SAMPLE CHAPTER

READING AND DYSLEXIA IN DIFFERENT ORTHOGRAPHIES

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## Contents

- List of figures vii
- List of tables xi
- List of editors and contributors xii
- Acknowledgements xiv
- Foreword xv

### UTA FRITH

#### SECTION 1

**The development of reading skills in different orthographies** 1

1 Reading and dyslexia in different orthographies: An introduction and overview 3
   **SINÉ McDougall, Nicola Brunswick and Paul De Mornay Davies**

2 A psycholinguistic grain size view of reading acquisition across languages 23
   **Usha Goswami**

3 Phonological development from a cross-linguistic perspective 43
   **Lynne G. Duncan**

4 Letter position encoding across deep and transparent orthographies 69
   **Maria Ktori and Nicola J. Pitchford**

5 Differences in reading ability between children attending Welsh- and English-speaking primary schools in Wales 87
   **J. Richard Hanley**

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Contents

6 Writing a language that you can’t hear 109
   TEREZINHA NUNES, DIANA BURMAN, DEBORAH EVANS AND DANIEL BELL

SECTION 2
Developmental dyslexia in different orthographies 129

7 Unimpaired reading development and dyslexia across different languages 131
   NICOLA BRUNSWICK

8 Reading acquisition and dyslexia in Spanish 155
   ROBERT A. I. DAVIES AND FERNANDO CUETOS

9 Lexical reading in Italian developmental dyslexic readers 181
   DESPINA PAIZI, PIERLUIGI ZOCCOLOTTI AND CRISTINA BURANI

10 Dyslexia in Chinese: Implications for connectionist models of reading 199
    I-FAN SU, KATHRIN KLINGEBIEL AND BRENDAN S. WEEKES

11 Dyslexia in biscriptal readers 221
   JOHN EVERATT, DINA OCAMPO, KAZUVIRE VEII, STYLIANI NENOPOULOU, IAN SMYTHE, HAYA AL MANNAI AND GAD ELBEHERI

SECTION 3
Neuroimaging studies of reading in different orthographies 247

12 Cross-cultural differences in unimpaired and dyslexic reading: Behavioural and functional anatomical observations in readers of regular and irregular orthographies 249
   ERALDO PAULESU, NICOLA BRUNSWICK AND FEDERICA PAGANELLI

13 Lexical retrieval in alphabetic and non-alphabetic scripts: Evidence from brain imaging 273
   BRENDAN S. WEEKES

Glossary 291
Author index 299
Subject index 307
1 Reading and dyslexia in different orthographies: An introduction and overview

Siné McDougall, Nicola Brunswick and Paul de Mornay Davies

Introduction

In the May 2009 edition of New Scientist, Andrew Robinson wrote about trying to decipher ancient lost languages. He stated that ‘Writing is one of the greatest inventions in human history. . . . Without writing, there could be no accumulation of knowledge, no historical record, no science—and of course no books, newspapers or internet.’ However, writing is no use if we are not able to read it. To decipher an ancient script, experts need to be able to link what they discover through archaeology with a known language, or at least one with which they are familiar. The research presented in this book shows that children learning to read are going through a similar deciphering process. Furthermore, the way that they learn to read is determined in no small part by the writing system that they are trying to decode. Even as adult skilled readers, the way that we read is constrained by the nature of the written code that we use.

There are over 400 writing systems, or orthographies, used around the world (Coulmas, 1989). The word orthography is derived from the Greek words orthós meaning ‘correct’ and gráphein meaning ‘to write’. An orthography is therefore the accepted usage of a set of symbols to represent a given language in a written form. When discussing the factors involved in creating new orthographies for unwritten languages, Cahill and Karan (2008) stipulated the following:

Not just any orthography will do; it needs to be effective. That is, it needs to be (a) linguistically sound, (b) acceptable to all stakeholders, (c) teachable, and (d) easy to reproduce. These roughly can be thought of as scientific, political, educational, and technical aspects (p. 3).

In contrast to the careful and systematic approach that can be taken when developing new orthographies, extant writing systems have evolved in a way which means that these reasonable requirements are rarely met. What follows is a brief overview of factors that have influenced the evolution of current orthographies to provide some insight into how the effectiveness of
orthographies may fall short of these ideals, and the challenges they present to readers as a result.

**Orthographies: A historical perspective**

**Pictograms and ideograms**

Cave drawings and paintings from the late Palaeolithic period (35–15,000 BC) have been found in many locations including France, India, Zimbabwe and Sweden. Some linguists and historians see these as the earliest precursors of writing. Others view them as straightforward pictorial representations of the world, but it is harder to see later collections of ‘picture writing’ by North American Indians—for example, those published by Mallery (1893) and Schoolcraft (1851)—as being purely pictorial. Figure 1.1 shows an example from Schoolcraft’s collection of drawings by Indian guides that tells the story of an exploratory expedition to the source of the Mississippi.

This drawing tells that there were 16 people on the expedition. Of these, two were American Indian guides and 14 were white men (denoted by the hats). The officer in charge is denoted by the sword on the far right. Next to him is the secretary of the party, who has a book in his hand. The figures at the top are infantry soldiers, and the muskets with which they were armed are shown beside them. At the bottom of the picture are a prairie hen and a tortoise, which had been caught the previous day.

This drawing is largely pictorial although we need to make several inferences (e.g., linking the muskets to the men to infer that they are infantry soldiers, and inferring the status of the officer in charge from the sword in his hand) to understand its full meaning.

![Figure 1.1](http://www.psypress.com/reading-and-dyslexia-in-different-orthographies-9781841697123)
Such drawings are often referred to as pictograms because they use a series of culturally accepted, fairly literal drawings of people and objects to tell a story. Over time, however, drawings gradually became more abstract and less pictorial—they became ideographic—representing mainly ideas and concepts rather than objects. In ideograms the relationship between what is depicted and what is meant is much more oblique, and viewers need to learn the meaning of individual symbols before they can grasp the concepts that they represent. One of the most famous examples of ideographic writing is the Yukaghir ‘love letter’ (see Figure 1.2). The Yukaghir tribe from north-eastern Siberia carved ideograms on birch bark to communicate affairs of the heart. In this particular image, the arrow shapes are believed to represent individual people (four adults and two children), and the solid and broken lines that connect them represent current and previous relationships between the adults (although see Unger, 2003, for an alternative view of this image). Even though these ideograms might superficially be regarded as pictorial, they

Figure 1.2 The Yukaghir ‘love letter’ (from Shargorodskii, 1895).
were actually highly stylized, represented complex ideas, and required considerable interpretation.

Although earlier writers (e.g., Diringer, 1947; Gelb, 1963) thought it a reasonable assumption that pictograms and ideograms formed the basis of subsequent writing, later researchers (e.g., Coulmas, 1985; DeFrancis, 1989) have been rather more sceptical. There were two main difficulties with the initial research. One was that although cultural meanings and interpretation were required to understand pictograms and ideograms, information was represented *semasiographically*. This means that there was no direct mapping between symbols and words, and no set of rules that related symbols to meaning, so the picture could be ‘read’ equally well in a number of different ways.

The second problem was that it was difficult to form a direct historical link between these early pictures and later writing. Many now think that the roots of true writing can be traced to the use of *tallies*, or early accounting systems, where the links between the written symbols and exactly what they meant was clearer. Meticulous research carried out by Schmandt-Besserat (1978, 1979) suggests that the roots of writing lie in early record-keeping and the use of tokens to record transactions. Stone clay tokens were kept in sealed containers called *bullae*. To identify the contents, the shape of each token was imprinted on the outside of the container. The crucial part of Schmandt-Besserat’s work was the discovery that the impressions of the tokens were graphically identical to the earliest form of what would become one of the most important early scripts: Sumerian cuneiform writing. In this way, her research formed a much-needed link between the earliest forms of writing and a later, fully fledged, written script.

**Logographic, syllabic and alphabetic orthographies**

**Sumerian cuneiform writing: A logographic orthography**

The Sumerians lived in southern Mesopotamia (modern-day Iraq). Excavations in this area, from sites at Uruk, Jemdet Nasr, Ur and Babylon, have brought to light traces of a great civilization, including thousands of clay tablets written in cuneiform script (see Figure 1.3). To produce this script, impressions were made in clay with a wedge made out of reeds that had a triangular tip (hence the name *cuneiform*, which derives from the Latin *cuneus*, meaning ‘wedge’). This technique produced linear pictograms, because the wedge impression was the fundamental component.

Over time, however, writing became progressively more stylized and less pictorial, until only those who were trained and had knowledge of the script could decipher what the symbols meant. This early form of writing is logographic (derived from the Greek *logos*, meaning ‘word’) because one symbol represented each word. In adopting a rule-based approach in which the relationship between a symbol and its meaning was prescribed, the guesswork...
involved in interpreting semasiographic scripts was avoided; writing thus became an effective way of representing a multiplicity of meanings rather than being restricted to limited meanings in particular contexts.

In later writing, logographic systems were adapted to represent syllables and, later still, consonants and vowels. The development of syllabaries and alphabets is largely the product of borrowing from earlier logographic writing systems and changing them to suit the needs of a particular language or culture (Olson, 1989).

**Akkadian: A syllabic orthography**

One of the first true syllabaries, Akkadian was derived from the Sumerian script around 2800 BE. The Akkadian people of Mesopotamia adapted the
cuneiform script to represent the sounds of the syllables in their own language, so the logographic cuneiform script evolved into a syllabic writing system.

**The development of the alphabet**

It is now generally agreed that the Phoenicians in Northern Syria used the first alphabetic writing system around 1500 BC; this was derived from a combination of adapted Egyptian hieroglyphics and the Akkadian script. In the Phoenician language the emphasis was on consonants rather than vowel sounds, and 26 of the 28 characters were consonants. For this reason, Phoenician is known as a consonantal alphabet.

The transition from consonantal to alphabetic writing occurred when these scripts were adapted for use in Greek. Like English and many other European languages, Greek is a language in which a change in vowel sounds changes the meaning of the word (e.g., cat, cot, cut); it is therefore important to represent those sounds in writing so that we can differentiate one word from another. To fill the ‘vowel gap’, Phoenician characters that represented sounds unknown in Greek were borrowed to represent vowels. It is this addition of vowel sounds that enabled the Greek script to become the root for many European languages, including English.

**Contemporary writing systems**

Figure 1.4 shows examples of contemporary logographic, syllabic and alphabetic writing systems (Chinese, Cherokee and Greek). Continued use of each type of script reflects to some extent the goodness-of-fit between a script and the language it is meant to represent.

<table>
<thead>
<tr>
<th>Logographic script</th>
<th>Syllabic script</th>
<th>Alphabetic script</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese</td>
<td>Cherokee</td>
<td>Greek</td>
</tr>
<tr>
<td>木</td>
<td>G tsa</td>
<td>a</td>
</tr>
<tr>
<td>tree</td>
<td>α</td>
<td>a</td>
</tr>
<tr>
<td>茶</td>
<td>V tse</td>
<td>e</td>
</tr>
<tr>
<td>chá</td>
<td>κ tsi</td>
<td>f</td>
</tr>
<tr>
<td>tea</td>
<td>μ wa</td>
<td>m</td>
</tr>
<tr>
<td>閏</td>
<td>φ we</td>
<td>p</td>
</tr>
<tr>
<td>wén</td>
<td>π wi</td>
<td>t</td>
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<tr>
<td>to hear</td>
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<td>海</td>
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<td>hai</td>
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<td>海</td>
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<tr>
<td>zhong sea</td>
<td></td>
<td></td>
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<tr>
<td>中</td>
<td></td>
<td></td>
</tr>
<tr>
<td>middle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 1.4 Examples of logographic, syllabic and alphabetic scripts (adapted from Campbell, 1997).*
Logographic writing systems

The early development of a strong written tradition in China has tended to preserve and maintain the initial logographic writing system, although 80–90 per cent of characters now include both a semantic element that provides information about the meaning of the character, and a phonetic element that provides information about its pronunciation (DeFrancis, 1989; Sampson, 1985; Zhou, 1978).

One reason why this combination of semantic and phonetic information within the character is so useful is because there are, on average, 11 homophones (words that sound the same but differ in meaning) for every single-syllable word in Chinese Mandarin (Beijing Language Institute, 1986). These homophonic words can be distinguished relatively easily on the basis of the visual cue provided by the semantic element of the character. Similarly, in English homophones are almost always visually distinguishable—for example, pair, pare and pear; raise, raze and rays.

Syllabic writing systems

There are many syllabic scripts, including Japanese, Korean, Hindi and Cherokee. Figure 1.4 shows examples of the Cherokee script in which 85 symbols are used to denote combinations of consonant–vowel sounds that comprise the syllables of the language. This syllabary is one of the most famous American Indian writing systems and was invented in 1821 by Sequoyah, a half-Cherokee Indian, for his native language. The simplicity of the writing system meant that it could be learned easily, and it was soon adopted throughout the Cherokee nation. Aside from its simplicity, a syllabary was ideally suited to the Cherokee language, in which concepts are represented by a series of prefixes and suffixes added to an original stem word.

Alphabetic writing systems

In the simplest and most straightforward alphabetic writing systems, such as Finnish or Turkish, each symbol or letter (grapheme) represents a single sound (phoneme) (Öney & Durgunoğlu, 1997; Seymour, Aro, & Erskine, 2003). In these languages ‘sounding out’ individual letters to read and pronounce them is a successful strategy. In Cahill and Karan’s (2008) terms, these scripts might be seen as meeting the requirements of an effective writing system since they are linguistically transparent as well as being easy to teach and reproduce. However, this one-to-one match, where graphemes map onto phonemes and vice versa, is not common. In most alphabetic languages more intricate and unpredictable letter–sound relationships appear. For example:

Several letters (complex graphemes) may represent a single phoneme (e.g., in light and sight, the letters ‘ght’ represent the final sound in the word).

Spelling of words may signal related lexical identities (e.g., sign and signature derive from the same orthographic root, as do bomb and bombard; see Venezky, 1970).

Spelling of words may provide a visual contrast for homophones (e.g., pair, pear and pare).

Letter–sound relationships may depend on the context in which they appear (e.g., a tear rolled down his cheek; a tear appeared on her sleeve).

Spelling may be simplified for morphological functions (e.g., adding an ‘s’ to pluralize robes and roses is much simpler than writing robz and rosiz; see Ellis, 1993).

The degree to which such variations occur in a language reflects its orthographic depth. Shallow, or transparent, orthographies (such as Finnish) are at one extreme while deep, or opaque, orthographies (such as English) are at the other (see Table 1.1).

Seymour et al. (2003) suggested that the complexity of syllables in a language (i.e., its linguistic complexity) is also important in determining the level of its orthographic complexity. Most Romance languages, such as Italian and Spanish, have simple syllables consisting of consonants and vowels (CV syllables) with few initial or final consonant clusters, as exemplified by the words pasta and costa. In contrast, Germanic languages (e.g., German, Danish, English) have numerous closed CVC syllables and complex consonant clusters, as exemplified by the word entschuldigen in German. Given the number of sounds in complex syllables, it is not surprising that they are not easily represented in an alphabetic script and that they require more letters and more complex letter combinations.

Logically, it might seem better to explore the possibility of representing Germanic languages using a syllabic script. However, if we take English as an

Table 1.1 Classification of languages in accordance with orthographic depth and complexity of syllabic structure

<table>
<thead>
<tr>
<th>Syllabic structure</th>
<th>Orthographic depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>Shallow</td>
</tr>
<tr>
<td>Finnish</td>
<td>Greek</td>
</tr>
<tr>
<td>Italian</td>
<td>Portuguese</td>
</tr>
<tr>
<td>Spanish</td>
<td>French</td>
</tr>
<tr>
<td>Complex</td>
<td>German</td>
</tr>
<tr>
<td>Norwegian</td>
<td>Dutch</td>
</tr>
<tr>
<td>Icelandic</td>
<td>Swedish</td>
</tr>
<tr>
<td></td>
<td>Danish</td>
</tr>
<tr>
<td></td>
<td>English</td>
</tr>
</tbody>
</table>

Adapted from Seymour, Aro, and Erskine (2003).
example, the number of possible syllables is huge. Frost (2005) noted that not only are there many possible syllable structures (CV, VC, CVC, CCVC, CVCC, etc.), there are also 24 consonant sounds and 15 vowel sounds. This means that one would need approximately 15,000 syllable symbols which would not exactly be effective as a means of representation. It therefore seems that some languages are more difficult to represent optimally, and some degree of ‘lack of fit’ is inevitable. However, it is worth noting that for English at least, the closeness of the relationship between what is said and what is written has waxed and waned across the centuries (Scragg, 1974). What tended to make letter–sound relationships (or the lack of them) more permanent was the introduction of the printing press in the fifteenth century followed by the publication of the first dictionaries in the sixteenth and seventeenth centuries.

The effect of these dictionaries was to establish ‘correct’ spellings, and later changes in pronunciation are therefore not reflected in current spelling practice. The divergence between earlier phonemic spellings and our current pronunciations is seen in many words that begin with a silent $h$; this was still pronounced in some words (such as honest, honour and heir) until the eighteenth century. Interestingly, the word herb is currently undergoing this divergence—in American English the $h$ is no longer pronounced, while in British English it is still pronounced.

**Contemporary research**

It is apparent that, for a variety of historical reasons, some orthographies are considerably more complex than others, but as yet there is no formal measure of orthographic complexity. In an attempt to address this issue, Seymour and colleagues (2003) produced the classification shown in Table 1.1 following their survey of experts from several European countries (for a discussion of possible orthographic complexity metrics, see also Ziegler, Stone, & Jacobs, 1997).

Research has shown that the rate at which children learn to read (and the difficulties that dyslexic readers experience) corresponds approximately to the orthographic complexity of the language that they speak (see Caravolas, 2005; and Ziegler & Goswami, 2005, for reviews). The precise nature of this relationship and the reasons for it are explored in the chapters that follow.

This volume is divided into three sections: Section 1 considers the skills required for learning to read in different orthographies and the differences in developmental trajectory resulting from the nature of the mapping between spoken language and the writing system. Section 2 explores the way in which the symptoms and aetiology of dyslexia vary as a result of differences between orthographies. Section 3 shows how neuroimaging studies inform our understanding of the role of orthography in reading. A brief summary and overview of each section is given below.
Section 1: The development of reading skills in different orthographies

The first two chapters in Section 1 provide differing theoretical perspectives on the nature of the relationship between language and orthography and how this shapes children’s progress in learning to read. Usha Goswami (chapter 2) presents a psycholinguistic grain size view of reading across languages. In this chapter she sets out a theoretical framework that seeks to explain how as children acquire literacy they form mappings between their knowledge of the phonological units, or grains, of language (syllables, rimes and phonemes) and the way the language is written. Only once children have developed an effective understanding of how component sounds in their spoken language map onto units of their written language can their reading progress successfully. The framework therefore provides a way of explaining differences in the ease and speed of reading acquisition across orthographies. A key assumption is that children develop an awareness of the larger grains of words first (i.e., syllables and rime) and then progressively of smaller grains (i.e., phonemes and individual letter sounds). Goswami argues that this ‘large-to-small progression’ in awareness is universal across languages although there may be variation in the speed at which it occurs.

Lynne Duncan’s approach in the following chapter (chapter 3) shares much with that taken by Goswami. Her review of the literature also highlights ways in which reading development is shaped by the nature and complexity of mappings between language and orthography. However, she takes issue with one of Goswami’s key assumptions—that progression in awareness follows a uniform pathway from large to small phonemic units. On the basis of her research examining acquisition of skills in the first year of reading across several European languages, Duncan argues that very different ‘grain size’ routes are taken by speakers of different languages. For example, despite their relatively poor awareness of syllables and rime, English speakers’ awareness of initial phonemes is just as good as that of their French, Icelandic, Portuguese and Spanish counterparts. This suggests that English readers may proceed straight to awareness of smaller grain sizes without developing anything more than a superficial awareness of larger units. She therefore concludes that, rather than there being a universal ‘large-to-small progression’, learning paths in phonological development are shaped by native language, orthography and reading instruction.

In attempting to reconcile the data reported in these two chapters, it should be noted that apparent differences in findings and subsequent theory can hinge on the way in which children’s knowledge and understanding of phonology is assessed. At the heart of the debate between Duncan and Goswami is Duncan’s use of tasks designed to assess implicit (holistic) phonological understanding and explicit (analytic) phonological understanding. Duncan argues that English speakers develop only an implicit understanding of larger units before progressing to an explicit understanding of phonemes. No such distinction is made by Goswami. For this reason, it is worth looking at

Duncan’s helpful table of phonological tasks (Table 3.2) and comparing the implicit and explicit tasks before reading both chapters carefully and drawing your own conclusions. Whatever conclusion you come to, it is worth bearing in mind that both viewpoints are influential in shaping current views of reading acquisition.

The remaining chapters in this section describe research examining differences in rates of reading acquisition that result from orthographic variation. Maria Ktori and Nicola Pitchford used a visual search paradigm to simulate how individuals scan words to identify letters and their positions (chapter 4). They showed that as children learn to read, a specialized system for doing this quickly emerges that is shaped by the orthography to which the children are exposed. When Ktori and Pitchford compared readers of Greek (a very transparent orthography) with readers of English, they found systematic differences in patterns of visual search that became progressively more marked as reading skills developed (see Figures 4.4 and 4.5). These patterns of visual search appear to reflect differences in underlying orthographic processing. Skilled English readers tend to search for, and identify, the first and last letters in a word; this is in line with whole-word parallel (or lexical) processing. However, while they are still learning to read, English children rely more heavily on identifying letters serially from left to right. This pattern is much more similar to that adopted by Greek readers, who tend to favour sequential decoding because of the transparency of the Greek orthography. The particular balance of processing in visual search is dependent on the demands of the orthography being used. These findings pose a challenge to existing models of letter position encoding, which assume either serial position encoding or parallel encoding. This chapter is a good example of how comparing and contrasting different orthographies helps to advance our understanding of the fundamental cognitive processes underpinning reading development. It also demonstrates that the orthographic mapping process requires specialist visual, as well as linguistic, processing. Not unrelated is the finding by Bosse, Tainturier, and Valdois (2007) that dyslexic children may have deficits in their visual attention span. The next logical step in research using the visual search paradigm may therefore be to explore the role of visual attention span in different orthographies in order to investigate whether or not this is related to the specialist visual search processing implicated in Ktori and Pitchford’s study.

The research reported by Rick Hanley in chapter 5 resulted from the situation where two languages coexist in one geographical area. In Wales, some children receive reading instruction in Welsh (a transparent orthography), while others receive instruction in English. Hanley found that children learning the transparent Welsh orthography did better than their peers on phoneme awareness tasks, and they learned to read more quickly. He argues that such differences cannot be easily attributed to cultural differences since the children are drawn from the same area of Wales. Of particular interest is the finding that, in the original longitudinal sample, the most profound
differences between Welsh- and English-speaking children emerged in the lowest quartile of readers. This suggests that children who experience reading difficulties have more trouble creating mappings between language and orthography when the orthography is inconsistent and opaque. This suggestion was borne out when, in a neat addition to the original work, another sample was tested several years later, after the development of a national phonics-based literacy strategy for English speakers. By this time, the lag in performance between the poorest readers in English and their Welsh counterparts had diminished considerably. Thus, while poor readers may encounter greater difficulties with less consistent and more complex orthographies, these difficulties can at least be partially overcome by intensive phonics instruction.

The final chapter in this section (chapter 6), by Terezinha Nunes, Diana Burman, Deborah Evans and Daniel Bell, considers the case of children who are deaf. These children have particular difficulty creating mappings between language and orthography, although, as this chapter shows, they may be able to use the indirect connection between oral and written language via meaning. Morphemes are the units in words that convey meaning. For example, the word *cars* consists of two morphemes, a stem *car* and the affix *s* to indicate the plural. The first study that Nunes and colleagues report shows that deaf children’s understanding of morphology makes an important contribution to their reading skills. In the second study, children were given a short intervention consisting of exercises to promote their awareness of morphemes, along with specially designed story books. This enhanced not only the children’s use of morphology in spelling but also their reading comprehension and writing skills. These findings have two major implications. First, that a simple intervention can substantially help deaf children to strengthen the tenuous and uncertain connection between British Sign Language and English orthography. Second, that we access orthography not only via phonology, but also via morphology. This latter finding is entirely congruent with other research that emphasizes the role of morphology in reading, particularly as children progress beyond the initial stages of learning (Castles & Nation, 2008; Nunes & Bryant, 2006, 2009).

To summarize, Section 1 provides an overview of current theoretical perspectives on how orthography shapes the rate and trajectory of reading development. It also shows that our ability to deal with orthography may rely not only on creating mappings between phonology and orthography, but also on the degree to which our visual processing and morphemic skills map onto the orthography that we use. The chapters by Hanley (chapter 5) and by Nunes and colleagues (chapter 6) also show how effective phonological and morphological interventions can be in determining final outcomes in learning to read.

**Section 2: Developmental dyslexia in different orthographies**

A great deal of what we know about the nature and incidence of developmental dyslexia comes from studies in English and may therefore be as
idiosyncratic as the orthography from which it is derived. Section 2 broadens this perspective.

Nicola Brunswick begins this section (chapter 7) with a review of skilled and impaired reading in different orthographies. Initially the orthographic depth hypothesis suggested that readers of transparent orthographies such as Spanish or Italian rely primarily on sub-lexical phonological recoding to read words, while readers of opaque languages such as Danish or English are much more likely to use whole-word lexical strategies (e.g., Katz & Frost, 1992). However, research findings have now accumulated which show that all readers, irrespective of orthography, use a combination of lexical and sub-lexical processing. This has led to the development of weaker versions of the orthographic depth hypothesis. The latest instantiation of this is the psycholinguistic grain size theory outlined by Goswami in chapter 2. Brunswick then presents evidence to show that the incidence of dyslexia depends upon a combination of the degree of granularity of the language and the transparency of the orthography (see Figure 7.4). This sets the scene for the remaining chapters in this section, which explore the nature and incidence of dyslexia in Spanish (Davies & Cuetos, chapter 8), Italian (Paizi, Zocolotti, & Burani, chapter 9), Chinese (Su, Klingebiel, & Weekes, chapter 10) and other deep and shallow languages (Everatt et al., chapter 11).

The findings of both Davies and Cuetos and Paizi and colleagues add weight to Brunswick’s contention that readers of transparent orthographies use a combination of sub-lexical and lexical processing. Dyslexic readers of Spanish and Italian do read more slowly, but they also show the lexical effects that are evident in more skilled readers, so these findings suggest that reading in Italian and Spanish is affected by morphology and semantics as well as by phonology. In this context, Davies and Cuetos’ suggestion that there is a convergence in processing mechanisms across orthographies in adult readers seems plausible. It is apparent from the research presented here that adult readers, irrespective of orthography, combine multiple forms of representation and processing to produce skilled reading. However, it is clear from Su and colleagues’ chapter that the balance of processing is likely to be different for the reading of logographic scripts such as Chinese. They argue that while there are similarities between dyslexia in Chinese and dyslexia in alphabetic languages, the difficulties experienced by these two groups of dyslexic readers cannot be identical because the orthographies are so different. For those of us used to dealing only with alphabetic scripts, the sheer complexity of the mappings required between language and orthography in Chinese is bewildering. The table describing Chinese writing (Table 10.1) is particularly helpful to the reader and, along with the description in the text, provides fascinating insights into the challenge of reading in Chinese.

In contrast to previous chapters, the authors of these three chapters situate their findings within connectionist models of reading such as the dual-route cascade (DRC) model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), the connectionist dual processing (CDP+) model (Perry, Ziegler, & Zorzi,
2007), the polysyllabic multiple-trace (ACV98) model (Ans, Carbonnel, & Valdois, 1998) and, for reading in Chinese, the lexical constituency (LC) model (Perfetti, Liu, & Tan, 2005). Davies and Cuetos’ review of connectionist theories, combined with their developmental approach, helps the reader to bring together these perspectives on the reading of both skilled adults and early learners.

The strain of existing connectionist models is almost palpable as these researchers seek to explain their findings. It is therefore not surprising that Davies and Cuetos put forward a model that combines connectionist principles with the self-teaching mechanism proposed by Share (1995) through which language-orthographic mappings emerge to allow successful reading. Su and colleagues utilize a new model of reading in Chinese to explain their findings (see Klingebiel & Weekes, 2008): this model allows for the complex representations of orthographic, phonological and semantic (lexical and morphemic) information in Chinese to interact to produce speech. It is clear that one of the challenges ahead in reading research is to provide computational models which are more developmental in their perspective and which specify more fully the nature and interaction of developing representational frameworks for reading.

In the final chapter of this section, Everatt and colleagues report an examination of dyslexia across several orthographies including English, Hungarian, Arabic, Chinese and Herero. While the measurement of phonological skills appears to be important in predicting reading difficulties across a variety of scripts, it is also clear that predictors of reading difficulty vary according to the nature of the script being learned. When bilingual children with reading difficulties were simultaneously learning to read one transparent and one opaque orthography, the predictors of literacy deficits in the less transparent language re-emerged as predictors of literacy in the more transparent language. Moreover, phonological skills in one language appeared to be good predictors of reading ability in both languages. This finding raises the issue of the degree to which common processes are being used in each language and the extent to which common representational structures—rather than individual representations—support bilingual reading.

The final section of this volume shows how neuroimaging research, by combining behavioural data with brain scanning (fMRI, PET and MEG), has been able to address these issues.

**Section 3: Neuroimaging studies of reading in different orthographies**

In a review of neuroimaging studies of skilled reading and dyslexia across languages, Paulesu, Brunswick and Paganelli show that several areas of the brain support reading. This multi-component reading system appears to be similar across languages although the extent to which different brain areas are implicated depends on the transparency of the orthography. This finding reflects a common theme running through the chapters in this book. A good
An example of this is provided by Paulesu et al.’s (2000) study, which compared PET scan data from Italian and English participants during reading. While both groups showed common activation in the classical language areas of the perisylvian cortex, Italian readers showed greater activation of the left planum temporale, which has been implicated in phonological processing. English readers, in contrast, showed greater activation in the left posterior inferior temporal cortex and the anterior inferior frontal gyrus, areas associated with word retrieval during reading and naming. Neuroimaging studies have also been able to provide convergent evidence of a phonological deficit underlying the reading deficits in dyslexia. Several studies have provided evidence for abnormal activation of, and connectivity between, areas of the brain associated with phonological processing, naming and sub-lexical processing. Also apparent is the brain’s ability to respond to reading remediation. Paulesu and colleagues review a number of studies in which improved reading performance has been reflected in increased activation of associated brain regions. These findings are encouraging, suggesting that reading difficulties are not immutable.

The final chapter, by Brendan Weekes (chapter 13), shows that brain imaging can help to tease out the nature of lexical processing in alphabetic and non-alphabetic scripts in a way that has not previously been possible in behavioural studies of word recognition. One of the great debates has been the extent to which the speed and accuracy of word reading are determined by the frequency with which we have previously encountered the word (e.g., say, a frequent word vs. sty, an infrequent word) and the age at which we acquired it (e.g., sun, an early-acquired word vs. sop, a late-acquired word; Morrison, Ellis, & Quinlan, 1992; Oldfield & Wingfield, 1965). In addition, the extent to which word frequency and age of acquisition effects are independent of one another (since typically words that are more frequent are also those that we are likely to acquire earlier) has also been the subject of much debate. Weekes reports work that he and his colleagues have conducted in which they capitalize on the nature of Chinese orthography to vary frequency and age of acquisition orthogonally. When fMRI was used in conjunction with a lexical decision task, frequency and age of acquisition showed independent effects on brain activity during reading, with activation in different loci for words that differ in frequency compared to words that differ in age of acquisition. These findings are comparable to those reported for German by Fiebach, Friederici, Müller, von Cramon, and Hernandez (2003).

Weekes’s chapter also explores the mapping between orthography and phonology in Chinese. His findings suggest that orthographic and phonological representations may be underpinned, at least in part, by different neural mechanisms in Chinese readers’ brains, making the development of connectivity between loci important in reading acquisition (see Paulesu, Frith, Snowling, & Gallagher, 1996, for an early brain scanning study showing the importance of brain connectivity in reading). He draws on these findings to inform current models of word reading and picture naming in Chinese.
The themes of localized neural activation and inter-region connectivity, which are central to current brain-based explanations of learning, emerge strongly from both chapters in this section, and it is clear that they will be at the heart of future studies examining reading acquisition across languages (Goswami, 2008).

Conclusion

The research reported here demonstrates the rapid advances that have been made in recent years in our understanding of how reading develops; it is a current collection of work in a tradition of cross-linguistic studies of reading that has spanned over three decades. This cross-linguistic thread can be traced in research collections from the 1980s (Henderson, 1984; Kavanagh & Venezky, 1980), the 1990s (Frost & Katz, 1992; Harris & Hatano, 1999; Taylor & Olson, 1995) and through the 2000s (Joshi & Aaron, 2006; Smythe, Everatt, & Salter, 2004). As we have already noted, current theoretical debates, new methodologies and ever-widening orthographic populations are included in this volume.

As well as indicating what we already know, this book also specifies where further research is required. In our view, there are four main areas that need to be addressed. These are:

Theory development

The work reported in this book shows that cross-language research has the potential to inform theoretical debates, particularly with respect to connectionist models (see chapters by Davies and Cuetos, Paizi et al. and Su et al.). A focus on research that specifically tests the assumptions of opposing models will help to develop our theoretical (as well as practical) understanding of reading. Examples of such research are now beginning to emerge (see, for example, Rastle, Havelka, Wydell, Coltheart, & Besner, 2009).

Information about the later stages of reading development

Research has traditionally focused on the very earliest stages of reading development, but this leaves a large gap in our understanding of how the child who can slowly read a few words becomes the skilled adult reader who reads automatically and effortlessly. This gap is now beginning to be filled by research examining morphemic and orthographic development (see Castles & Nation, 2008; Nunes & Bryant, 2006, 2009; Nunes et al., chapter 6).

Adopting a flexible and multi-causal approach

What is apparent from the research reported in this volume is that tactics that individuals adopt to help them to read are based on a multi-strategic and
problem-solving approach. While developing an effective mapping between phonology and orthography is clearly critical, it is also apparent that other basic processes support our reading. An example of this is the nuanced visual scanning developed by readers in response to different orthographies (see Ktori and Pitchford, chapter 4). Similarly, it is still an open question as to whether or not the learning mechanisms that underlie visual and verbal paired-associate learning contribute to learning, particularly in languages with opaque and complex orthographies (for a discussion, see Lervåg, Bråten, & Hulme, 2009).

**Reliable and replicated fMRI studies**

Brain scanning techniques such as fMRI clearly have enormous potential, not only to provide evidence in support of existing behavioural data but also to extend our understanding of the brain mechanisms involved in reading. In reading research, as in other areas of psychology, there is a need to show reliable and replicable findings from these studies which typically have a small number of participants and large assumptions built into the data analysis.

Research in all of these areas is only likely to be meaningful if it goes beyond the idiosyncratic and constrained confines of English orthography to embrace the advantages that can be found in comparing and contrasting reading and its development across languages.

**References**


