling development during a phonics through spelling intervention. From a lexical quality perspective, this can be interpreted as a way of compensation or facilitation of the growth of the phonology-orthography connection, that is necessary for spelling as described in the triangular framework (Seidenberg & McClelland, 1989). A more dynamic approach towards semantic abilities by means of verbal learning and consolidation did not influence the response to intervention of children with dyslexia. A possible relation of verbal learning and spelling was found before the intervention but did not continue to influence the spelling development throughout the intervention. We may speculate that a tailored intervention diminishes the need for compensation for weaker spelling abilities via verbal learning because children are able to integrate visual codes, phonological structures and to retrieve this phonological information which enables them to read and spell more fluently (Price & Friston 1997; Simos et al., 2002).

The positive effects of a phonics through spelling intervention that were found, support the hypothesis that combining spelling and reading in one intervention helps to build strong bi-directional relations between phonology and orthography and thereby benefits reading and spelling development. In line with other studies including spelling in phonics interventions (see Kirk & Gillon, 2009; Tijms et al., 2011), we showed that phonics through spelling interventions are relatively successful in helping children with dyslexia in strengthening the connections between phonological and orthographic representations and thereby improved both reading and spelling results. As mentioned before, reading and spelling are reversed processes and combining reading and spelling during instruction and practice could be beneficial for both learning to read and learning to spell (e.g., Conrad, 2008) as better orthographic representations (e.g., spelling) could facilitate phonological growth. Although promising results were found, this study also showed the persistence of spelling but even more so of reading problems after an intervention among children with dyslexia. Individual differences in strengths and weaknesses in phonological abilities, verbal learning, and verbal consolidation did not influence the progress during the phonics through spelling intervention but semantic abilities did (at least for spelling). This highlights the importance of this domain in the triangular framework. With regard to our second research question, we can conclude that stimulating orthographic representations with a phonics through spelling intervention benefits reading and spelling development of children with dyslexia. Semantic abilities could be seen as a compensatory factor to optimize the response to intervention outcomes for spelling.

Compensating reading and spelling in children with dyslexia revisited

The findings in this dissertation indicate that relative strengths and weaknesses in semantic abilities and stimulating orthographic representations influence the reading and spelling development of children with dyslexia. Results of our studies revealed that semantic abilities and the stimulation of orthographic representations in their own way could be seen as compensatory factors for the poorly developed phonological pathway of children with dyslexia (Conrad, 2008; Nation & Snowling, 2004). The two compensatory factors under consideration were derived from the triangular framework (Seidenberg & McClelland, 1989). This framework consists of phonological, orthographic, and semantic representations. The bi-directional relationship between these factors forms an efficient and recurrent network that is necessary to efficiently read and spell. In alphabetical languages the bi-directional relation between phonological and orthographic representations seems to be the most prominent factor facilitating proficient reading and spelling (see Bosman & Van Orden, 1997). However, children with dyslexia have underspecified and inaccurate phonological and orthographic representations (Conrad, 2008), mostly due to the underlying phonological deficit (Melby-Lervåg et al., 2012) and thereby develop reading and spelling problems. These children may need to activate compensatory pathways to learn to read and spell (Hoeft et al., 2011; Kearns et al., 2019), as is also indicated by brain studies that showed that different parts of the brain were activated during reading among children with dyslexia (Paulesu et al., 2001; Shaywitz et al., 2003). Our first hypothesis was that well-developed semantic representations could facilitate such an alternative route. Our results indicate that children with dyslexia are able to compensate for their phonological shortcomings by using well-developed semantic representations to facilitate reading indirectly via phonological awareness and rapid automatized naming and by facilitating spelling directly. We also found that verbal learning, which can be considered a more dynamic approach towards semantic abilities, was related to spelling as well, indicating that not only the semantic knowledge present is of importance but also the ability to learn new semantic information. Children with dyslexia may thus use their semantic abilities in line with the lexical quality hypothesis (Perfetti, 2007) and lexical restructuring hypothesis (e.g., Metsala & Walley, 1998) to boost their reading via the phonological pathway and spelling directly. This confirmed the suggestions that semantic abilities help to circumvent phonological decoding deficits as mentioned by Haft et al. (2016)

Besides the compensatory effects of semantic abilities, we also hypothesized that a phonics through spelling intervention could help children with dyslexia to strengthen their phonology-orthography bi-directional connection by stimulating reading and spelling to the same extent in a phonics through spelling intervention. Most phonics interventions so far focused mainly on reading and thus on strengthening the orthography-phonology connection (see Galuschka et al., 2014). Since spelling is more difficult than reading (Bosman & Van Orden, 1997), more time on instruction and practice of spelling development seems necessary. This time can be used to form the more detailed and specific orthographic representations that are necessary to learn to spell. According to the lexical restructuring hypothesis this could benefit phonological development as well. So, by combining reading and spelling in a phonics through spelling intervention both orthography-phonology and phonology-orthography relations grow stronger. The addition of a great deal of spelling therefore is important to arrive at better-defined bi-directional orthography-phonology connections. Our results showed that such an intervention for children with dyslexia indeed has a significant impact on word reading, pseudoword reading, and spelling development. Additional analyses regarding the response to intervention revealed that the results of the intervention were robust to individual differences in the phonological deficit, verbal learning, and verbal consolidation. We found that spelling results were influenced by individual differences in semantic abilities in the sense that more defined semantic abilities were related to a better response to the phonics through spelling intervention.

Our findings contribute to knowledge about the complex interplay between multiple cognitive factors in defining difficulties in learning to read and spell as described in the Multifactorial causal model of dyslexia (Catts et al., 2017; McGrath et al, 2020; O'Brien & Yeatman, 2021; Pennington, 2006; Protopapas, 2019; Van Bergen, 2014b). We contribute to the existing literature by pointing out that a strength in semantic representations can foster children's reading and spelling development in a rather transparent language such as the Dutch language, and may possibly compensate for weak bi-directional phonology-orthography relations. Children with dyslexia benefit from stronger semantic-phonology relations when learning to read and spell. In addition, interventions that focus on both reading and spelling stimulate the bi-directional relationship between phonology and orthography by building more specific orthographic representations. Although these compensatory sources matter for children with dyslexia, the effects are rather small. Consequently, these strengths did not prevent them from becoming weak readers and spellers and did not lead to proficient reading and spelling after a phonics through spelling intervention. However, in the complex interplay of multiple cognitive factors these two factors give children with dyslexia an additional boost, which may have prevented them from even weaker performances in reading and spelling.

Limitations and future perspectives

This dissertation showed two possible compensatory sources for children with dyslexia, but some limitations should be acknowledged at this point along with recommendations for future research. First of all, the data used to answer the first research question were cross-sectional. In addition, the participants included in the dissertation showed large variation in age, and, with regard to the reported effect of semantic abilities on reading and spelling errors in chapter 2, 3, and 4, control groups of typically developing peers missed. Causal conclusions should thus be regarded with caution, and larger samples with a more homogeneous age-group of children with dyslexia compared to reading-matched and age-matched control groups are needed to replicate the current findings. As a case in point, Van Viersen and colleagues (2017) studied the role of semantic abilities and family risk for dyslexia in two developmental pathways towards reading comprehension, through word reading and through oral language abilities. They followed children with a risk for dyslexia and controls between 4 and 12 years old and our finding that semantic abilities are at the base of preliteracy skills and thereby word decoding replicates their conclusion.

Second, we found that a phonics through spelling intervention is beneficial for both reading and spelling. However, control conditions and data on the effectiveness of elements of the intervention were not part of this dissertation and, therefore, it remains unknown whether the intervention is more successful than others and which elements are particularly effective. In line with Galuschka and colleagues (2014), we found in this dissertation that a phonics intervention is successful, but future research could compare different forms of phonics interventions (including a phonics through spelling intervention). This could focus on the intervention as a whole and different elements of the interventions to gather knowledge about what works best for children with reading and spelling problems. Since the phonics through spelling intervention most difference from other phonics interventions in the amount of spelling instruction and exercise, it would be interesting to compare the results of the intervention to interventions that included reading solely, spelling solely and both in different proportions. Based on the fact that spelling is more difficult than reading (Bosman & Van Orden, 1997) and the fact that knowledge of spelling transfers to reading and vice versa (Conrad, 2008) we expect that a combined intervention is more effective and that integrating spelling to a bigger extent is the best way to facilitate literacy development.

Third, although the present dissertation did address individual differences in cognition, the literate home environment of children was not taken into account. The home literacy environment could have influenced reading and spelling development in general but also during the intervention as home exercises that need tutoring by parents were part of the intervention. The home literacy environment can provide children and their parents with certain skills, abilities, dispositions, and resources that provide the opportunity to learn and is related to reading-related abilities (e.g., Burgess et al., 2002) and semantic development (Mol et al., 2008). Therefore, we recommend future research to include home literacy environment as a control variable in response to intervention studies to find out what the effect of home literacy environment is on reading and spelling in general but also on response to intervention. As Sénéchal and Young (2008) found that parental involvement can have positive effects on the child's reading acquisition and that training is a very important aspect, we expect that without parental training the effects of the home literacy environment will be closely related to socio-economic status of the parents.

Clinical implications

Implications for clinical and educational practice emerge from the findings in this dissertation. First, our findings emphasise the positive impact of a deep and broad semantic network for reading and spelling. This highlights the need to include measures of (deep and broad) semantic abilities in the assessment of children with dyslexia. Well-developed semantic representations could be seen as a protective factor, whereas poor developed semantic representations could be seen as a risk factor for further literacy development. Including these additional measures to gain insight in the compensatory sources of children with dyslexia is in line with the idea that learning to read and spell is caused by a combination and/or interaction between multiple factors (e.g., Catts et al., 2007) and the idea that both strengths and weaknesses are necessary in order to tailor the intervention to the child's needs. In January 2022 the renewed Dutch protocol for assessment and intervention (Tijms et al., 2021) was implemented. The new protocol concludes that focusing on a limited set of typical (neuro)cognitive processes, as was the case in the protocol by Blomert (2006), does not do justice to the heterogeneity of dyslexia. Therefore, this renewed protocol gives educational psychologists the opportunity to include measures of both relative strengths and weaknesses and use the outcomes from these measures to tailor the intervention to the child's needs. When extensive semantic representations are present these could be used to facilitate the spelling development, which could indirectly facilitate reading development.

Second, we recommend educational psychologists to consider a phonics through spelling intervention for children with dyslexia. Although more research is necessary to compare this specific phonics through spelling intervention to other interventions and to find out what elements of the intervention have the biggest impact, our results showed that such an intervention benefits word reading, pseudoword reading and spelling development of children with dyslexia notwithstanding phonological abilities. A part of the phonics through spelling intervention is described in further detail in Ruijssenaars and colleagues (2009; 2010).

The need to strengthen the depth and breadth of semantic representations not only applies to clinical practice but to educational practice as well. To be more specific, given the fact that building a semantic network with deep word knowledge takes time as it develops slowly (Bloom, 2002; Bolger et al., 2008), stimulation of semantic representations should start early in the child's development to be helpful in early literacy development. This early start is important because knowledge builds upon prior knowledge (Stanovich, 1986). Therefore, teaching methods should include opportunities to let children learn new words, and link these words to previously learned concepts (Boroysky, et al., 2016). For example, prior research points at the importance of explicit instruction of meaning of words and the link with other words (see Bolger et al., 2008; Durso & Coggings, 1991) and the importance of guided play in stimulating vocabulary development (see Leseman & Veen, 2016). Guided play is a teaching method in which the teacher stimulates verbalization, symbolization, role-taking, planning, and cooperation and monitors play and metacommunication (these operationalization of guided play is derived from program Tools of the Mind by Barnett et al., 2008). Studies in the Netherlands showed that pre-school and school programs can be effective in expanding the vocabulary of children, especially for children with a non-Western background and that guided play is an effective element (see Leseman & Veen, 2016). In addition, an example of activities in which the broadness and depth of words can be stimulated with explicit instruction, thematic relation and repetition, and change of context is a combination of book reading and guided play. Shared book reading introduces new concepts and a narrative to play during which children actively process the meaning of words and its relations in their own context (Hadley et al., 2018).

Second, we recommend teachers to include elements of the phonics through spelling intervention in their lessons as we found that such an intervention benefits both reading and spelling abilities of children with dyslexia. The general principle underlying the intervention is the principle of mastery learning (as described in Bloom, 1971); a clear curriculum with explicit learning goals subdivided in short periods with explicit instruction, formative assessment in order to give feedback, and lessons adjusted to the child's needs in order to arrive at the next learning goal. To build such a curriculum, a so-called task analysis for reading and spelling needs to be carried out by the teacher (the

Dutch task analysis can be found in Struiksma et al., 2004 or parts of it in Ruijssenaars et al., 2010). These task analyses provide clear goals to start designing lessons. The phonics through spelling intervention lessons that were carried out in the present dissertation were build according to the principles of direct instruction (see Hollingsworth & Ybarra 2017; 2020). Prior research showed that this instruction method is very effective in stimulating both reading (see National Institute for Literacy, 2007) and spelling abilities (Cordewener et al., 2015). Lessons that are based on direct instruction include (among other things) explicit teaching of declarative, procedural, and metacognitive knowledge, next to the use of modelling and scaffolding techniques on the part of the teacher (see e.g., Rosenshine, 2010).

Another element from the phonics through spelling intervention that was carried out in the present dissertation that could be included in the classroom is the principle to work from isolation to generalization of knowledge and skills in order to prevent cognitive overload (Paas et al., 2004). To be more specific, learning to read and spell could start with the isolation of new knowledge and skills, followed by integrating this with prior knowledge (e.g., after learning to read short and long vowels separately, children learn to read long and short vowel together). Thereafter, this acquired knowledge is being transferred to new situations (e.g., after learning to write words with ‘c’ a child needs to write a story for school and needs to learn to pay attention to the ‘c’ as well) that can be monitored by the teacher by asking questions to the child to check whether he or she has understood the material and by adjusting the lessons to the child’s individual needs.

This dissertation showed that, in the complex interplay between multiple cognitive factors that are related to reading and spelling, semantic representations and, orthographic stimulation can give children with dyslexia an extra boost, which helps them to be perform slightly better in reading and spelling compared to children with dyslexia without these resources. These promising findings show that there are ways in which we can facilitate children with dyslexia to perform at their best.

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APPENDIX

Nederlandse Samenvatting (Dutch Summary)

Goed kunnen lezen en spellen is essentieel voor schoolsucces, toegang krijgen tot de arbeidsmarkt en om te kunnen communiceren in de hedendaagse (digitale) samenleving. Goed leren lezen en spellen vraagt om een efficiënt georganiseerd en nauw met elkaar verbonden netwerk van kennis bestaande uit; semantiek (betekenis), fonologie (klanken) en orthografie (letters). Hoe specifieker en overdadiger dit netwerk is, des te makkelijker het lezen en spellen zal gaan. Vooral de relatie tussen fonologie en orthografie (van klank naar letter) en de relatie tussen orthografie en fonologie (van letter naar klank) zijn voor lezen en spellen van essentieel belang. Lezen en spellen versterken elkaar, omdat bij beide processen de relatie tussen fonologie en orthografie, elk vanuit een andere richting, versterkt wordt. Kinderen met dyslexie blijven echter achter in hun ontwikkeling met betrekking tot lezen en spellen. Onderzoekers lijken het erover eens te zijn dat hiervoor geen eenduidige oorzaak aan te wijzen is, maar dat de achterstand veroorzaakt wordt door meerdere factoren die in combinatie en in interactie met elkaar zorgen voor achterstanden in het lezen en spellen. Voor de meeste kinderen met dyslexie blijken fonologische tekorten een belangrijke oorzaak te vormen voor hun lees- en spellingproblemen. Naast het kijken naar tekorten is het ook zinvol om in kaart te brengen welke sterke punten kinderen met dyslexie kunnen benutten; in welke mate kunnen kinderen hun tekorten compenseren met hun sterke punten? Zouden andere onderdelen van het netwerk van kennis wellicht de veelvoorkomende tekorten in de fonologische kennis kunnen compenseren? Hoewel eerder onderzoek heeft laten zien dat zowel semantische als orthografische kennis het lezen en spellen beïnvloedt, hebben deze mogelijk compenserende factoren in onderzoek onder kinderen met dyslexie weinig aandacht gekregen. In het geval van semantiek wordt bovendien vooral gekeken naar de omvang van het netwerk (de kwantiteit) en minder naar de diepte van de kennis die aanwezig is in het netwerk (de kwaliteit). Wat betreft de rol van de behandeling, valt op dat spelling in de meeste behandeling slechts een klein aandeel heeft, terwijl spelling van zichzelf moeilijker is dan lezen. Daarom is in het huidige proefschrift onderzocht in welke mate de semantische kennis die een kind heeft opgedaan en de orthografische kennis die een kind opdoet in een geïntegreerde lees- en spellingbehandeling, de fonologische tekorten van kinderen met dyslexie in Nederland kan compenseren. Er werden voor dit onderzoek twee onderzoeksvragen geformuleerd:

1. In hoeverre compenseert de semantische kennis de lees- en spellingresultaten van kinderen met dyslexie?
2. In hoeverre wordt de lees- en spellingontwikkeling van kinderen met dyslexie met verschillende cognitieve profielen gestimuleerd door een geïntegreerde lees- en spellingbehandeling?

De rol van semantiek

In hoofdstuk 2 en 4 worden de analyses beschreven waarmee de rol van semantiek werd onderzocht. In beide hoofdstukken werd semantiek -in combinatie met andere cognitieve variabelen- gerelateerd aan de lees- en/of spellingontwikkeling. Om niet alleen de omvang maar ook de diepte van de semantische kennis mee te nemen, werd gebruik gemaakt van een samengestelde maat bestaande uit woordenschat, verbale productie en verbaal begrip. Lezen werd in kaart gebracht middels een taak voor het lezen van bestaande woorden en een taak voor het lezen van pseudowoorden. Spelling werd in kaart gebracht aan de hand van een woorddictee. In hoofdstuk 5 onderzochten we in welke mate het verbaal leervermogen van kinderen -verbaal leren en consolideren- het lezen en spellen van kinderen met dyslexie zou kunnen voorspellen. De kinderen kregen vijf keer 15 woorden te horen en na iedere keer werd hen gevraagd zoveel mogelijk van deze woorden te noemen (verbaal leren). Na een interval van 30 minuten werd hen (zonder herhaald aanbod) gevraagd welke woorden zij nog onthouden hadden (consolidation).

In hoofdstuk 2 werd onderzocht of voor kinderen met dyslexie (n = 55) semantiek direct of indirect via fonologische vaardigheden (fonologisch bewustzijn, benoemsnelheid en verbaal werkgeheugen) aan het lezen gerelateerd is. De resultaten in dit hoofdstuk laten zien dat semantiek indirect via fonologisch bewustzijn en benoemsnelheid het vloeiend lezen van kinderen met dyslexie lijkt te voorspellen, zowel voor bestaande woorden als voor pseudowoorden.

In hoofdstuk 4 werd allereerst onderzocht of kinderen met dyslexie dezelfde spelfouten maken als typisch ontwikkelende kinderen en of semantiek gerelateerd is aan het aantal spelfouten dat kinderen met dyslexie (n = 52) maken. Er werd in dit onderzoek onderscheid gemaakt tussen fonologische spelling (fonologische fouten) en orthografische spelling (morfologische en orthografische fouten). Fonologische fouten zijn fouten in de klanktekenkoppeling die de uitspraak veranderen (een verkeerd teken wordt bij een klank gekozen, bijvoorbeeld k*i*m ipv k*a*m). Morfologische fouten zijn fouten door het niet (correct) toepassen van regels, maar waarbij de uitspraak van het woord niet verandert (bijvoorbeeld r*aa*men ipv r*a*men). Orthografische fouten zijn fouten door het schrijven van een onjuiste letter of onjuiste letters waar geen regel voor is en die de uitspraak van het woord niet veranderen (bijvoorbeeld g*ij*t ipv g*ei*t). Naast semantiek werden ook de fonologische vaardigheden (fonologisch bewustzijn, benoemsnelheid en verbaal werkgeheugen) meegenomen als controlematen. Uit het onderzoek kwam naar voren dat kinderen met dyslexie dezelfde fouten maken als kinderen zonder dyslexie. Beide groepen maken verhoudingsgewijs de meeste morfologische fouten, gevolgd door orthografische fouten en tenslotte fonologische fouten. De verschillen tussen beide groepen zijn het grootst voor de fonologische fouten. Verbaal werkgeheugen bleek gerelateerd aan het aantal morfologische fouten. Semantiek bleek gerelateerd aan alle type fouten; kinderen met een breder en dieper semantisch netwerk maakten minder fonologische, morfologische en orthografische fouten. Kinderen met een beter verbaal werkgeheugen maakten dus minder fouten met spellingregels en kinderen met een breder en dieper semantisch netwerk waren dus beter met klankzuivere woorden en woorden die gewoon gekend moeten zijn in vergelijking met kinderen met een minder goed ontwikkeld semantisch netwerk.

Bovenstaande uitkomsten laten zien dat hoe specifieker en overdadiger het semantisch netwerk is, des te beter kinderen zijn in lezen en spellen. In het geval van lezen gaat het daarbij om een indirecte relatie, dat wil zeggen dat het specifiekere en overdadigere semantische netwerk het fonologische netwerk uitdaagt of prikkelt om ook te gaan groeien. Het feit dat we geen directe relatie van semantiek op lezen vonden, sluit niet aan bij eerder onderzoek. Het zou kunnen zijn dat het voor kinderen met dyslexie -die nog aan het begin van hun leesontwikkeling staan- vooral gaat over het verklanken van woorden op basis van fonologie. Dat verklanken leunt vooral op fonologisch bewustzijn en benoemsnelheid. Voor spelling werd wel een directe relatie gevonden tussen semantiek en het aantal gemaakte fonologische, morfologische en orthografische spelfouten. Dit sluit wel aan bij eerder onderzoek en laat eveneens zien dat specifiekere en overdadige semantische netwerken tekorten in de fonologische netwerken gedeeltelijk kunnen compenseren.

Naast onderzoek naar het reeds aanwezige en meer statische semantische netwerk werd de rol van semantiek ook vanuit een meer dynamische maat onderzocht; het verbaal leervermogen (meer hierover in hoofdstuk 5). Het verbaal leren (de groei in het kort onthouden van een lijst auditief aangeboden items) en consolideren (het langdurig vasthouden van deze auditief aangeboden items) van kinderen met dyslexie (*n* = 52) en typisch ontwikkelde kinderen (*n* = 36) werd gemeten en gerelateerd aan hun lees- en spellingresultaten. De fonologische maten en de statische maat voor semantiek werden in dit onderzoek meegenomen als controlevariabelen. Uit het onderzoek kwam naar voren dat zowel voor kinderen met als zonder dyslexie verbaal leren niet gerelateerd is aan lezen, maar wel aan spelling. Het opslaan van deze (auditief aangeboden) verbale informatie lijkt dus bij te dragen aan de specificiteit en overdadigheid van het fonologisch netwerk en draagt daarmee weer bij aan de spellingontwikkeling. Uit onderzoek is bekend dat kinderen voor spelling meer afhankelijk zijn van het fonologisch netwerk dan voor lezen en dat zou mogelijk de verschillen in uitkomsten tussen lezen en spellen kunnen verklaren. Dit bleek zowel voor kinderen met als zonder dyslexie het geval te zijn voor spelling en niet voor lezen. Hoewel deze factor dus voor kinderen met dyslexie compenserend kan werken, profiteren ook kinderen zonder dyslexie van hun verbaal leervermogen als het gaat om hun spellingvaardigheid. Er werden geen effecten gevonden van de verbale consolidatie op lezen of spelling. Mogelijk doordat consolidatie meer samenhangt met de toegankelijkheid van de talige kennis zoals bij benoemsnelheid het geval is.

De rol van de geïntegreerde lees- en spellingbehandeling

In hoofdstuk 3, 4 en 5 worden de analyses beschreven waarmee werd onderzocht of het stimuleren van het orthografisch netwerk door middel van een geïntegreerde lees- en spellingbehandeling bij kinderen met dyslexie bijdraagt aan hun lees- en spellingvaardigheid. Daarnaast werden verschillende cognitieve factoren gerelateerd aan de vooruitgang die de kinderen met dyslexie lieten zien in de behandeling. Hiermee werd onderzocht of individuele variatie in de vooruitgang vanuit die cognitieve factoren te verklaren valt. Vooraf werden positieve effecten verwacht van dit type behandeling, omdat zo'n geïntegreerde behandeling niet alleen de verbindingen tussen orthografie en fonologie versterkt (wat bij lezen gebeurt), maar ook de verbindingen tussen fonologie en orthografie (bij spelling). De relatie tussen beide onderdelen van het netwerk wordt zo vanuit twee richtingen versterkt in plaats vanuit slechts een van beide richtingen.

In hoofdstuk 3 werd onderzocht of kinderen met dyslexie profiteren van een geïntegreerde lees- en spellingbehandeling door hen te vergelijken met leeftijdsgenoten in de normgroepen van de gebruikte testen. De resultaten lieten zien dat de kinderen met dyslexie gemiddeld genomen meer groeiden dan hun leeftijdsgenoten in de normgroepen van de verschillende taken; de kinderen met dyslexie maakten een inhaalslag. Na de behandeling behoorde bijna de helft van de kinderen niet meer tot de zwakste 10% voor spelling, iets meer dan een kwart van de groep behoorde niet meer tot de zwakste 10% voor pseudowoord lezen en bijna een derde van de groep behoorde niet meer tot de zwakste 10% voor het lezen van bestaande woorden. Ondanks het feit dat dit mooie resultaten zijn blijft een substantieel deel van de groep nog altijd een zwakke lezer en een kleiner -maar nog altijd significant- deel van de groep een zwakke speller. Dit laat zien dat de lees- en spellingproblemen van kinderen met dyslexie hardnekkig zijn. Individuele verschillen in de vooruitgang bleken we niet te kunnen verklaren door individuele verschillen in cognitieve profielen bestaande uit fonologisch bewustzijn, benoemsnelheid en verbaal werkgeheugen. Het effect van de geïntegreerde lees- en spellingbehandeling is dus niet afhankelijk van de ernst van de fonologische tekorten van de kinderen met dyslexie.

In hoofdstuk 4 werd onderzocht of kinderen met dyslexie na een geïntegreerde lees- en spellingbehandeling vooruitgang laten zien op zowel fonologische (minder fonologische fouten) als orthografische spelling (minder morfologische en orthografische fouten).

De resultaten laten zien dat kinderen met dyslexie na een geïntegreerde lees- en spellingbehandeling minder fonologische, morfologische en orthografische fouten maken. Kinderen met dyslexie blijven ook na de behandeling verhoudingsgewijs de meeste morfologische fouten maken, gevolgd door orthografische en fonologische fouten. Een geïntegreerde lees- en spellingbehandeling heeft dus een positief effect op zowel de fonologische als orthografische spellingontwikkeling. Individuele verschillen in de vooruitgang bleken niet verklaard te kunnen worden door individuele verschillen in cognitieve profielen bestaande uit fonologisch bewustzijn, benoemsnelheid en verbaal werkgeheugen. Semantiek bleek wel individuele verschillen te verklaren op alle type fouten. Het effect van de geïntegreerde lees- en spellingbehandeling is dus niet afhankelijk van de ernst van de fonologische tekorten van de kinderen met dyslexie, maar wordt wel beïnvloed door de omvang en diepte van het semantisch netwerk. Hoe specifieker en overdadiger dit netwerk, des te beter de spellingresultaten.

In hoofdstuk 5 werd onderzocht of individuele variatie in de vooruitgang van kinderen met dyslexie na een geïntegreerde lees- en spellingbehandeling beïnvloed werd door het verbaal leervermogen (verbaal leren en consolideren). Zowel de leercurve van het verbaal leren als het consolideren voorspelden geen individuele variatie in de vooruitgang die naar aanleiding van de behandeling werd bewerkstelligd.

Samenvattend kan gesteld worden dat de kinderen met dyslexie profiteren van de geïntegreerde lees- en spellingbehandeling die de relatie tussen fonologie en orthografie en andersom stimuleert. De individuele variatie in het behandelresultaat kan niet verklaard worden vanuit de fonologische vaardigheden. Semantiek bleek wel individuele variatie te verklaren in de spellingresultaten.

Conclusie

De huidige dissertatie toont aan dat de semantische kennis van kinderen met dyslexie inderdaad gerelateerd is aan de lees- en spellingresultaten van kinderen met dyslexie en dat kinderen met dyslexie profiteren van een geïntegreerde lees- en spellingbehandeling ongeacht de verschillen in fonologische vaardigheden tussen deze kinderen. Semantiek lijkt aanvullend nog de individuele variatie in spellingresultaten naar aanleiding van de behandeling te verklaren. Uit deze resultaten blijkt dat sterke kanten van kinderen met dyslexie inderdaad van invloed zijn op hun lees- en spellingresultaten en laten daarmee zien dat verschillen in lees- en spellingresultaten niet alleen het gevolg zijn van tekorten, maar ook het gevolg van sterke kanten van deze kinderen. Deze sterke kanten dragen bij aan de lees- en spellingresultaten van kinderen met dyslexie, maar konden niet voorkomen dat ze tot de zwakste lezers en spellers zouden behoren of ervoor zorgen dat ze na een geïntegreerde lees- en spellingbehandeling extreem goede lezers en spellers werden. Van de andere kant kunnen deze sterke kanten wel voorkomen dat kinderen nog zwakker presteren en zijn daarmee voor hen zeer betekenisvol. Deze dissertatie toont daarmee aan dat kinderen met dyslexie andere krachten aanwenden om op hun best te presteren.

Implicaties voor de praktijk

Deze dissertatie laat het belang zien van sterke, compenserende factoren bij kinderen met dyslexie. Gezien het belang van semantiek voor deze groep kinderen (zoals blijkt uit de in dit proefschrift beschreven onderzoeken) wordt de klinische praktijk aangeraden om in hun onderzoek het semantische netwerk (zowel kwantiteit als kwaliteit) in kaart te brengen omdat deze gezien kan worden als protectieve factor. Het nieuwe protocol voor de diagnose en behandeling van dyslexie dat sinds januari 2022 van kracht is, benoemt ook het belang van het in kaart brengen van belemmerende én protectieve factoren. Daarnaast wordt aangeraden gebruik te (blijven) maken van een geïntegreerde lees- en spellingbehandeling waarin naast aan leesvaardigheid ook in ruime mate aandacht wordt besteed aan de spellingvaardigheid. De resultaten van dit proefschrift laten immers zien dat deze behandeling het woordlezen, pseudowoordlezen en spelling positief stimuleert ongeacht de verschillen in fonologische vaardigheden. Een voorbeeld van een uitwerking van het spellingprogramma binnen de behandeling (zoals ook gebruikt in de behandeling waar in dit proefschrift naar verwezen wordt) is terug te vinden in de methodiek 'Geregeld!'.

Gezien het belang van een breed en diep semantisch netwerk wordt iedereen die betrokken is bij de voorschoolse en schoolse periode van kinderen aangeraden om veel aandacht te besteden aan het opbouwen van zo'n semantisch netwerk. Om zo'n breed en diep netwerk op te bouwen is het essentieel dat kinderen in aanraking komen met veel nieuwe woorden en dat ze deze nieuwe woorden expliciet verbinden met eerder geleerde concepten. Uit onderzoek blijkt dat expliciete instructie en begeleid spel hiervoor geschikte werkvormen zijn, die ook beide goed in te zetten zijn bijvoorbeeld bij het voorlezen van (prenten)boeken. Verder zouden elementen uit de geïntegreerde lees- en spellingbehandeling ingezet kunnen worden door leerkrachten in het basisonderwijs. Uitgangspunt in deze behandeling, dat ook in de klas gebruikt kan worden, is het beheersingsgerichte leren. Het doel is dat leerlingen elke voorwaarde voor het lezen en spellen gaan beheersen. Dit lukt alleen als de leerkracht zelf goed weet wat deze voorwaarden zijn en de taakanalyses van lezen en spelling paraat heeft. Aan de hand van deze taakanalyse kan een curriculum gebouwd worden met heldere, expliciete doelen die vervolgens via expliciete instructie en formatieve toetsing aangeleerd kunnen worden. In dit proces is het van belang kennis en vaardigheden eerst geïsoleerd en daarna pas geïntegreerd aan te bieden om cognitieve overbelasting te voorkomen. Het is in dit proces van groot belang dat de leerkracht de ontwikkeling van leerlingen op de voet volgt en hiaten zo snel mogelijk wegwerkt om zo iedere leerling dezelfde stevige basis te geven als het gaat om lezen en spellen (een zogenaamd gegarandeerd curriculum).

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Mijn liefde voor het lerende kind en vooral ook de context waarin dat gebeurt, is verder gegroeid in mijn masterstage onder de bezielende begeleiding van *Marijke van Beurden*. *Marijke*, jij was het die in mij het vuur deed ontbranden als het gaat om mijn interesse voor onderwijs. Op maandag tijdens onze besprekingen konden we vol hartstocht en overgave spreken over onderwijs en wat onze rol daarin kon zijn op de prachtige school waar je destijds werkte en je gaf me het vertrouwen om die gesprekken gedurende de rest van de week om te zetten in praktisch handelen met een stevige wetenschappelijke basis. Jij was het die me deed inzien hoe belangrijk het is om te werken als scientist-practitioner; hoe het pendelen tussen praktijk en wetenschap je kracht geeft en hoe je in een stormwind aan leuke ideeën en goede bedoelingen koers kunt houden en doelgericht te werk kunt blijven gaan. Ook na de masterstage hielden we contact. We werkten (door jouw toedoen) samen op de universiteit in het klinisch onderwijs waar je me al snel behandelde als een gelijke, maar me ook altijd bleef stimuleren om me verder te ontwikkelen. Onze samenwerking heeft ertoe geleid dat ik me ook nog heb laten scholen tot leerkracht voor het basisonderwijs. Gedurende al die jaren spraken we over tal van zaken en wisselden we artikelen en boeken uit. Zo raadde je me ook het boek ‘Expliciete Directe Instructie’ van Hollingsworth & Ybarra (2015) aan, niet wetende dat dit boek mijn werk als orthopedagoog, maar ook mijn volledige loopbaan daarna op zijn kop heeft gezet. Dat ik nu bij PWPO mee aan het roer sta is onder andere te danken aan die literatuurtip! Toen PWPO op mijn pad kwam werkten we niet meer samen op de universiteit, maar bleef je me vanaf de zijlijn aanmoedigen. Bedankt voor alles wat je voor mijn loopbaan en voor mij persoonlijk hebt gedaan en nog altijd doet. Dank voor de uitstekende basis die je me meegegeven hebt en voor alles wat je daarna nog aan mijn professionele en persoonlijke ontwikkeling hebt toegevoegd. Ik ben je voor altijd dankbaar voor wat je voor mij betekend hebt. Ik hoop dat we contact kunnen houden, ook als het niet meer vanzelfsprekend is dat we elkaar op de universiteit tegenkomen.

Mijn liefde voor de wetenschap, het lerende kind en het onderwijs mocht ik (naast mijn werk bij OPM Nijmegen) al vroeg in mijn loopbaan ook tot uitdrukking brengen als docent op de universiteit. Met name in het klinisch practicum van leerproblemen voelde ik mij als een vis in het water. Ik mocht anderen leren wat ik zelf in de praktijk graag deed. In de beginjaren deed ik dit onder de bezielende leiding van *Claire Hulsman*. *Claire*, ik wil jou bedanken voor het vertrouwen dat je altijd in me gehad hebt binnen dat practicum en de gesprekken die we met elkaar gevoerd hebben. Jij zag toen al in dat het voor mij van belang zou zijn om te gaan promoveren en je hebt er alles aan gedaan om mij zover te krijgen dat ik dat ging doen: van overtuigende gespreksvoering tot het regelen van een sollicitatiegesprek voor een heuse promotieplek. Hoewel het die plek niet geworden is, is het er (mede dankzij jou) toch van gekomen. Ik hoop dat je trots op me bent dat het is gelukt en wil je danken voor het vertrouwen dat je me toen al gegeven hebt. Later toen *Claire* stopte, werd het klinisch practicum leerproblemen geleid door *Geert Thoonen* en *Tijs Kleemans*. Als coördinatoren hebben jullie me vleugels gegeven. Ik werd als professional door jullie serieus genomen en gestimuleerd bij te dragen aan de ontwikkeling van het onderwijs op de universiteit. Ik groeide in mijn rol als docent, maar ook als onderwijsontwikkelaar. Iets wat later in mijn carrière nog erg goed van pas is gekomen. Dank heren dat jullie me deze kansen en dit vertrouwen gegeven hebben. Sinds die tijd hebben jullie altijd interesse getoond in mijn bezigheden. In lijn met de hiervoor genoemde mensen wil ik ook *alle andere collega's van PWO* bedanken die met me samengewerkt hebben en me gevoed hebben in mijn ontwikkeling tot de docent die ik vandaag de dag ben. Het zijn er te veel om te noemen maar ik ben jullie allen dankbaar.

Uiteindelijk kwamen alle geplante zaadjes of alle aangewakkerde vuurtjes in 2016 tezamen tijdens een Interacademiale van PWO want toen sprak jij, *Anna Bosman,* mij aan na een kritische opmerking over didactiek van mijn kant. Je bleek me naar aanleiding van die opmerking graag te betrekken bij een nieuw te ontwikkelen lerarenopleiding voor het primair onderwijs. Dit was het moment in mijn loopbaan dat er in mijn hoofd een knop om ging en ik wist wat ik wilde doen. Ik las alles wat los en vast zat over onderwijs, volgde iedereen op twitter, ging met iedereen het gesprek aan en liep over van enthousiasme en toewijding om het doel dat we samen gesteld hadden te behalen. Nu zes jaar later is onze lerarenopleiding een feit en in Nijmegen en ver daarbuiten bekend onder de naam Pedagogische Wetenschappen van Primair Onderwijs (PWPO). Mijn inzet en hart voor onze opleiding groeide met het jaar en dat betekende helaas dat ik afscheid moest nemen van mijn werk bij OPM. PWPO had me nodig, maar je beschermde samen met mij de tijd om ook mijn proefschrift te kunnen afronden. *Anna,* ik ben je onwaarschijnlijk dankbaar voor wat je in me zag toen ik het nog niet zag. Ik dank je voor alle kansen die je me binnen PWPO gegeven hebt, het vertrouwen dat je daarin altijd naar me uitgestraald hebt en voor de vele mooie gesprekken die we over onderwijs gevoerd hebben. Ik dank je voor je luisterend oor en wijze raad als het ging over mijn proefschrift en de uitgestoken hand als leidinggevende toen ik bij OPM wegging en mijn onderzoek in eigen tijd moest gaan doen. Tot slot dank ik je voor de inspiratie die je me biedt in hoe je in het leven en je werk staat, voor je revolutionaire ideeën over onderwijs die ik echt heel waardevol acht en de manier waarop jij die revolutionaire ideeën stapje voor stapje waarheid tot werkelijkheid hebt gemaakt. Dank voor dit alles en nog heel veel meer. Je hebt een bijzondere plek in mijn hart en ik hoop dat we nog lang samen mogen werken en als jij stopt met werken dat we dan nog met regelmaat (al dan niet onder het genot van een wijntje) mogen praten over alles waar wij het zo graag over hebben.

Naast Anna heb ik de afgelopen jaren ook heel nauw samengewerkt met het *volledige team van PWPO*. Het team is inmiddels te groot om iedereen persoonlijk af te gaan maar jullie weten allemaal dat ik jullie dankbaar ben voor de fantastische samenwerking die we in de afgelopen jaren met elkaar hebben opgebouwd. De energie die me dat gaf nam ik mee in het schrijven aan dit proefschrift. Ik kon goede en slechte tijden met jullie delen en daarin kwam ook vaak mijn proefschrift voorbij. Dank dat jullie er altijd voor me waren als ik dat nodig had. Een aantal mensen wil ik in het bijzonder bedanken omdat ik met hen de afgelopen jaren lief en leed heb gedeeld rondom PWPO, maar ook alles daaromheen (waaronder ook mijn proefschrift). *Kim Cordewener* als mijn partner in crime. We hebben zoveel overeenkomsten. We zijn allebei opgeleid in hetzelfde nest, hebben gewerkt bij OPM Nijmegen, houden er (in ieder geval voor onszelf) een ongelofelijk streng werkethos op na en hebben beiden de overtuiging dat de leraar er onwijs toe kan doen voor leerlingen en dat de wetenschap voor de leerkracht een onmisbare raadgever zou moeten zijn. Het was dan ook een geschenk dat we samen onze tanden hebben mogen zetten in een enorm project dat we nu kennen als PWPO. Wat was het een bijzondere reis samen en hoewel we onze hoogte- en dieptepunten hadden kan niemand ons deze gedeelde ervaring en de trots die we samen voelen voor PWPO afpakken. We zullen hierin voor altijd verenigd zijn en hopelijk volgen er nog veel meer zaken om samen trots op te zijn. Toen we samen met PWPO aan de slag gingen hebben we natuurlijk ook veel gesproken over andere zaken die ons bezighielden, zo ook mijn promotietraject. Jij was een van de eerste oud-promovendi met wie ik gesprekken voerde over mijn project en alle uitdagingen die daarbij hoorden. Het was fijn dat jij altijd een luisterend oor bood, vanuit jouw ervaringen met me mee kon denken, maar ook over me waakte en voor me op de bres sprong als het nodig was. Je hebt hierin veel voor me betekend, veel meer dan ik op dat moment doorhad. Dank voor dit alles! *Erik Meester*, jij liet Kim en mij inzien dat wat we gebouwd hadden (PWPO) ook gezien moest worden. Langzaamaan nam je de rol van buitenbaas op je en over de jaren heen heb je mij daarmee vertrouwen gegeven. Het vertrouwen dat we iets goeds hebben neergezet met PWPO. Naast dat vertrouwen ben ik ongelofelijk blij met jou als collega en vriend. Ik kan altijd bij je terecht voor een hartstochtelijk gesprek over de opleiding, onderwijs of elk ander thema eigenlijk. Samen sparren en brainstormen, samen plannetjes uitzetten en dat altijd met een goede grap erbij. Jouw relativeringsvermogen en de lucht die jouw humor met zich meebrengt hebben me bijgestaan in de laatste jaren van dit promotietraject waarin ik het soms echt zwaar had en waar met name de werkdruk voor mij hoog was. *Norma Montulet,* op kamer 5.11 maar ook daarbuiten hebben we vele gesprekken gevoerd over tal van zaken waaronder mijn proefschrift en alles wat ik daarvoor moest doen. Je bood een luisterend oor waar ik dat nodig had en wist me altijd weer te steunen. Jouw warme glimlach en lieve woorden gaf me steun! Dank daarvoor! *Matthijs Brussen* die er altijd is voor raad en daad over opleiding en studenten, maar met wie ik over de jaren heen ook veel gesprekken gevoerd heb. Fijn dat ik altijd bij je terecht kan. Tot slot *Lonneke Mulders.* Als ik in het Spinozagebouw even verlegen zat om een praatje of simpelweg om even te kletsen of te klagen dan kon ik altijd bij jou terecht. Dat begon met kleine momentjes en gesprekken maar over de jaren heen werden onze gesprekken steeds langer en diepgaander. Ik weet dat ik altijd bij je terecht kan en ik voel me onwijs door je gesteund en geholpen. Dank voor alles wat je hierin voor mij gedaan hebt.

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Evelien Mulder: nu ben je gelukkig mijn fijne collega maar eerder was je mijn koorgenoot, student en collega PhD. Als buitenpromovendus voelde ik me met name in de beginjaren nog niet echt verbonden met de PhD's. Jij was het die dat al snel opmerkte en me actief betrok bij deze groep. Je trok me mee naar de gezamenlijke lunches, overleggen, promoties en trok me de appgroep in. Jij zorgde ervoor dat ik in contact kwam met mede-PhD's wat me ontzettend veel steun en ook plezier heeft opgeleverd in de tijd daarna. We werden een hechte club die elkaar steeds weer wist te vinden op de universiteit en de jaren daarna op elke promotie die we bezochten. Dank dat jij me deze wereld in getrokken hebt want dat had ik hard nodig. Naast initiator van voorgaande raakten we ook steeds vaker in gesprek. Hoewel die gesprekken over van alles gingen, gingen ze ook vaak over onderzoek en dus ook over alle gevoelens en gedachten (en helaas vaak ook over onzekerheid) die ik daarbij voelde. Jij luisterde en bood me wat ik nodig had. Soms gewoon een luisterend oor, soms een wijs advies of je hulp. Een uitstekende basis voor de vriendschap die ik vandaag de dag voor je voel. Ik ben dan ook onwijs dankbaar dat jij deze betekenisvolle rol naar een nog hoger plan wilde tillen als mijn paranimf. Je bent in mijn promotietraject van onmisbare waarde geweest en laat dat in de aanloop naar de verdediging ook maar weer eens zien!

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Curriculum Vitae

Robin van Rijthoven is geboren op 22 februari 1989 in Lage mierde. Na het afronden van het gymnasium (2007) aan het Pius-X college in Bladel behaalde Robin zijn Bachelor (2010) en Master (2011, Bene Meritum) Pedagogische Wetenschappen aan de Radboud Universiteit in Nijmegen. Tijdens zijn Bachelor was hij actief lid bij studievereniging Postelein. Hij nam zitting in veel commissies en was zelfs een jaar bestuurslid van de vereniging. In zowel de Bachelor als de Master richtte Robin zijn aandacht op alles wat te maken had met leren en ontwikkeling en in het bijzonder op kinderen met speciale leerbehoeften. In de Master liep hij als orthopedagoog stage in het regulier basisonderwijs, schreef hij zijn masterscriptie over de effectiviteit van een nieuwe methode voor Begrijpend lezen onder supervisie van dr. Mienke Droop en behaalde hij de Diagnostiekaantekeningen van de Nederlandse Vereniging van pedagogen en Onderwijskundigen (NVO).

Na het afronden van zijn Master werkte hij als orthopedagoog bij OPM Nijmegen, een praktijk voor diagnostiek en behandeling van kinderen met leer- en ontwikkelings-problematiek. Hij richtte zich in eerste instantie op de behandeling van kinderen met dyslexie, maar hij breidde zijn werkzaamheden uit en deed ook behandelingen op diverse andere leergebieden en bijbehorende diagnostiek. Naast zijn loopbaan bij OPM Nijmegen kreeg Robin een aanstelling als docent bij de Bachelor en Master Pedagogisch Wetenschappen aan de Radboud Universiteit in Nijmegen. Hij gaf colleges en begeleidde studenten bij klinische stages in de Bachelor en Master. In de Master begeleidde hij daarnaast casuïstiek voor het behalen van de Diagnostiekaantekening en scripties. Naast voorgenoemde werkzaamheden behaalde Robin zijn Bachelor of Education (2013) aan de Hogeschool van Arnhem en Nijmegen, waarna hij zijn bevoegdheid kreeg om les te geven in het basisonderwijs. Na het afronden van deze opleiding heeft Robin in het basisonderwijs gewerkt. Tevens volgde hij drie jaar lang een deeltijd musicalopleiding, waarna hij naast zijn academische werk altijd als acteur werkzaam is gebleven.

Door de combinatie van werkzaamheden bij OPM Nijmegen en aan de universiteit werd Robin in 2014 gevraagd een onderzoeksvoorstel te schrijven voor een PhD project onder begeleiding van dr. Tijs Kleemans, prof. dr. Eliane Segers en prof. dr. Ludo Verhoeven in samenwerking met OPM Nijmegen. Een jaar later werd zijn onderzoeksvoorstel goedgekeurd en begon hij als buitenpromovendus aan het Behavioural Science Institute van de Radboud Universiteit. Zijn onderzoek richtte zich op de compensatiemogelijkheden van kinderen met dyslexie. In zijn onderzoek werd gekeken naar compensatie vanuit semantische representaties en vanuit het versterken van orthografische representaties middels een geïntegreerde lees- en spellingbehandeling met een significant groot aandeel spelling. Robin schreef zijn proefschrift naast zijn werk op de universiteit en gebruikt de inzichten uit zijn proefschrift in zijn onderwijs en gaf een lezing op de nationale dyslexieconferentie om zijn bevindingen te delen met iedereen die in Nederland werkzaam is in de dyslexiezorg. Zijn grootste valorisatieproject startte echter toen hij in 2016 (in nauwe samenwerking met prof. dr. Anna Bosman en dr. Kim Cordewener) startte met de ontwikkeling van de eerste volledig universitaire lerarenopleiding voor het basisonderwijs in Nederland. De opleiding Pedagogische Wetenschappen van Primair Onderwijs (PWPO) is -na het verkrijgen van een accreditatie van de NVAO- o.a. door Robin verder uitgewerkt tot een volwaardig studieprogramma. In 2017 is de Bachelor gestart en in 2020 zijn de eerste studenten van deze nieuwe opleiding afgestudeerd. Robin is samen met zijn collega Kim Cordewener tot op de dag van vandaag opleidingscoördinator van deze opleiding; een veelomvattende rol waarin zij de opleiding voortdurend monitoren en optimaliseren. Robin geeft naast zijn rol als opleidingscoördinator binnen deze opleiding colleges en werkgroepen over algemeen didactiek (waaronder de expliciete directe instructie) en de vakdidactiek van rekenen en wiskunde. Daarnaast heeft hij in alle jaren van de opleiding stages begeleid. Sinds 2021 is Robin lid van de adviesraad van de opleidingsdirecteur van het onderwijsinstituut PWO, waaronder PWPO valt. Op dit moment werkt hij aan een vertaling van een onderwijsgerelateerd boek dat hopelijk in 2023 zal verschijnen.

Publications

Scientific publications

Van Rijthoven, R., Kleemans, T., Segers, E., & Verhoeven, L. (2017). Beyond the phonological deficit: Semantic abilities contributes indirectly to decoding efficiency in children with dyslexia. *Dyslexia, 24*(4), 309-321. doi:10.1002/dys.1597

Van Rijthoven, R., Kleemans, T., Segers, E., & Verhoeven, L. (2021). Response to phonics through spelling intervention in children with dyslexia. *Reading & Writing Quarterly*, *37*(1), 17-31. doi:10.1080/10573569.2019.1707732

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Professional Publications

Bosman, A., **Van Rijthoven, R**., & Meester, E. (2019, 11 april). Nieuw: ouderwets onderwijs. *NRC*. Geraadpleegd op 19 juli 2022 van https://www.nrc.nl/nieuws/2019/04/11/nieuw-ouderwets-onderwijs-a3956604

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Brandriet, A. (2018, 6 oktober). De gang is geen straf meer. *Groene hart*, 2-3.

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Data Management and Transparency

Radboud University and the Behavioural Science Institute (BSI) have set strict conditions for the management of research data. All research data resulting from this dissertation were handled in accordance with the university's research data management policy (https://www.ru.nl/rdm/) and the BSI's General Data Protection Regulations (GDPR; https://www.radboudnet.nl/bsi/procedures/bsi-specific/gdpr/). Accordingly, I registered all published chapters and their corresponding data sets on the Research Data Repository (RDR). Unfortunately, it is not possible to publish our data openly as we don't have permission to do so from the participants. Should a reader of this dissertation nevertheless wish to inspect the data for valid reasons, please contact the first author (robin.vanrijthoven@ru.nl).

Doi data chapter 2: https://doi.org/10.34973/rvna-kr90
Doi data chapter 3: https://doi.org/10.34973/y9yx-m259
Doi data chapter 4: https://doi.org/10.34973/cvne-zp67
Doi data chapter 5: https://doi.org/10.34973/z5dk-sh23

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