1 Introduction

Developmental Dyslexia – A Cross-Linguistic Perspective

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Reading involves decoding written language in order to understand it. In learning to read, children implicitly learn how their writing system encodes their spoken language and how they can decode printed words into spoken words to derive meaning (see Verhoeven & Perfetti, 2017). However, many children around the world encounter problems learning to read, fail to develop fluent decoding, and are thus diagnosed as dyslexic.

A large body of research supports the conclusion that a phonological deficit underlies most developmental dyslexia. Much of the existing evidence, however, is based on studies of children learning to read in English. It is important to note that English has an opaque orthography that creates challenges beyond those facing children who read more transparent orthographies. In recent years, the research base for developmental dyslexia has broadened across languages, allowing the question of differences and similarities across languages and writing systems to receive attention. It has been suggested, for example, that developmental dyslexia can involve not only phonological problems but also – particularly for writing systems that are more transparent than that of English – delayed development of decoding fluency. Other processing factors, such as rapid automatized naming and visual attention, have been argued to play a role in the occurrence of developmental dyslexia. And language factors beyond phonology, especially morphological processing, become visible when languages beyond English are considered. Whether the observed cross-linguistic differences in developmental dyslexia reflect more or less superficial variation around a common, underlying phonological disturbance or result from deeper, more fundamental variation in the causes of developmental dyslexia still remains to be seen (see Pugh & Verhoeven, 2018). Indeed, this question is a special case of the more general question of universal reading procedures and the adaptations that these procedures make to specific writing system and language factors (Perfetti, 2003; Perfetti & Harris, 2013).

The time is thus ripe to bring together what we know about reading problems and their underlying etiology across languages and writing systems. The present volume starts with a review of what is known about developmental dyslexia for nine different languages and orthographies (Part I) and then addresses the possible underlying mechanisms (Part II). Our selection of languages is based on the seventeen languages (and five writing systems) that were reviewed in Verhoeven and Perfetti (2017), in a collection of chapters that examined the languages, their writing systems, and research on learning to read in those languages. We chose nine of these languages for follow-up in the present volumes. We chose these nine languages to represent four major writing systems, excluding only alphasyllabaries, for which research on dyslexia is sparse. Our aim was to have some contrast among languages and writing systems (e.g., Finnish and Dutch (alphabetic), Chinese (morphosyllabic), Hebrew (abjad)) for which there has been substantial dyslexia research. We limited our examination to developmental dyslexia, excluding acquired dyslexia, thus allowing examination of risk factors, biological bases, interventions, and other important aspects of dyslexia that accompany children's difficulties in reading.

In this introductory chapter, we set the stage for taking a comparative perspective on developmental dyslexia by briefly reviewing the acknowledged universals for learning to read in general, and the definition, treatment, and neurocognitive foundations of dyslexia.

1.1 Learning to Read across Languages and Writing Systems

Several models have been proposed to account for the processing of visual word forms. The central assumption underlying so-called dual-route theories of reading, which are applied specifically to alphabetic writing, is that two independent routes can be followed to generate the pronunciation of a word: the nonlexical route or the lexical route. The nonlexical, computational route involves the computation of an orthographic code via the application of orthography-to-phonology mapping rules for the reading of letters, words, and text. The lexical retrieval route involves accessing a word's *written* representation from the so-called orthographic input lexicon followed by retrieval of the word's *spoken* form from the so-called phonological output lexicon (e.g., Coltheart et al., 2001). It is important to note that familiarity with a given writing system generally is thought to shift word reading from the computational to the retrieval route on these accounts (Pugh et al., 2013). Indeed, this is one of the conclusions considered to be universal based on comparisons across seventeen writing systems (Perfetti & Verhoeven, 2017). That is, computational routines are called upon for the reading of unknown or infrequent words and thus during the early stages of learning to read as well.

Sublexical mappings of phonology or morphology to orthography are used to determine the pronunciation (and meaning) of the whole word. With increased word familiarity and retrieval from memory on the basis of a few identified features of the whole word, computation becomes less necessary. This assumption also represents a more general observation about the nature of memory-based information processing by humans: Non-computational retrieval processes operate more frequently as experience establishes addressable memory forms. It should be noted here that alternative classes of computational models, such as the Division of Labor connectionist account (Harm & Seidenberg, 2004), challenge some key assumptions in the dual-route theories (such as independent pathways) while accounting for the same observed shifts with reading experience and the contrasts remains an active research domain.

Learning to read entails discovering how a writing system encodes a spoken language. The basic assumption underlying our understanding of the processes of reading and learning to read is that fluent reading draws upon lexical representations contain both orthographic and phonological components (see Perfetti, 1997). As we know, however, writing systems can show minor but *significant* variation in the mapping of spoken linguistic units to written linguistic units (see Dehaene, 2009). In Figure 1.1, it is shown how language units are related to graphic units across writing systems and orthographies. It is assumed that both reading and spelling draw upon lexical representations that contain orthographic and morpho-phonological constituents (see Verhoeven &

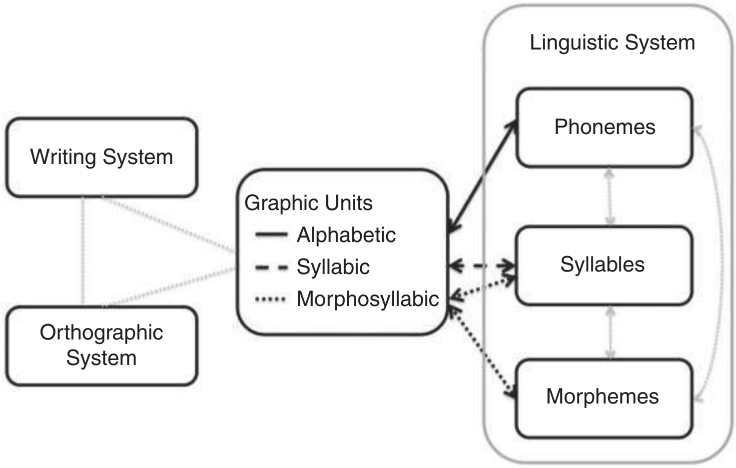

Figure 1.1 How graphic units mediate the relationship between writing systems and orthographies, on the one hand, and linguistic units, on the other hand

Perfetti, 2017). Accordingly, writing systems can reflect a dominance of mapping at the level of *morphemes*, with graphs corresponding to the basic units of meaning or morphemes), *syllables*, with graphs corresponding to spoken syllables, or *phonemes*, with graphs corresponding to the minimal units of speech, or phonemes.

Stated differently, writing systems have been found to show a varying predominance of phonological mapping at the morphemic, syllabic, and phonemic levels. According to the Universal Phonological Principle (Perfetti, Zhang, & Berent, 1992), word reading entails the activation of phonology at the lowest linguistic level encoded by the relevant writing system: the phoneme, the syllable, the morpheme, or the word. For systems using alphabetic writing, phonological activation is typically driven by grapheme-to-phoneme mappings. Even within the family of alphabetic writings, however, variation in orthographic depth or the extent to which the written language deviates from a simple grapheme-to-phoneme correspondence has been found to affect the course of the word-identification process (Frost, Katz, & Bentin, 1987). Grapheme–phoneme consistency (high for shallow orthographies, low for deep orthographies) and morpheme recovery (higher for deep orthographies, and reliance on morphemic as opposed to phonemic information for word decoding/reading) might produce corresponding variations in reading processes and processes of learning to read (Daniels & Share, 2018). Other writing systems, such as those of Japanese Kanji and Chinese, encourage direct activation of not only morphological but also syllabic information on the basis of orthographic form (Perfetti, Liu, & Tan, 2005).

Given that reading development requires learning how a writing system encodes the spoken language, it can be posited that universal operating principles guide children's perception, analysis, and use of a writing system to master a language's orthography. As is displayed in Figure 1.2, learning to read universally requires children to become linguistically aware, build orthographic representations, and develop routines for efficient word-to-text integration (see Verhoeven & Perfetti, 2017).

1.1.1 Becoming Linguistically Aware

Learning to read is known to be facilitated by the development of a sensitivity to the spoken units of a language. To the extent that visual word identification requires the connection of familiar sound units to to-be-learned or familiar orthographic units within a given language, the quality of the child's morphophonological knowledge and phonological processing will be essential. However, the speech signal is continuous and rapid with sharp modulations in both frequency and amplitude, making it difficult to segment the speech stream and identify the relevant units for reading. Moreover, the same speech

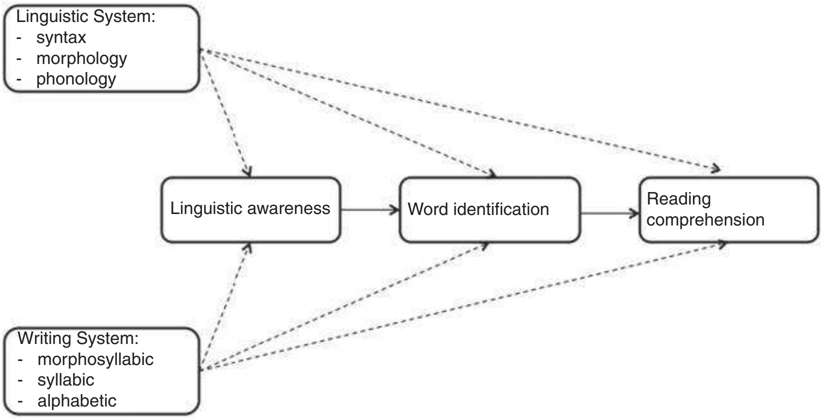

Figure 1.2 How the linguistic system and writing system impact the development of linguistic awareness, word identification, and reading comprehension

sound can manifest itself differently depending on the phonetic environment, the prosody, and the rate of speech. To solve this so-called variability problem, the speech signal can be normalized. Acoustic variants can then be mapped onto canonical phonemes and, in turn, onto spoken word representations within the mental lexicon (see McQueen & Cutler, 1997). It is already known that, with exposure to speech, infants begin to segment the incoming acoustic signal into consistent, replicable chunks that come to represent phonemes (cf. Kuhl et al., 1997). Stress, intonation, and the rhythm of the incoming speech signal can further alert children to significant units of speech and help them build high-quality, speech-based lexical representations. The quality of the representation is important, as precise and stable representations at the level of the phoneme are needed for the efficient retrieval of word forms. And word representations that are only partially specified may set the stage for impoverished reading development (see Goswami, 2000).

Learning to read in an alphabetic orthography builds upon a child's emerging phonological awareness (Snowling, 2000); that is, its ability to attend to the sounds of language independent of meaning. Stated generally, this awareness entails the ability to isolate words within sentences. More specifically, phonological awareness entails the ability to identify sublexical units, syllables, rhymes, the beginnings of words, the ends of words, and phonemes. Attention to salient syllabic, onset–rime, or phoneme boundaries within words is therefore highly important for children's reading development. Phonological awareness is usually assessed using tasks that measure segmentation, blending, or the manipulation of speech sounds. It has been found to progress from the syllable and onset–rime levels to the phoneme level (cf. I. Y. Liberman & Shankweiler, 1985; Shankweiler & I. Y. Liberman, 1989; Treiman & Zukowski, 1996). In recent research, when Moll et al. (2014) compared the roles of differential phonological processing (phonological awareness and memory vs. rapid naming) in reading development across various orthographies, rapid naming was found to be the best predictor of reading speed while phonological awareness and memory accounted for higher amounts of unique variance in the accuracy of the children's reading and later spelling. In other research, Shu, Peng, and McBride-Chang (2008) examined the nature of phonological awareness in 4–6-year-old Chinese children. They found syllable and rime awareness, but also tone awareness, to gradually and steadily increase, while awareness of phoneme onset remained at chance levels until the start of instruction on phonological coding (Pinyin) in first grade. The variance in Chinese character recognition was then best explained by phonological processing tasks measuring syllable awareness, tone awareness, and naming speed.

Children must not only attend to spoken language but also obviously have opportunities to link spoken to written linguistic forms in order to learn to read. With attention to salient script signs, they can acquire the inventory of graphic forms for a given writing system and gain insight into the orthographic units (graphemes) connected to the spoken units within the language (phonemes and morphemes). As a result of further analysis of the constituent sounds (phonemes, syllables) and graphemes of familiar words, they may then discover the more general mapping principle. And such self-learning is likely to be applicable across writing systems and orthographies. However, at least for alphabetic orthographies, the outcomes of research suggest that spontaneous self-discovery is not sufficient for most children to learn to read. More systematic instruction on the so-called alphabetic principle and the specific grapheme–phoneme correspondences within a language is required (de Graaff et al. 2009; Torgerson, Brooks, & Hall, 2006). Given such instruction, considerable research has shown phonological precursors as measured in preschool to predict later literacy development (cf. Blachman, 2000; Goswami, 2001).

Across a variety of orthographies (English, Finnish, Swedish), early phonological awareness and rapid naming (measured in kindergarten) have been found to correlate with later word-reading and spelling skill (measured in first and second grade; Furnes & Samuelsson, 2011). In a meta-analysis on correlates of later reading outcomes, Swanson et al. (2003) showed phonological awareness and rapid naming to moderately correlate with the reading of real words, but weaker associations were found within groups of poor as opposed to skilled readers. Strong support has consistently been found for associations between poor phonological abilities and problems learning to read (Elbro & Scarborough, 2004; Torgesen et al., 1997). More specifically, poor readers appear to have less precise phonemic discrimination and also problems with phoneme segmentation and other tests of phonological awareness (Høien & Sundberg, 2000; Wagner, Torgesen, & Rashotte, 1994). In sum: Phonological awareness has been found to play a key role in literacy outcomes, with later literacy problems often stemming from early and persistent deficits in phonological awareness.

1.1.2 Building Orthographic Representations

The building of the underlying orthographic representations needed for fluent reading requires the additional learning of graphic forms that might extend beyond beginning reading experiences, depending on the writing system. Alphabetic writing systems have the advantage of calling upon a relatively small inventory of graphs (letters). This inventory can usually be mastered during the first year of instruction or even prior to this. In contrast, the alphasyllabaries of the languages in South and Southeast Asia are more demanding than those of – for example – English and Dutch. This is due to more graphs to start with and greater variation among the consonant graphs. Chinese requires the largest inventory of graphs, with over 6,000 graphs commonly in use and even more in dictionaries containing traditional characters. Mastering the Chinese writing system is therefore known to place the greatest demand on learning and requires more continuous learning than mastering the writing systems of other languages.

Across languages, written words can become familiar perceptual objects, which can then be recognized at a glance. According to Jorm and Share (1983) and Share (1995), a first encounter with a written word can lead to *phonological recoding*, which is then fed back to the word's orthographic representation to thereby initiate the word-specific reading identification process. With the aid of this mechanism, only a few exposures to the same word may thus be sufficient to create a high-quality, orthographic representation with sufficient prevision and redundancy for subsequent quick recognition (Perfetti, 1992, 2003, 2007; Share, 2004). Beyond making words familiar, experience with reading can produce gains in word-reading fluency as well. And highly fluent word reading, in other words, entails an effortless perceptual response to visual information, automatization of word decoding, and familiarity-based memory retrieval (see Verhoeven & van Leeuwe, 2009). Across different orthographies, research shows parallel developmental gains in both the speed and accuracy of word decoding immediately following the start of explicit reading instruction and steady improvements in lexical retrieval during the years thereafter. Retrieval of word representations on the basis of familiarity can be assumed to be universal (Verhoeven & Perfetti, 2017; Ziegler & Goswami, 2005). And given that such familiarity-based retrieval has been shown to be important for fluent alphabetic reading, it can similarly be assumed to be important – or possibly even more important – for such morpheme-based orthographies as Chinese. It should then be kept in mind that most reading problems have been shown to stem from limited reading fluency (Torgesen & Hudson, 2006).

Most current models of learning to read have focused on how letter strings are converted into phonological strings (pronunciations) but have essentially ignored the internal structure of words or morpheme units, which constitute the core of such morpheme-based orthographies as Chinese. The reading of more complex words across languages and writing systems nevertheless requires the processing of morphological structure in addition to the identification of grapheme–phoneme connections and the retrieval of whole words from memory. The processing of morphological structure or, in other words, morphological decomposition, can be viewed as an acquired sensitivity to the systematic associations between the surface forms of words and their underlying meanings (cf. Plaut & Gonnerman, 2000; Seidenberg & Gonnerman, 2000). Morphological decomposition can be graded rather than all-or-none, depending on the degree of phonological and semantic transparency characterizing the language. Transparent associations between the orthographic, phonological, and semantic representations within a language can facilitate recognition of written forms and activation of meaning to thereby promote reading comprehension. And such transparent associations can be seen to constitute an important cornerstone for interventions with poor readers (Bowers, Kirby, & Deacon, 2010).

1.1.3 Word-to-Text Integration

The ultimate goal of reading is, of course, comprehension of a written text. The comprehension of a text starts from the identification of words for integration into the ongoing representation of the text. Word-to-text integration entails each individual word being connected to a larger syntactic phrase, leading to the integration of words and phrases into sentences and larger text frames (Hagoort, 2005; Verhoeven & Perfetti, 2008). It is important to note that identified words are attached to not only syntactic phrases but also their underlying meanings of the semantic representation of a text. The referential integration of the meanings of words thus feeds the situation model being created by a written text. Word-by-word processing leads to word-to-text integration. And readers must then call upon prior knowledge to integrate the meaning of successive sentences and update the linguistic representation of the text being read and its underlying situation model. A situation model can also help the reader identify comprehension problems and find solutions for those problems (see Kintsch, 1988, 1998). When word identification is hampered as in the case of poor reading, however, comprehension will also be hampered (Stanovich, 2000).

In the *simple view of reading* as initially proposed by Hoover and Gough (1990), reading comprehension is presumed to be completely accounted for by word decoding and listening comprehension. That is, the pronunciation of a word is determined and, on the basis of this internal pronunciation, the meaning of the word and text is discerned. Reading comprehension is assumed to be the same as listening comprehension, once the decoding of a word (or word identification; Tunmer & Hoover, 1993) has taken place. And further in the simple view of reading, the reader's spoken language skill is assumed to determine the entire comprehension processes: the parsing of sentences into their constituent parts, the drawing of inferences to make the relations within and between sentences sufficiently apparent, the further facilitation of the integration of information, and the identification of the propositional structure (micro structure) underlying a text along with the global gist (macro structure) of the text (see Balota, Flores d'Arcais, & Rayner, 1990).

Extending from the simple view, the importance of lexical knowledge for reading comprehension cannot be overestimated. Both knowledge of word meanings (vocabulary) and the fluent retrieval of this knowledge on the basis of written words are critical for reading comprehension. The reading comprehension of both children and adults is supported by their knowledge of words and of the relevant orthographic, phonological, and semantic representations that can vary in their precision and interconnectedness. According to the lexical quality hypothesis (Perfetti & Hart, 2001), not only the sheer number of available words but also the quality of the reader's lexical representations can directly affect reading comprehension. There is a well-documented and strong association between vocabulary size and reading comprehension (cf. Torgeson et al., 1997; Verhoeven, 2000; Verhoeven, van Leeuwe, & Vermeer, 2011; Verhoeven & Perfetti, 2011).

1.2 Developmental Dyslexia: Definition and Intervention

1.2.1 Definition

Developmental dyslexia is typically defined as a specific learning disability "characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities" (International Dyslexia Association: https://dyslexiaida.org/definition-of-dyslexia/). The disability occurs despite the receipt of normal classroom instruction and sociocultural stimulation and opportunities. Although there are no uniform criteria for dyslexia and its genetic or neurocognitive underpinnings (see Elliott & Grigorenko, 2014), it is generally accepted that developmental dyslexia can be considered a neurobiological disorder with a genetic origin (e.g., Eden & Moats, 2002; Shaywitz & Shaywitz, 2008). As a case in point, Byrne et al. (2008) report that

40 percent of children with a familial risk for dyslexia do indeed develop reading deficits that manifest themselves within a few months of the start of formal reading instruction in a language with a relatively transparent orthography. The prevalence of developmental dyslexia varies according to the definition adhered to. By means of computational modeling, Perry, Zorzi, and Ziegler (2019) have recently identified subtypes of dyslexia stemming from problems with the nonlexical route for word identification, the lexical route, or both. In many places throughout the world, a cut-off criterion in terms of standard deviations below the population mean for word and pseudoword decoding and spelling tasks is adopted to identify cases of dyslexia. And using such a criterion, 5 to 10 percent of children are then identified as having dyslexia. In the current version of the *Diagnostic and Statistical Manual of Mental Disorders* (i.e., the *DSM-5*), dyslexia is classified in the broad category of specific learning disorders, which entails three main subtypes: reading disorders, mathematics disorders, and written expression disorders. For reading disorders, the components of word-reading accuracy, reading rate, reading fluency, and reading comprehension are distinguished. And according to Snowling and Hulme (2012), two different types of reading disorders can be distinguished on the basis of this information: decoding disorders and comprehension disorders. Children identified as having a decoding disorder generally suffer from developmental dyslexia and show difficulties mastering the relationships between the spelling patterns in words and their pronunciations. These children typically show slow and inaccurate reading, and they also show spelling problems.

Children identified as having a comprehension disorder are able to read words accurately and fluently but show difficulties understanding what they have read. Although dyslexia can be distinguished in a number of ways from other neurobiological disorders, it is often observed along with other impairments. For example, comorbidity with attention-deficit disorders has been found. Children with attention-deficit disorders often suffer from dyslexia as a consequence of an incapacity for sustained attention (Willcutt & Pennington, 2000). Dyslexia has also been found to show comorbidity with specific language disorders. Children with a specific language impairment (SLI), for example, show a significant spoken language deficit that cannot be attributed to neurological damage, hearing impairment, or intellectual disability (Leonard, 2014); SLI is known to affect about 7 percent of the population. Finally, as Bishop and Snowling (2004) have shown, distinguishing specific phonological as opposed to more general linguistic dimensions of impairment can help us identify neurobiologically and etiologically coherent subgroups, which reinforces the potential value of brain-based research models in this domain. Phonological skills form the basis for learning to read, whereas vocabulary and grammar are essential for reading comprehension.