The role of orthographic and phonological processing in dyslexia and reading

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Chapter 1 General introduction

1.1 Reading fluency development

One goal in reading development is to become a fluent reader, which involves accuracy and automaticity. Automaticity implies fast, effortless, autonomous, and not consciously aware processing. This automaticity enables the reader to shift attention to more higher-order tasks such as reading comprehension (Kuhn & Stahl, 2003; LaBerge & Samuels, 1974; Logan, 1997).

In order to develop automatic and efficient visual word recognition Perfetti (1992) proposes two sublexicons to acquire a lexical representation system: the functional and the autonomous lexicon. In the functional lexicon the representations are not yet fully specified, whereas the autonomous lexicon is characterized by fully specified representations. The autonomous lexicon refers to precise (accurate) orthographic and phonemic connections and redundant orthographic and phonemic connections on the sublexical and lexical level, in which the lexical representation becomes "encapsulated" (Perfetti, 1992, p.162). This implies accurate direct word recognition. Fluency is thought to be reached when the representations increase in quality and, as a byproduct, the access to these representations increases.

Reaching reading fluency involves efficient processing of words on a continuum of high to low frequency. At the same time, reading experience leads to the transition of words from unfamiliar to familiar (Share, 2008a). To establish the transition and improve the quality of the lexicons, experience is needed, which involves shifting the words from the functional to the autonomous lexicon (Perfetti, 1992). In reading development, phonological recoding, which is the print-to-sound conversion, is of major importance in word identification. Phonological recoding forms the key to acquire orthographic representations (Share, 1995), since each time after a successful decoding of a (new) word, word-specific information is obtained. This forms the basis of the self-teaching mechanism which allows a child to

develop its own orthographic lexicon. The forming of a large autonomous lexicon (i.e., acquiring word-specific knowledge) is a requirement for reading fluency. In parallel, this knowledge may be used to identify unfamiliar words which are still part of the functional lexicon. Therefore, children are helped achieving reading fluency through information about the orthographic structure of the words and using these larger orthographic units in word identification (Reitsma, 1983). For example, there is evidence that larger orthographic units of known words are used to identify equal parts in other words (so called orthographic neighbour words, e.g., Andrews, 1997; Marinus & de Jong, 2010).

Necessary prerequisites and important predictors for the development of reading fluency are at least phoneme awareness, rapid serial naming, and orthographic processing. The first step before establishing a functional lexicon is to grasp the alphabetic principle that a phoneme maps a grapheme (Snowling & Hulme, 2005). In this process phoneme awareness is of importance, the understanding and awareness that spoken words exist of a sequence of sounds and the ability to manipulate those sounds (Bowey, 2005, Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wagner & Torgesen, 1987). Another important phonological processing variable is rapid serial naming, the quick retrieval of symbolic information from the long term memory, involving intermodal processing between a visual symbol and a speech sound (Jorm & Share, 1983; Wagner & Torgesen, 1987). Rapid serial naming represents in particular the fast access and retrieval of well-known symbols from memory. However, it is not reading-specific, it is also related to arithmetic fluency (van der Sluis, de Jong, & van der Leij, 2007).

Besides phonological processing, orthographic processing is another important source in predicting word identification, even when phonological processing, including phonological recoding, is controlled for (Cunningham, Perry, & Stanovich, 2001; Morfidi, van der Leij, de Jong, Scheltinga, & Bekebrede, 2007). Orthographic processing is an umbrella term which includes the accuracy and speed of access and retrieval of word-specific orthographic knowledge, representing crystallized orthographic ability (Share, 2008b) and is often measured with lexical decision tasks (e.g., *rane* -

rain paradigm of Olson, Forsberg, Wise, & Rack, 1994). In addition to the lexical level, the sublexical level of single letters, letter clusters, and syllables (Berninger et al., 1992) is involved as well. This information is already available in the functional lexicon, but does not involve a fully specified representation (Perfetti, 1992). The sublexical level includes orthographic awareness, which refers to the awareness of legal letter strings (wordlikeness), how letters are organized in words and statistical regularities of letter sound combinations (Siegel, Share, & Geva, 1995; Stanovic & Siegel, 1994; Vellutino et al., 2004). However, the role of orthographic processing in word identification is still debated (see reviews of Burt, 2006; Castles & Nation, 2006; see also Chapter 6 of the present thesis).

1.2 Reading-related processes and reading difficulties

Unfortunately, not all persons develop into fluent readers. Some encounter major difficulties in reaching adequate levels of accuracy and/or fluency. Around 10% of the children experiences difficulties with learning to read (Vellutino et al., 2004). In a transparent orthography like Dutch estimates are somewhat lower. Approximately 9% of the children have severe difficulties in the accurate and quick identification of written words and 4% is diagnosed as dyslexic (Blomert, 2006). This difference could be related to the transparency of the orthography under study. English is an opaque orthography, in which many irregularities in the one-to-one mapping of graphemes to phonemes exists (Seymour, Aro, & Erskine, 2003), whereas Dutch is a relatively transparent orthography. Transparent orthographies are characterized by the finding that poorly reading children already early in reading development reach relatively adequate accuracy levels. In contrast, they have persistent problems with developing adequate levels of reading fluency to obtain automaticity (see Landerl & Wimmer, 2008; Seymour et al., 2003; Share, 2008a; van der Leij & van Daal, 1999; Verhoeven & van Leeuwe, 2009).

There is consensus that the main deficit in developmental dyslexia is a deficit in phonological processing (see for a review Vellutino et al., 2004). Phonological processing is a universal and stable core characteristic of dyslexia independent of orthography and age. This is characterized by problems with phoneme awareness and rapid serial naming. Problems with phoneme awareness are found in all alphabetic languages and in all ages, provided that task demands are adapted to the developmental level of the dyslexic (e.g., English: Bruck, 1992; Snowling, Nation, Moxham, Gallagher, & Frith, 1997; Swanson & Hsieh, 2009; Czech: Caravolas, Volín, & Hulme, 2005; Dutch: de Jong & van der Leij, 2003; Morfidi et al., 2007). Problems with rapid serial naming are also commonly found in all alphabetic languages, which persist into adolescence and adulthood (e.g., English: Swanson & Hsieh, 2009; Vukovic, Wilson, & Nash, 2004; Dutch: de Jong & van der Leij, 2003; Morfidi et al., 2007; Vaessen, Gerretsen, & Blomert, 2009; German: Wimmer, Mayringer, & Landerl, 2000).

1.3 Heterogeneity of dyslexia

Reading acquisition is a complex process which involves large individual differences in the reading-related processes (Share & Stanovich, 1995). As a consequence the group of dyslexics is not a homogeneous group (e.g., Beaton, 2004). Even among adult dyslexics, this group is still characterized by a large heterogeneity (e.g., Lyytinen, Leinonen, Nikula, Aro, & Leiwo, 1995; Ramus et al., 2003; Vukovic et al., 2004; Zabell & Everatt, 2002). The consensus about the core phonological processing deficit in dyslexia (Vellutino et al., 2004) suggests a single cause of dyslexia. However, this line of reasoning contradicts the evidence about heterogeneity in cognitive profiles. A probabilistic multifactorial model forms a better explanation for the heterogeneity than a deterministic single cause (Pennington, 2006), including orthographic, visual, and rapid serial naming deficits, next to phoneme awareness deficits.

The question is whether heterogeneity of cognitive profiles of poor readers is determined by intraindividual variation of reading-related subskills in the phonological domain (in particular phoneme awareness and rapid serial naming), or whether more reading-specific subskills account for additional variance. In order to solve this issue and investigate the heterogeneity in dyslexia, one solution is the development of sub-classifications within the group of dyslexics. It is important to note that subtypes are not naturally occurring, but are imposed (Rispens, van der Stege, & Bode, 1994). Subtypes entail different underlying processes that lead to the same problem at the surface. Studying subtypes in dyslexia implies that multiple causes should be considered and that there is not a single processing deficit accounting for the problem (Licht, 1994). There are various subtypes considered based on reading-related processes. For instance, subtypes based on the double deficit theory (Wolf & Bowers, 1999) and based on the multiple-trace memory model for polysyllabic word reading (ACV98 model; Ans, Carbonnel, & Valdois, 1998) are suggested.

The double deficit hypothesis proposes a single phoneme awareness deficit, a single rapid serial naming deficit, and a combination of both deficits (Wolf & Bowers, 1999) underlying dyslexia. The subtypes based on the ACV98 model advocate a distinction between phoneme awareness and visual attention span (Bosse, Tainturier, & Valdois, 2007). Moreover, there are also subtypes thoroughly investigated that are based on specific processes in reading, as the dual route model with two routes for word identification: the sublexical and lexical route (DRC model; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Derived of these two routes are the phonological and surface subtypes (e.g., Castles & Coltheart, 1993), in which the phonological subtype represents a deficit in the sublexical route leading to problems with pseudoword reading and the surface subtype has a deficit in the lexical route leading to problems with irregular words. It should be noted that the term phonological subtype may be somewhat misleading because it does not relate to reading-related subskills such as phoneme awareness and rapid serial naming, but to reading-specific processes only.

However, these subtype distinctions have been criticized (Share, 2008a; Vellutino et al., 2004; Ziegler et al., 2008; see also the General discussion). Although subtypes should entail multiple causes (Licht, 1994), most subtypes are seen as deterministic single "opposite" causes, leaving no room for the multiplicity and complex patterns in cognitive profiles (Pennington, 2006). This is supported by Ziegler et al. (2008) who imply that the causes of dyslexia must not be investigated as a unitary disorder, but at individual levels, since there is no single cause of dyslexia.

An alternative way to solve the problem of a phonological core deficit on the one hand and additional variables that may play a role on the other, is expressed in the phonological-core variable-differences (PCVD) framework of Stanovich (1988). This framework embraces the phonological core deficit, implicating that all poor readers exhibited a core phonological processing deficit. The heterogeneity elicits in the aspect of possible differences in other, mainly general, cognitive skills. This is not a subtype model, in which two reading-related processes are contrasted. Stanovich's framework was proposed to account for the differences found between IQ-discrepant dyslexics and non-IQ-discrepant ("garden variety") poor readers in measures outside the phonological core domain, which indicate differences in their general cognitive abilities. This was followed by the suggestion that dyslexic readers were relatively less disadvantaged in orthographic processing compared to phonological processing than non-discrepant poor readers (Stanovich & Siegel, 1994).

1.4 Variability in orthographic processing

The PCVD framework (Stanovich, 1988) stresses the need to look for variable differences outside the phonological core domain. In addition to cognitive abilities, orthographic processing was mentioned (Stanovich & Siegel, 1994). To further investigate the heterogeneity within dyslexics and to deviate from the aptitude achievement discrepancy, variability in orthographic processing within dyslexics is a promising possibility. As was

shown by Cunningham and colleagues (2001), orthographic processing explained additional variance in word recognition. Moreover, individual variability among the group of dyslexics was found (Miller-Guron & Lundberg, 2000; van der Leij & Morfidi, 2006). Among Swedish college students there was a subgroup of dyslexics who were better in English reading and had a preference for English instead of Swedish, although the latter has a transparent orthography (Miller-Gruon & Lundberg, 2000). In a Dutch study with dyslexic adolescents, van der Leij and Morfidi (2006) also found a dyslexic subgroup that was better in English reading. This subgroup had superior orthographic skills in both English and Dutch contrasted to another dyslexic subgroup. Both dyslexic subgroups had equal phonological processing deficits. It was suggested that the subgroup with better orthographic skills that performed better in English had a preference for larger orthographic units.

Therefore, van der Leij and Morfidi (2006) extended the PCVD model of Stanovich (1988 and Stanovich & Siegel, 1994) to individual variability within the group of dyslexics, resulting in the phonological-core variable-orthographic differences model (PCVOD). The PCVOD model assumes that all dyslexics suffer from a core phonological processing deficit whereas there are large individual differences in orthographic processing. This model predicts that some dyslexics may have orthographic processing skills in the normal range, whereas other dyslexics have deficits in both phonological and orthographic processing leading to less compensatory potential in orthographic processing. One of the central issues in the present thesis is to investigate whether there is larger individual variability within dyslexics in orthographic processing than in phonological processing, testing the PCVOD-model.

1.5 Themes and outline of this thesis

The present thesis involves three main themes. Firstly, the role of orthographic processing in addition to phonological processing as a

predictor of reading fluency is investigated. This was examined in three different age groups: middle childhood (mean age 7;10 in Grade 2), young adolescents (mean age 15;7), and adults (mean age 37;3) (see Chapter 2, 3, and 4).

The second theme considers the universality and stability of deficits in phonological processing across age, the cornerstone of causal theories of dyslexia. Deficits in phoneme awareness and rapid serial naming are known to be present in poor readers in middle childhood (Chapter 5). The hypothesis is extended to Dutch dyslexic young adolescents (Chapter 3 and 5) and Dutch dyslexic adults (Chapter 4 and 5). The fact that most evidence comes from studies investigating readers in the acquisition phase or from more opaque orthographies, mostly English studies, whereas the Dutch language is a more transparent orthography, supports the relevance of this choice.

The third major theme is to investigate the heterogeneity among dyslexics by highlighting two different ways to look at the heterogeneity. In the first approach the variability within dyslexics in orthographic processing is considered by examining the PCVOD model in Dutch young adolescents (Chapter 3) and adults (Chapter 4). The second approach (Chapter 5) is to examine the cognitive profiles using multiple case studies across different ages (Ramus et al., 2003, Sprenger-Charolles, Colé, Kipffer-Piquard, Pinton, & Bilard, 2009; White et al., 2006). Multiple case studies serve as a possibility to address the heterogeneity of cognitive profiles at the individual level, because they search for possible combinations of deficits in individuals. This is without restrictions of reading theories about different routes and subtypes, and without restrictions in contrasting reading-related processes to form subtypes. The methodology is to select variables that have shown to differentiate between poor and typical readers and combine them in one design.

In line with this lay-out, the study in Chapter 2 describes the role of orthographic processing in predicting word and pseudoword reading fluency and spelling ability in the fluency-acquisition phase in primary school in a longitudinal design (from Grade 2 to Grade 4). In this chapter, the influence

of orthographic processing as a predictor in addition to phoneme awareness and rapid serial naming is investigated in children across the whole reading distribution.

The first part of Chapter 3 examines orthographic processing as a predictor for word reading fluency and spelling ability after controlling for phonological processing among young adolescents with and without dyslexia. Secondly, the core deficit in phonological processing is investigated. Finally, the variability within dyslexics in orthographic processing is considered with the PCVOD model.

While Chapter 4 addresses the same topics as in the previous chapter, the participants are a different age-group: adults with and without dyslexia. Also in this age group, the influence of orthographic processing in predicting word reading fluency is investigated. Secondly, the persistence of the phonological core deficit is examined by comparing the adult dyslexics both with control adult readers and secondary school students as a reading-level match group. Third, the variability within dyslexics in orthographic processing is investigated within the framework of the PCVOD model.

In Chapter 5 the cognitive profiles of poor readers from four different age groups (mid-primary school, beginning and end of secondary school, and adults) are investigated and compared to typical readers. This was accomplished by using multiple case studies investigating the possible multiplicity in weaknesses in reading-related processes. Comparisons are made between poor and typical readers and age groups on reading fluency and three reading-related processes: phoneme awareness, rapid serial naming, and parallel symbol processing.

Finally, in Chapter 6 the main findings in this thesis are discussed. First a review of the findings according to the three themes is given, followed by the implications for reading theories, practice and future research, regarding the role of orthographic processing, the persistence of the problems, and the heterogeneity among dyslexics.