

Cross-Cultural/Linguistic Differences in the Prevalence of Developmental Dyslexia and the Hypothesis of Granularity and Transparency

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1. Introduction

In this chapter, cross-cultural and cross-linguistic differences in the prevalence of developmental dyslexia will be discussed. In order to account for the differences, the Hypothesis of Granularity and Transparency postulated by Wydell and Butterworth (1999) will be revisited.

Developmental dyslexia is defined as a failure to acquire reading skills, despite adequate intelligence, education and sociocultural opportunity (Chrichey, 1975), and it is generally accepted that it is a neurobiological disorder with a genetic origin (e.g., Eden & Moat, 2002; Fisher & DeFries, 2002). It has been reported that up to 10 - 12% of children in the English speaking world suffer from developmental dyslexia (e.g., Shaywitz, Shaywitz, Fletcher, & Escobar, 1990; Snowling, 2000). Extensive research has been conducted in order to ascertain the causes of dyslexia (and subsequently to develop intervention programmes), since dyslexia sufferers form a large minority group, and yet there seems to be no consensus amongst the researchers as to what causes developmental dyslexia.

Ramus (2003) reviewed recent empirical studies in relation to major theories accounting for the causes of developmental dyslexia, such as for example, *the auditory processing (in particular, rapid or temporal processing) deficit hypothesis* (e.g., Tallal, 1980; Share, Jorm, MacLean, & Matthews, 2002); *the visual processing deficit hypothesis including magnocellular dysfunction hypothesis* (e.g., Hansen, Stein, Orde, Winter and Talcott, 2001; Stein, 2001; 2003); *the motor control deficit hypothesis* (e.g., Wolf, 2002) including *the cerebellar dysfunction hypothesis* (e.g., Nicholson, Fawcett, & Dean, 2001); *the general sensorimotor processing deficit hypothesis* (e.g., Laasonen, Service, & Virsu, 2001; 2002) and the *phonological processing deficit hypothesis* (e.g., Ramus, 2001; Snowling, 2000). In his succinctly written review, Ramus pointed out that behavioural genetic studies revealed that phonological deficits are highly heritable, whereas auditory and visual deficits are not (e.g., Davis, Gayan, Knopik, Smith, Cardon, Pennington, Olson, & DeFries, 2001; Olson & Datta, 2002), and concluded that “although the phonological deficit is still in need of a complete cognitive and neurological characterisation, the case for its causal role in the aetiology of the reading and writing disability of the great majority of dyslexic children is overwhelming” (p.216).

Indeed, many behavioural studies in English have found core phonological deficits in children with developmental dyslexia (e.g., Stanovich, 1988; Stanovich & Siegel, 1994;

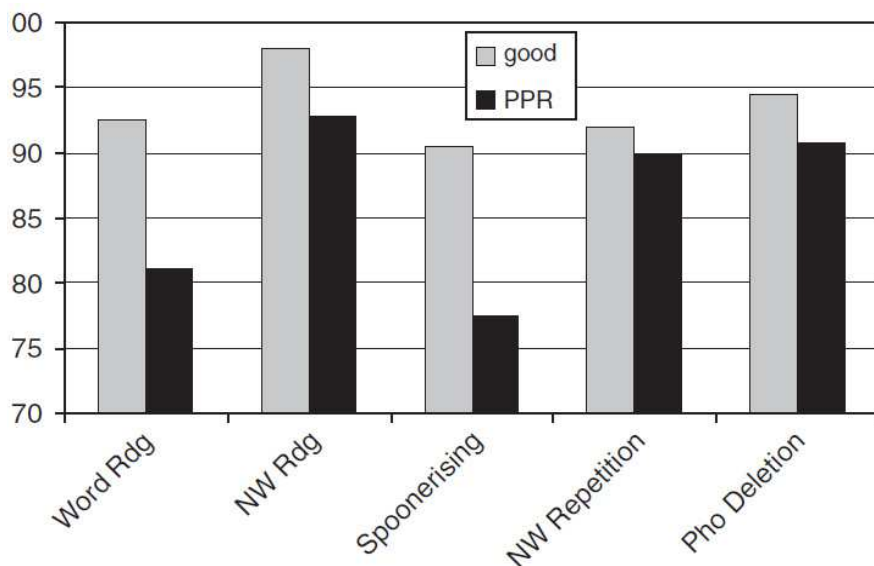
Snowling 2000). The phonological deficits tend to interfere with the acquisition of appropriate grapheme-to-phoneme conversion skills. Moreover, adults with childhood diagnoses of dyslexia also revealed persistent phonological deficits (e.g., Bruck, 1992). For example, Felton, Naylor, and Wood (1990) found that adults with developmental dyslexia were impaired compared with normal controls using Rapid-Automatized-Naming (RAN), phonological awareness skills and non-word reading tests. Similarly, Paulesu, Frith, Snowling, Gallagher, Morton, Frackowiak and Frith (1996) found that even well-compensated dyslexic adults showed residual phonological deficits on phoneme deletions and Spoonerizing (exchange the initial phonemes of a pair of words, e.g., /car/ /park/ -> /par/ /cark/) tests.

2. Dyslexia and poor phonological recoders

More recently, Wydell in Shapiro, Hurry, Masterson, Wydell and Doctor (2009) tested 158 male and female students aged 14–15 in a state-funded selective and highly academic secondary school in the UK, and identified a subset students with phonological deficits.

The following five phonological tests (in written format) were administered to all the participating students: Rhyme-Judgements in words (e.g., YES to 'head-bed'), Rhyme-Judgement in nonwords (e.g., YES to 'kape-bap'), Homophone-Judgements in words (e.g., YES to 'their-there'), Homophone-Judgements in nonwords (e.g., YES to 'kane-kain'), Phonological-Lexical Decisions (e.g., YES to 'brane').

Wydell identified 16 students out of this cohort (*approximately just over 10%*), whose scores on any of these tests fell more than 1.5 standard deviations (SD) below the mean of the group, as *poor phonological recoder (PPR) readers* (i.e., those with phonological deficits).



Note: The figure was extracted from Shapiro, Hurry, Masterson, Wydell and Doctor (2009).

Fig. 1. Proportion correct for reading and phonological tasks of PPR-Readers compared with that of the controls.

Those PPR-readers and 16 randomly selected normal readers were further tested for their skills in Word Reading, Nonword Reading, Spoonerizing, Phoneme Deletions, and Non-word Repetition. As illustrated in *Figure 1*, the results revealed that PPR-readers were significantly worse than the controls on all the tests ($p > .01$ – $p > .0001$) except for Phoneme Deletions ($p = .08$) and Non-word repetition ($p > 1$). Note that Gathercole and Baddeley's (1996) Non-word Repetition test is known to be one of the most effective diagnostic tools to identify developmental dyslexia in young children. Yet, this test did not show any difference between the PPR-readers and the normal controls. This might be because the test was developed primarily to assess young children's phonological skills, and that the test might not be sensitive enough for these adolescent individuals.

Furthermore, Wydell compared these PPR-readers' performance on SATs¹ in English, Science and Mathematics individually, with that of the normal controls using z-scores².

The results revealed that 60% of PPR-readers' SAT-English scores, and 70% of their SAT-Science scores were significantly lower than those of normal controls (both at $p < .001$). In SAT-Maths scores, however, none of the PPR-readers were significantly worse than the controls, indicating that cognitive processes involved in reading may be different from those involved in mathematical operations (a similar pattern of data can be seen in the case study reported by Wydell & Butterworth, 1999).

Wydell thus identified a subset of students aged 14-15 with phonological deficits even in a selective and competitive academic environment, where all students appeared to be performing well against the national average. Yet, these PPR-readers can still be considered as academic underachievers, as Hannell (2004) suggested.

3. Dyslexia and the hypothesis of granularity and transparency

Wydell and Butterworth (1999) reported the case of an adolescent English-Japanese bilingual male, AS, whose reading and writing difficulties are confined to English only. Extensive investigations into his reading/writing difficulties in English revealed that he has typical phonological processing deficits (Wydell & Butterworth, 1999; Wydell & Kondo, 2003). *Figure 2* illustrates his performance in reading and phonological processing tests in English together with those of age-matched English and Japanese monolingual controls, which clearly indicate his phonological processing deficits.

However his ability to read Japanese was equivalent and often better than that of his Japanese peers, as illustrated in *Table 1*.

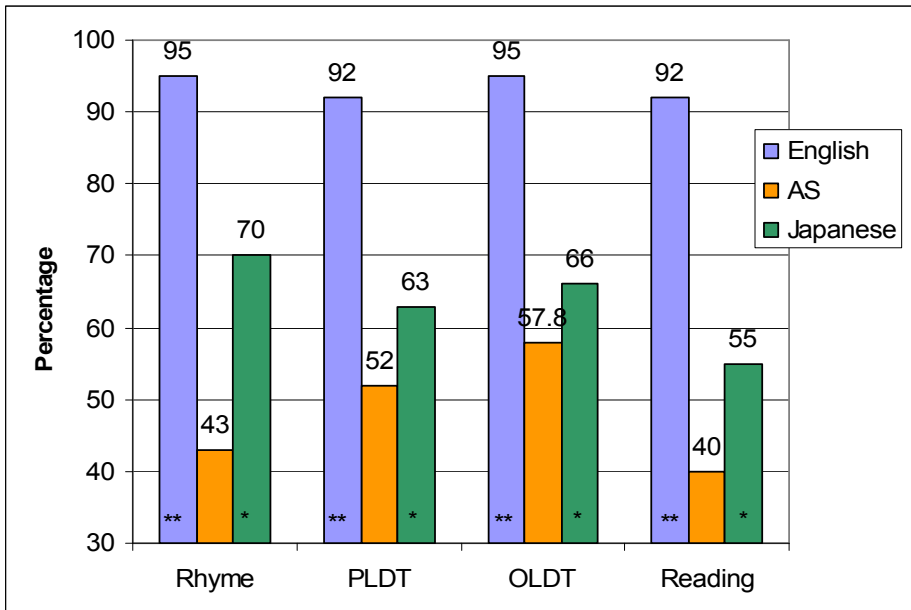
Note that the Japanese writing system consists of two qualitatively different scripts: logographic, morphographic Kanji, derived from Chinese characters, and two forms of syllabic Kana, Hiragana and Katakana which are derived from Kanji characters (see Wydell, Patterson, & Humphreys, 1993 for more details). These three scripts are used to write different classes of words. Kanji characters are used for nouns and for the root morphemes

¹ SATs - Standard Assessment Tests: national achievement tests given to all the children across the UK at the end of Year-2 (aged seven), Year-6 (aged 11) and Year-9 (aged 14).

² This is because it has been reported that there are marked individual differences among children with developmental dyslexia both in terms of the extent of the severity and the nature of difficulties/impairments (e.g., Snowling & Griffiths, 2005).

of inflected verbs, adjectives and adverbs. Hiragana characters are used mainly for function words and the inflections of verbs, adjectives and adverbs, and for some nouns with uncommon Kanji representations. Katakana characters are used for the large number of foreign loan words (e.g. テレビ/terebi/TV) in contemporary Japanese.

Both forms of Kana have an almost perfect one-to-one relationship between character and pronunciation. That is, one character always represents one particular syllable or mora (syllable like unit) of the Japanese language and its sound value does not change whether the character appears in the first position, the middle position or at the end of a multi-syllable word. This is different from English, where orthographic units not only map onto sub-syllabic phonological units, but the mapping will also depend on context, i.e. the location within the word.



Note: These tests are in written format: Rhyme = Rhyme judgements; PLDT = Phonological lexical decision task (YES to pseudohomophones, e.g., brane); PLDT = Orthographic lexical decision task (i.e., spell checking); Reading = reading aloud. ** = $p < .01$; * = $p < .05$. The data were extracted from Wydell and Kondo (2003).

Fig. 2. A comparison of AS's performance with that of Japanese and English monolingual controls for reading and phonological tests

Words in Kanji have 1-5 characters with two being the modal number, and 2.4 the mean.

The relationship between character and pronunciation in Kanji is very opaque. This is because each Kanji character is a morphographic element that cannot phonetically be decomposed in the way that an alphabetic word can be. There are no separate components of a character that correspond to the individual phonemes (see Wydell, Patterson & Butterworth, 1995 for a further discussion). Also, most Kanji characters have one or more ON-readings,

(pronunciations that were imported from spoken Chinese along with their corresponding characters) as well as a KUN-reading from the original Japanese spoken language. Some characters have no KUN-reading, but for those which have, the KUN-reading is almost always the correct reading when this character constitutes a word on its own (e.g., 花/hana/ in KUN-reading, meaning 'flower' which represents a single-character word; 花束/hana-tabu/ in KUN-reading, meaning 'bouquet' vs. 花瓶/ka-bin/ in ON-reading, meaning 'vase').

Word type	AS (Control)		AS (Control)		
	High frequency (n = 40)		Low frequency (n = 40)		
		S.7	S.14	S.7	S.14
Consistent	95%	(99.2%)		95%	(97.9%)
RT (ms)	880	814	924	800	786 776
Inc-ON	100%	(98.7%)		90%	(89.2%)
RT (ms)	883	813	812	802	760 810
Inc-KUN	100%	(97.9%)		80%	(87.2%)
RT (ms)	965	919	1377	838	791 916
Jukujikun	85%	(89.2%)		60%*	(81.7%)
RT (ms)	1070	1119	1215	843	960 1052

*Outside of the range of normal adults (aged between 20 and 54 years, mean age 31 years). The control data are the adult data from Wydell et al. (1997).

Note: Consistent = each character in a two-character Kanji word has one invariant ON (or occasionally KUN)-reading; Inc-ON (Inconsistent ON-reading) = each character takes ON-reading in a two-character word, but each character has a KUN-reading and/or another ON-reading; Inc-KUN (Inconsistent KUN) = each character takes KUN-reading in a two-character word, but each character has at least one ON-reading; Jukujikun = truly exception words, neither character in a two-character Kanji word takes typical ON or KUN-reading, e.g., 雪崩/nadare/ meaning 'avalanche' however the first character means 'snow', and it is /yuki/ in KUN-reading, while it is /setsu/ in ON-reading; the second character means 'collapse', and it is /kuzu/ in KUN-reading, while it is /hou/ in ON-reading. The table was extracted from Wydell & Butterworth (1999).

Table 1. AS's Performance for two-character Kanji word naming

Table 1 shows that his accuracy in reading two-character Kanji words is equivalent to Japanese undergraduate level except for low familiar Jukujikun ($z = -3.63, P = 0.0009$). Wydell and Butterworth stated that the latter may be due to the fact that he had not had enough exposure to low familiar Jukujikun. When AS was tested with these words, he was 16 years old, while the youngest participant who took part in the experiment of Wydell, Butterworth, Shibahara and Zorzi (1997) was 20 years old (mean age was 31 years old). Kanji learning is essentially a life-long continuous learning process. If he were continuously educated within the Japanese educational system, he would most probably be able to read these low familiar Jukujikun by the time he graduated from a Japanese university.

In order to account for the dissociation between his ability to read in English and Japanese, Wydell and Butterworth (1999) put forward the Hypothesis of Granularity³ and

³ In their review paper, Ziegler and Goswami (2005) also pointed out the importance of 'granularity' in order to explain developmental dyslexia across different languages, and postulated the "Psycholinguistic grain size theory", which, however, "does not predict that orthographic consistency

Transparency as illustrated in Figure 3. The hypothesis maintains that orthographies can be described in these two dimensions - (1) any orthography, where the print-to-sound translation is one-to-one or transparent *would not produce a high incidence of phonological dyslexia* (i.e., dyslexia due to phonological deficits) regardless of the level of translation, i.e. phoneme, syllable, character, etc. This is the 'transparency' dimension, and (2) even when this relationship is opaque and not one-to-one, any orthography whose smallest orthographic unit representing sound is coarse, i.e. a whole character or whole word, *would not produce a high incidence of phonological dyslexia*. This is the 'granularity' dimension. Any orthography used in any language can be placed in the transparency-granularity orthogonal dimension described by this hypothesis.

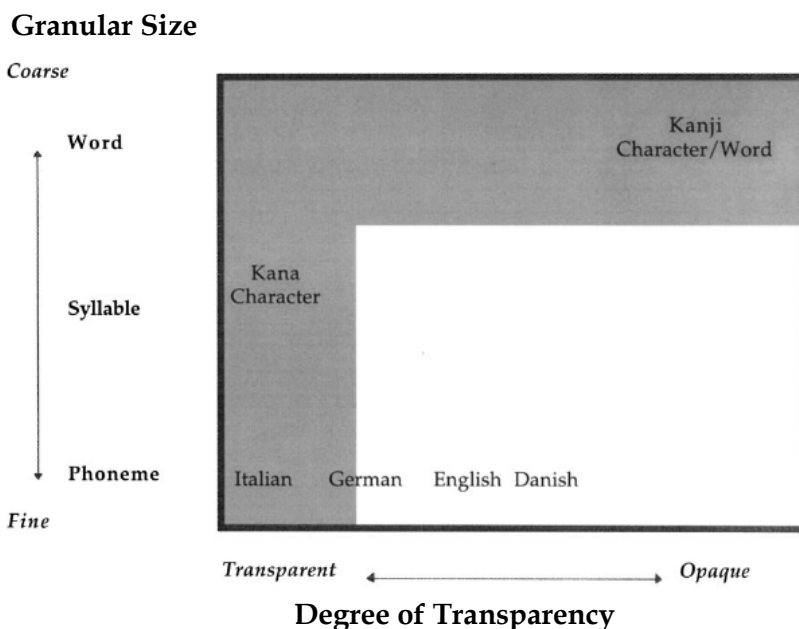


Fig. 3. Hypothesis of Granularity and Transparency and orthography-to-phonology correspondence.

For example, the granularity of the smallest orthographic unit representing phonology for *Japanese Kana* is finer than the whole word, but coarser than the grapheme, and its orthography-to-phonology mapping is at the level of syllables and one-to-one. In contrast, for *Japanese Kanji*, the unit of granularity is much coarser, i.e. a character or a whole word,

(i.e., transparency) reduced developmental dyslexia" (p.20). They further argued that had Wydell and Butterworth included nonword reading tasks in terms of "timed performance", he (AS) would have "displayed clear deficits in reading" in both languages (p.20). However, Zigler and Goswami did not include Wydell and Kondo (2003)'s follow-up study in their review paper. Wydell and Kondo stated that "AS's reading was never laborious and slow" (p.40). Although they did not measure RT for each stimulus word or nonword in milliseconds, they measured AS's reading latencies for stimulus lists (in minutes/seconds), which included nonwords in English and Japanese Kana. AS's reading latencies were comparable to those of the English controls, and were shorter than those of the Japanese controls.

and the orthography -to-phonology mapping is very opaque, hence Kanji can be placed in the shaded area. By this hypothesis, therefore, either of the two scripts used in Japanese should *not lead to a high incidence of phonological dyslexia*.

Now with this categorisation, English can be placed outside of the shaded area, since the granularity for English is small/finer, however, the orthography-to-phonology mapping is not always one-to-one and not transparent. By this hypothesis, English orthography *may lead to a high incidence of phonological dyslexia*. Given the differences between the two orthographies used in Japanese and English, therefore, the hypothesis of granularity and transparency argues that it might be possible for an English-Japanese bilingual individual to be dyslexic in English but not in Japanese.

4. Prevalence of dyslexia and the hypothesis of granularity and transparency

Indeed, researchers have argued that the difference in the prevalence of developmental dyslexia in the different languages might be primarily due to the differences inherent in the characteristics of each orthography, in particular, the way in which phonology is computed from orthography (e.g., de Luca, Burani, Paizi, Spinelli, Zoccolotti, 2010; Landerl, Wimmer, Frith, 1997; Wydell & Butterworth, 1999; Zoccolotti, de Luca, de Pace, Gasperini, Judica, Spinelli, 2005). Earlier it was mentioned that in English up to 10 - 12% of children are reported to suffer from developmental dyslexia (e.g., Shaywitz, et al., 1990; Snowling, 2000). In Danish, as many as 12% of adults in Denmark have difficulties in reading, which was revealed in the study conducted by Elbro, Moller, and Nielsen (1995). In these languages, orthography-to-phonology correspondence (which means grapheme-to-phoneme correspondence in alphabetic languages) is not consistent, i.e., not always one-to-one or transparent (e.g., hint, lint, tint vs. pint; bread, head vs. bead, mead; colonel; yacht; bough vs. dough vs. through vs. thorough). However, in alphabetical languages whereby the grapheme-to-phoneme correspondence is consistent or transparent, such as for example, Dutch, German, or Italian, the prevalence of developmental dyslexia is much lower (e.g., de Luca, et al., 2010; Zoccolotti et al., 2005 for Italian; Landerl, et al., 1997 for the comparison between German and English speakers; Paulesu, De´monet, Fazio, McCrory, Chanoine, Brunswick, Cappa, Cossu, Habib, Frith, C.D., & Frith U., 2001 for the comparison between English, French and Italian speakers).

For example, Landerl et al. (1997) examined the reading and phonological processing skills of English and German dyslexic children against their normal chronological and reading age-matched controls, and found that although the same underlying phonological processing deficit might exist in both German and English dyslexic children, there were differences in the severity of the reading impairment. English dyslexic children showed a marked adverse effect in the acquisition of reading skills compared to German dyslexic children. These differences were also seen between the normal German and English control children in their reading performance. Landerl et al. suggested that these differences were due to differences in orthographic ‘consistency’. That is, different orthographies have different mapping rules, and there is a wide range in the degree of consistency with which alphabets represent phonemes by graphemes. ‘Consistency’ here is interchangeable with ‘transparency’. For orthographies such as German, Italian or Spanish, the grapheme-to-phoneme mapping is, in general, one-to-one, and consistent/transparent. For other orthographies such as English or Danish, the grapheme-to-phoneme mapping is often one-

to-many (e.g., food vs. hood vs. flood or blood), and less consistent/transparent (e.g. Seidenberg, Waters, Barnes, & Tanenhaus, 1984). Thus it was assumed that orthographic consistency/transparency affects both the nature and degree of reading difficulties (de Luca, et al., 2010; Zoccolotti et al., 2005).

Landerl et al. further argued that phonological recoding itself may not necessarily be a demanding task. When grapheme-to-phoneme mapping is consistent/transparent, children can easily acquire the grapheme-phoneme correspondence rules, and use these to assemble pronunciations for novel letter strings (as seen with Italian or Spanish children for example). Therefore, the phonological recoding may become a demanding task, only when the grapheme-phoneme correspondence in an orthography is not consistent/transparent, such as for example, English (Snowling, 2000) or Danish (Elbo et al., 1995). Therefore, if the grapheme-phoneme correspondence is consistent, even children with phonological deficits may be able to learn to map print onto sound thus without showing a delay in reading acquisition. Similarly, the ‘hypothesis of granularity and transparency’ in particular, the transparency dimension predicts that *developmental phonological dyslexia* should not manifest itself in a writing system where the print-to-sound correspondence is transparent regardless of the size unit of granularity.

Moreover, the granularity dimension of the hypothesis predicts that developmental phonological dyslexia should not manifest itself in a writing system where the unit of granularity is coarse at a whole character or whole word level. It should therefore be possible to find a bilingual individual with monolingual dyslexia, especially between two orthographies such as English and Japanese.

Further evidence which lends support to the Hypothesis can be seen in a recent cross sectional study conducted in Japanese by Uno, Wydell, Haruhara, Kaneko and Shinya (2009). In their study, 495 Japanese primary school children (from 2nd Grade aged eight to 6th Grade aged 12) in Japan were tested for their reading, writing and other cognitive skills including phonological awareness (STRAW, 2006). The results showed that percentages of children who had reading difficulties (defined as those whose reading/writing/phonological tests’ scores fell below -1.5SD) in syllabic Hiragana, syllabic Katakana, and logographic Kanji were 0.2%, 1.4%, and 6.9% respectively – these figures were significantly lower than those reported in the studies in English (Shaywitz et al., 1997; Snowling, 2000) or Danish (Elbo et al., 1995). Yet there was no significant difference in the IQ scores between the normal group and reading/writing disabled (RWD) group (measured by Ravens Coloured Progressive Matrices, 1976).

The study also suggested that different reading strategies might be adopted when reading in Kana and Kanji. For Kana, where the character-to-sound-mapping is transparent, a simple on-line phonological processing (i.e., sublexical analytical reading) strategy might be used (Wydell & Butterworth, 1999; Rastle, Havelka, Wydell, Colheart, Besner 2009), just like other consistent orthographies such as Italian (de Luca, et al., 2010; Zoccolotti et al., 2005) or German (Landerl et al., 1997). In contrast, for Kanji, because the character-to-sound-relationship is opaque, and the correct pronunciation is determined at the whole-word level, a lexical whole-word reading strategy might be used (e.g., Morton, Sasanuma, Patterson & Sakuma, 1992; Wydell, 1998; Wydell & Butterworth, 1999; Wydell, et al., 1993; Wydell, Butterworth & Patterson, 1995; however also see Fushimi, Ijuin, Patterson & Tatsumi, 1999 for counter argument).

Thus the results of Uno et al.'s (2009) study further lend support to the Hypothesis of Granularity and Transparency. Wydell and Butterworth (1999) argued that English orthography would require a fine tuning of the orthography-to-phonology mapping, because English orthography is not completely transparent at the subsyllabic level (i.e. smaller grain-unit than syllables). In contrast, the grain size for Kana is at the whole character level (i.e., greater grain-unit than graphemes), and its orthography-to-phonology mapping is transparent (one-to-one). Hence Japanese children in general find it easier to master reading in Kana. This is because, as Landerl et al. (1997) argued for German, the phonological recoding of Kana is not a demanding task. Moreover, although the grain size for Kanji is either at whole character or whole word level, its orthography-to-phonology mapping is opaque (one-to-many). Consequently learning to read in Kanji for Japanese children is harder than that in Kana. The results thus indicate that reading Kanji may require different reading strategies or different cognitive skills to those required for reading Kana. If so, reading English may yet require different reading strategies to those required for Kanji or Kana.

Wydell and Butterworth (1999) thus speculated that it is therefore possible to be a Danish or English-Japanese bilingual with monolingual dyslexia in Danish or English.

5. Dyslexia and cross-cultural and cross-linguistic differences

Interestingly, in Japan rather than group studies, single case studies of children with reading disorders have started to emerge (e.g., Kaneko, Uno, Kaga, Matsuda, Inagaki, & Haruhara, 1997; 1998; Uno, Kaneko, Haruhara, Matsuda, Kato, & Kasahara, 2002). The majority of these children in Japan tend to have both reading and writing difficulties, and often the writing impairment is more severe than the reading impairment⁴. Significantly, in Japan there are very few reported cases of children with reading impairments only. The Japanese researchers usually attribute these reading and writing impairments among children to 'visual' or 'visuospatial' processing problems (e.g., Kaneko et al., 1998) rather than phonological processing problems.

Unlike alphabetic orthographies but similar to Japanese KANJI, the Chinese language uses a logographic writing system whereby the basic orthographic units, the Chinese characters, correspond directly to morphemic meanings and to syllables in the spoken language. The pronunciations of Chinese characters are represented at the monosyllabic level, and no phonemes are represented in a character. That is, reading a Chinese character does not allow the segmental analysis (i.e., grapheme-to-phoneme conversion), which is fundamental in alphabetic orthographies (Wanga, Bi, Gao, & Wydell, 2010). Therefore Chinese is often referred as a morphosyllabic writing system (Shu & Anderson, 1997). Further, Meng, Sai, Wang X., Wang, J., Sha, and Zhou (2005) pointed out that there is only limited systematic correspondence between orthography and phonology. Moreover, Mandarin Chinese has a large number of homophonic morphemes and homophonic characters. Therefore it is often stated that the use of phonological information may not be as critical in reading Chinese as it is in reading alphabetic languages (Ho, Chan, Lee, Tsang, & Luan, 2004; Ho, Chan, Tsang, & Lee, 2002; Shu, McBride-Chang, Wu, & Liu, 2006). If this were the case, then a high incidence

⁴ In English, it is often the case that when reading is impaired, writing is also impaired, and therefore dyslexia is assumed to mean both reading and writing impairments.

of phonological dyslexia in Chinese should not be seen (*cf* the Hypothesis of Granularity and Transparency (Wydell & Butterworth, 1999)).

Similar to Uno et al.'s (2009) study in Japanese, Li, Shu, McBride-Chang, Liu and Peng (in press) investigated the acquisition of reading in Chinese, and tested 184 kindergarten children and 273 primary school children from Beijing, Mainland China for their skills in (a) Chinese character recognition, (b) visual-spatial relationships and visual memory, (c) orthographic judgement, (d) phonological awareness including (d1) Rime deletion, (d2) Syllable deletion, (d3) Phoneme deletion and (d4) Rapid number naming, (e) Morphological awareness including (e1) Homophone judgements, (e2) Morphological construction, and (e3) Morpheme production.

The results showed that especially for the primary school children, a unique and relatively strong relationship between (c) orthographic knowledge (and not (b) visual skills) and reading was found. In addition, (d) phonological and (e) morphological awareness "appear to be somewhat important for reading throughout the very beginning and intermediate periods of character acquisition" (p.15). However, (d3) phoneme deletion was not uniquely associated with reading particularly for the primary school children. Li et al. thus argued that "phoneme awareness by itself is relatively unimportant for reading Chinese because the phoneme is not explicitly represented in the Chinese orthography" (p.16). Li et al. further argued that unlike most alphabetic writing systems where there is a strong relationship between phoneme awareness and reading skills, in Chinese larger unit size such as syllable or rime may be a better predictor variable for reading Chinese characters.

Indeed, recent research has revealed that the major cause of developmental dyslexia in Chinese is a deficit in orthographic processing skills, rather than in phonological processing skills (e.g., Chan, Ho, Tsang, Lee, & Chung, 2006; Ho et al., 2004; Shu et al., 2006), though some studies did show that Chinese dyslexic children had phonological deficits (e.g., deficits in rapid naming (e.g., Ho, Law, & Ng, 2000) and auditory processing (e.g., Meng et al., 2005).

In order to ascertain neurophysiologically a cause of developmental dyslexia in Chinese, Wang, Bi, Gao, and Wydell (2010) conducted an ERP (Event Related Potential) study with Chinese dyslexic and chronological-age-matched, and reading-level-matched non-dyslexic children from Beijing, Mainland China, employing a psychophysical experiment, i.e., the motion-onset paradigm. A similar psychophysical paradigm was first employed by Rogers-Ramachandran and Ramachandran (1998) with English-speakers as their participants, whereby two distinct visual systems/pathways in human vision were identified, namely, "a fast, sign-invariant system concerned with extracting controls" (p.71) which is the magnocellular visual system, and "a shallower, sign-sensitive system concerned with assigning surface colour" (p.71), which is the parvocellular visual system. Subsequent similar psychophysics studies with English-speaking children as participants showed that the performance of the participating children significantly correlated with the measures of orthographic skills in the Magnocellular Condition (e.g., Sperling, Lu, Manis, and Seidenberg, 2003; Talcott, Witton, McLean, Hansen, Rees, & Green, 2000).

Wang et al.'s ERP study revealed that the Chinese dyslexic children's orthographic processing skills were significantly compromised, when compared to their Chinese chronological and reading age-matched control children, which in turn, Wang et al. argued, is linked to a deficit in the visual magnocellular system.

Other brain imaging studies using fMRI (functional Magnetic Resonance Imaging) in Chinese such as Siok, Niu, Jin, Perfetti, and Tan (2008) or Siok, Perfetti, Jin, & Tan (2004) revealed functional and structural abnormalities in the left middle frontal gyrus of Chinese dyslexic children, but not in the left temporoparietal and occipitotemporal regions that are important for reading in alphabetic languages (e.g., Paulesu, McCrory, et al., 2000; Wydell, Vuorinen, Helenius & Salmelin, 2003), and are typically compromised in dyslexic children in alphabetic languages (e.g., Horwitz, Rumsey, & Donohue, 1998; Temple, Poldrack, Salidis, Deutsch, Tallal, Merzenich, & Gabriel, 2001). These researchers therefore argued that reading Chinese characters might require firstly greater cognitive demand for visual processing than reading in alphabetic languages such as English, and secondly a greater inter-activity between orthography and phonology. This is because, like Japanese Kanji, reading Chinese characters requires retrieving phonology as a whole rather than addressing phonology in piece-meal fashion (see Wang et al., 2010 for more details). Therefore Siok and his colleagues also suggested that the neural abnormality found in impaired readers is dependent on culture (see also Paulesu, Frith, et al., 2001 for a similar argument).

Thus in this Chapter, having reviewed recent empirical studies in alphabetical as well as non-alphabetic languages such as Chinese and Japanese, the chapter has shown significant cross-cultural/linguistic differences in the prevalence of developmental dyslexia in different languages.

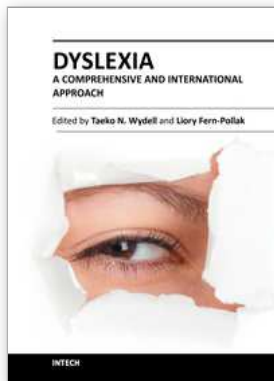
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This book brings together dyslexia research from different perspectives and from different parts of the world, with the aim of providing a valuable source of information to medical professionals specializing in paediatrics, audiology, psychiatry and neurology as well as general practitioners, to psychologists who specialise in developmental psychology, clinical psychology or educational psychology, to other professions such as school health professionals and educators, and to those who may be interested in research into developmental dyslexia. It provides a comprehensive overview of Developmental Dyslexia, its clinical presentation, pathophysiology and epidemiology, as well as detailed descriptions of particular aspects of the condition. It covers all aspects of the field from underlying aetiology to currently available, routinely used diagnostic tests and intervention strategies, and addresses important social, cultural and quality of life issues.

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