Reading Difficulties in English and Japanese

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Developmental Dyslexia in English and other European Languages/orthographies

Reading and writing skills are one of the most important cognitive skills that every child has to acquire, and also are considered to be central to educational attainment in the world. Yet there are some children (and adults) who unfortunately do not develop these literacy skills and are said to be afflicted by developmental dyslexia.

Developmental dyslexia is characterised by unexpected reading problems that cannot be attributed to poor hearing or vision, low intelligence or inadequate education and social opportunities (Snowling, 1987; Shaywiz, 1988).

A more detailed working definition of dyslexia is given by the Rose Review (2009) as follows:

Dyslexia is a learning difficulty which primarily affects the skills involved in accurate and fluent word reading and spelling, which is characterised by difficulties in (i) phonological awareness, (ii) verbal memory and (iii) verbal processing speed. Dyslexia occurs across the range of intellectual abilities, sometimes co-occurring other developmental disorders, such as specific language impairment (SLI), poor comprehenders, dyspraxia, dyscalculia, attention or attention deficit hyperactivity deficit (ADHD, often as ADD). However this Review notes that these developmental disorders themselves are not the markers of dyslexia.

Dyslexia is now considered as one of the Specific Learning Difficulties in the UK, and more specifically these children are considered as children with Special Educational Needs and Disabilities (SEND) by the Department of Education in the UK (2014), and are given appropriate educational support.

In the English-speaking countries, the prevalence of dyslexia has been reported as 10-12% of the general population (Shaywitz et al., 1990; Snowling, 2000), which is greater than that in other European countries, for example, 3-4% in Italian (Paulesu et al., 2001), and it is often thought that learning to read English is harder than other European orthographies (Seymour, Aro & Erskine (2003) cited by Ziegler et al. 2003).

This is because the English orthography is known as 'quasi-regular' or 'opaque', characterised as having inconsistent/ irregular print-to-sound conversion. For example, the word-body/rhyme, *'–int'* is pronounced consistently in *hint*, *lint,* *mint*, or *tint* but inconsistently in *pint.* Similarly, the words containing '-ea-' are pronounced inconsistently in *beak, head*, *learn*, or *steak.* There are also *exception words* such as *through*, *though, thorough*, *bough*, *cough*, or *dough,* whereby the word body/rhyme, '-ough' is pronounced differently in each of these words. Further, the print-to-sound conversions occur at the grapheme-to-

phoneme level which is smaller than a syllable. Thus it is said that English has one of the most complicated grapheme-to-phoneme correspondences (e.g., Garrod & Daneman, 2003). Therefore for reading in English phonological awareness/processing skills are essential. Further, a deficit in phonological processing is said to remain the most consistent finding in all studies of dyslexia in English (Stanovich & Siegel, 1994; Snowling 2000) and other alphabetic languages (Landerl, Ramus, Moll, Lyytinen, Leppanen, et al., 2012).
Phonological processing deficits can be identified by impaired performance in tasks such as (i) phoneme deletions - “Say ‘soil’ without the sound /s/ ?” or “Say ‘brave’ without the sound /r/ ?”, (ii) Spoonerising (Perin, 1983) – Swap the initial sounds of a pair of words, /<u>B</u>ad, <u>M</u>anners/ -> /<u>M</u>ad, <u>B</u>anners/ or Nonword Repetition (Gathercole & Baddeley, 1996) - /*perplisteronk*/, *confrantually*/, /*voltularity*/, etc.
Thus the most widely-accepted causal model of dyslexia is the Phonological Deficit Hypothesis (e.g., Ramus et al., 2003; 2011).

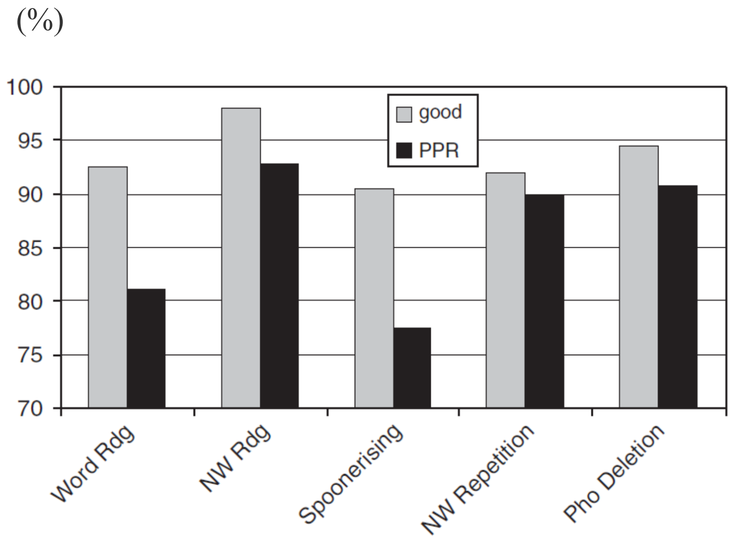
Other hypotheses which are essentially based on visual or visual attention span deficits have been postulated, such as for example the physiological Magnocellular Abnormality hypothesis (e.g., Stain & Walsh, 1997; Stein 2015) or the behavioural Visual Attention Span (VAS) Deficit hypothesis (e.g., Bosse et al., 2007; Lobier, Zoubrinetzky, & Valdois, 2012) based on the Multi Trace Memory (MTM) model (Ans, Carbonnel & Valdois, 1998). However these hypotheses can explain only few cases of dyslexia (only 12.5% of Ramus et al.’s (2003) dyslexic adults had a Magnocellular abnormality) or the validity of the hypotheses have been questioned (see Goswmi (2015) who argued that the VAS deficit in dyslexics are a consequence rather than a cause of developmental dyslexia).

The main findings in dyslexia research in English and other alphabetic languages/ orthographies can be briefly summarized as follows:
(1) As discussed earlier many behavioural studies have found <u>core phonological deficits</u> in children with dyslexia (Ramus et al., 2003; 2011).

(2) Adults with childhood diagnoses of dyslexia have shown <u>persistent phonological deficits</u> (Bruck, 1992; Elbo et al., 1995 (Danish); Wydell & Kondo, 2003). For example, Felton, Naylor, and Wood (1990) found that dyslexic adults were impaired compared with normal controls using Rapid-Automatized-Naming (RAN), whereby a participant is asked to name either pictures or digits as fast as possible; phonological awareness skills; and non-word

reading tests. Similarly, Paulesu, Frith, Snowling, et al. (1996) found that even well-compensated dyslexic university students showed residual phonological deficits on phoneme deletions and Spoonerising tests. Ramus et al. (2003) also found that well-compensated dyslexic university students showed phonological deficits in RAN with pictures and digits, Spoonerising and nonword repetitions.

More recently, Wydell in Shapiro, Hurry, Masterson, Wydell and Doctor (2009) tested 158 male/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. Wydell identified 16 out of 158 students (*approximately 10%*) as *poor phonological recoder (PPR)-readers* (i.e., those with phonological deficits) with a 1.5SD cut-off. As shown ***Fig-1***, the PPRs' performance on the reading/phonological processing tests were significantly lower than the controls (all at p<.05).



The figure was extracted from Shapiro et al. (2009).

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

(3) Dyslexia has genetic and neurobiological origins (e.g., Fisher & DeFries, 2002; Eden & Moats, 2002). Pennington (1990) reviewed literature on twin studies as well as family studies in both the USA and UK, and confirmed that dyslexia aggregates in families: (i) a substantial majority of affected children had affected relatives, (ii) the average recurrence rate among first-degree relatives is high, and (iii) there is frequent transmission across two or more generations. Fisher and DeFries (2002) also showed that greater concordance for the trait of dyslexia was found amongst monozygotic than dizygotic twins.

It was further revealed that phonological deficits are highly heritable, whereas auditory and visual deficits are not (e.g., Olson & Datta, 2002).

Dyslexia in Japanese and Non-Alphabetic Languages/orthographies

The Japanese writing system uniquely consists of two qualitatively difference scripts: morphographic/logographic Kanji derived from Chinese characters, and two forms of syllabic Kana – Hiragana and Katakana which are both derived from kanji characters (Wydell & Butterworth, 1999). These different scripts are used to write different classes of words: Kanji for nouns and the root morphemes of verbs, adjectives and adverbs; Katakana for the large number of foreign loan words; and Hiragana for function words, inflected parts of verbs, adjectives and adverbs, and for transcribing low frequency Kanji words. The syllabic Kana has a transparent Kana-character-to-pronunciation-correspondence between a Kana character and its pronunciation, i.e., one character represents a whole mora (syllable like unit). It is known that Japanese children master both Kana scripts very quickly. Most children learn the Hiragana scripts even before they start primary school education (Makita, 1968). Because of this transparent nature of the computation of phonology from Kana, behavioural studies showed that the most optimal way of reading in Kana is a simple character-to-sound conversion (i.e., sub-lexical) processing as with other shallow orthographies (e.g., see Wydell, Vuorinen, Helenius & Salmelin (2003) for Finnish or Zoccolotti, de Luca, de Pace, Gasperini, Judica, & Spinelli (2005) for Italian).

In contrast, the computation of phonology from Kanji is opaque, as the relationship between a Kanji character and its pronunciation is one to many. This is because each character is an orthographic 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 (Wydell, Butterworth & Patterson, 1995). Further, most Kanji characters have one or more ON-readings of Chinese origin, and a KUN-reading of Japanese origin. 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 (i.e., a single-character word). For example, the character 歌 pronounced as /uta/ in KUN-reading is a single-character word meaning 'song'. The same KUN-reading can be seen in two-character words such as 歌声/uta-goe/ (singing voice). However, the same character is also pronounced as /ka/ in ON-reading as in 歌手/ka-shu/ (singer) (Wydell, et al., 1993; 1995). Therefore

Kanji learning is essentially by rote: children are introduced to new Kanji characters in texts. The learning method which is in common use is repeated writing or rehearsal by writing (e.g., Naka & Naoi, 1995). In Japan the common core curriculums are used during the compulsory education, i.e., the first six years of primary school (aged 7-12), and the subsequent three years of junior-high school (aged 13-15) education. During the primary school education the children across Japan are introduced to the list of about 1000 different Kanji characters prescribed by the Ministry of Education and Science. By the end of junior-high school education a total of just over 2000 Kanji characters[1] are taught.

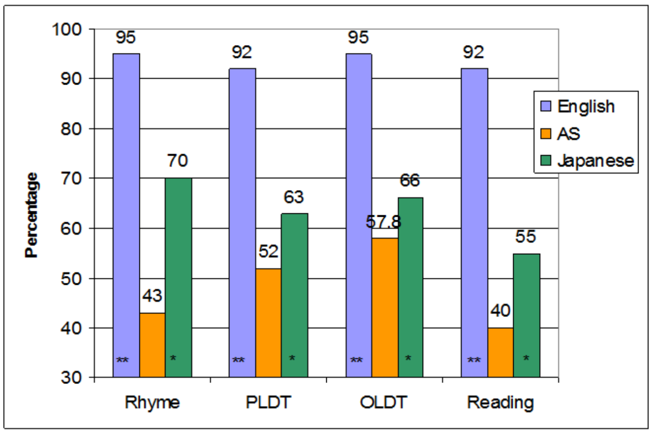
Given that the Japanese children have to learn three different writing systems, it may be reasonable to assume that the prevalence of dyslexia in Japanese might be high. In order to answer this question Uno, Wydell, Haruhara, Kaneko and Shinya (2009) employed an objective measure, and tested 495 Grade-2 to Grade-6 Japanese primary school children in Japan on their reading, writing and other cognitive skills including phonological awareness/ processing skills. The results showed that the percentages of children who had reading difficulties in syllabic Hiragana and 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 (i.e., 10-12%). A series of multiple-regression analyses further revealed that for Level-2 to Level-5-children the single most potent variable to explain Kanji Word reading was the vocabulary for abstract words, measured by the Standardised-Comprehension-Test-of-Abstract-Words (SCTAW) (Haurhara & Kaneko, 2003). Phonological processing skills measured by nonword-reading and nonword-repetition became important only when children were older (Grade-6). This is very different to the studies in English.

English-Japanese Bilingual with Mono-lingual Dyslexia & Hypothesis of Granularity and Transparency

In 1999 Wydell and Butterworth reported the case study of an adolescent English-Japanese bilingual male, AS, with monolingual dyslexia in English. His reading/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). ***Fig-2*** illustrates his performance in reading and phonological

[1] Note however adults require around 3000 characters for most everyday literacy activities (e.g., reading a national newspaper) (Wydell & Butterworth, 1999).

processing tests in English together with those of age-matched English and Japanese monolingual controls, which clearly indicate his phonological processing deficits.



The figure was created based on the data from Wydell & Kondo (2003).

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

Note: * p<.05; ** p<.001; PLDT-Phonological LDT = brane (brain) (YES); OLDT-Orthographic LDT = brane (brain) (NO)

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

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

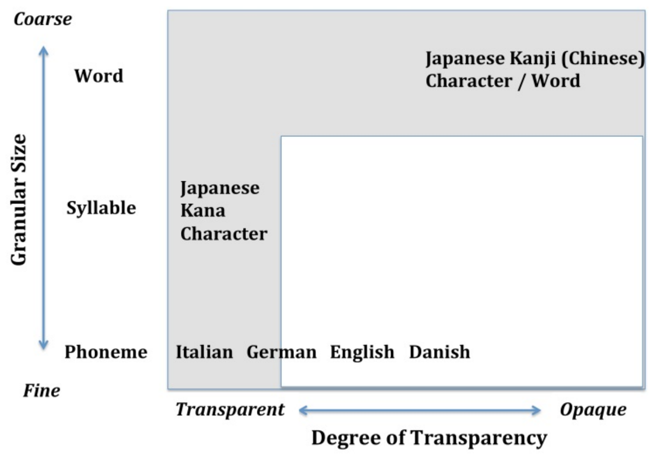
Word type	AS	(Control)		AS	(Control)	
	High frequency (*n* = 40)			Low frequency (*n* = 40)		
		S.7	S.14		S.7	S.14
Consistent	95%	(99.2%)		95%	(97.9%)	
RT (ms)	880	*814*	*924*	800	*786*	*776*
Inc-ON	100%	(98.7%)		90%	(89.2%)	
RT (ms)	883	*813*	*812*	802	*760*	*810*
Inc-KUN	100%	(97.9%)		80%	(87.2%)	
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).

(1) Consistent-ON	
気候	ON
(2) Inconsistent-ON	
家屋	ON
(3) Inconsistent-KUN	
毛糸	KUN
(4) Jukujikun	
雪崩	JUKUJIKUN

The figure was extracted from Wydell & Butterworth (1999).

In order to account for AS's dissociation between his ability to read in Japanese (superior) and his ability to read English (inferior), Wydell and Butterworth postulated the Hypothesis of Granularity and Transparency hypothesis with the predictions that (a) any orthography where print-sound-translation is transparent (one-to-one) will not produce a high incidence of phonological dyslexia, regardless of the level of translation (e.g., phoneme, syllable, character, etc.), e.g., Japanese Kana, Italian or Finnish, and that (b) even when the print-sound-translation is opaque (one-to-many), any orthography whose smallest orthographic unit representing sound is coarse (i.e., larger grain size) such as a whole character/word, e.g., Japanese Kanji or Chinese, will also not produce a high incidence of phonological dyslexia. Thus any orthography used in any language can be placed in the transparency-granularity orthogonal dimension as illustrated in ***Fig-3***, and any orthography that falls into the shaded area in the figure should not give rise to a high incidence of phonological dyslexia.

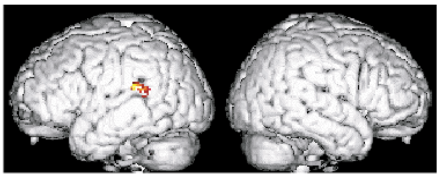


The figure was recreated based on Wydell & Butterworth (1999).

Figure 3. Hypothesis of Granularity and Transparency

Neural Correlates of Reading in Alphabetic Languages

Behavioural studies have thus shown differences in the manifestation of dyslexia due to language specificity of reading processes. These differences might also be reflected in the patterns of brain activation. Paulesu et al. (2000) using a Positron Emission Tomography (PET) conducted a study whereby English and Italian university students were asked to read words and nonwords. They found a common distributed brain network of activation across the two languages including the left inferior frontal/premotor cortices, superior middle/inferior temporal gyri, and fusiform gyrus as well as the right superior temporal gyrus, thus showing the language universality aspect of reading. However, Italian participants showed greater activation in the left superior temporal regions, which are often implicated with sub-word grapheme-to-phoneme phonological processing. In contrast English participants showed greater activations in the left posterior inferior temporal and anterior inferior frontal gyrus, which are known to be associated with whole word retrieval, thus showing the language specificity aspect of reading (See ***Fig-4a*** and ***Fig-4b*** below *from Paulesu et al., 2000*).



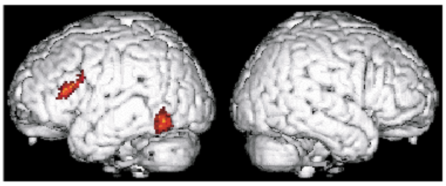


Figure 4a ***Figure 4b***

Showing Italian specific (4a) and English specific (4b) cortical activations respectively

Paulesu et al. (2001) conducted another PET study where English, French and Italian participants with/without dyslexia were asked to read words/nonwords. They found the same reduced activity in a region of the left occicipito-temporal region as shown in ***Fig-4c*** (from Paulesu et al., 2001). Shaywitz, Shaywitz, et al.'s (2002) functional Magnetic Resonance Imaging (fMRI) study of reading found similar results in the dyslexic children. These neuroimaging studies thus showed neural/biological unity in the dyslexic brains.

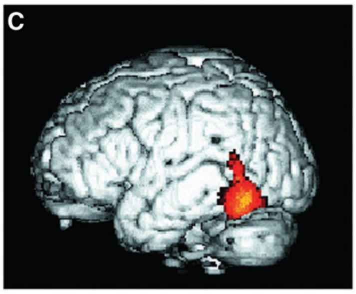
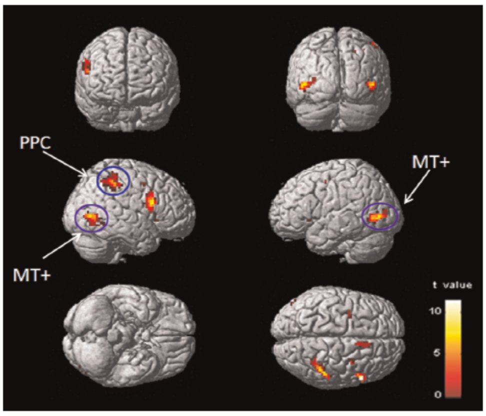


Figure 4c English, French and Italian dyslexic participants all revealing reduced activation in the left Occipito-temporal region, thus showing neural/biological unity

In contrast, Chinese researchers have shown that neural correlates during reading Chinese (another morphographic/logographic orthography) are different from those found in English and other alphabetic languages. These results have a direct relevance and important implication to reading Japanese Kanji. For example, Qian, Deng, Zhao and Bi (2015) conducted a psychophysical study with fMRI, where Chinese participants participated in a coherent motion perception task, which is thought to measure the function of the magnocellular dorsal (MD) visual pathway. As shown in ***Fig-5*** it was found that several cortical regions of the MD pathway, including bilateral middle temporal visual motion areas (MT+), and the right posterior parietal cortex (PPC) were activated, the latter activation of which was positively correlated with orthographic awareness skills but not with phonological awareness skills.



The figure was extracted from Qian et al. (2015).

Figure 5 Magnocellular Dorsal Visual Pathway and Chinese Reading

Wei, Bi, Chen, Liu, Weng and Wydell's (2014) behavioral data lend further support to the importance of the orthographic awareness skills in reading Chinese. They investigated the relationship between Chinese reading competency and phonological, morphological, and orthographic awareness skills in 391 Chinese children from pre-school to Grade-3. The results showed that all three metalinguistic awareness skills significantly predicted reading success. However, the orthographic awareness skills played a dominant role in the early stages of reading acquisition, and its influence decreased with age, while the opposite was true for the contribution of morphological awareness skills. The phonological awareness skills became more important in the later stages in development of reading skills in Chinese, the result of which is similar to that found in Uno et al.'s (2009) Kanji word reading. Thus Qian et al. showed that neural collates in reading Chinese might be quite different from those found in alphabetic languages.

Similarly Wang, Bi, Gao and Wydell (2010) conducted visual and auditory event-related potential experiments with electroencephalography (EEG) eliciting mismatch negativity (MMN) to investigate the link between visual magnocellular functional abnormalities and dyslexia in Chinese. The Chinese children with/without dyslexia aged 8-11 participated in both the behavioral and electrophysiological experiments, and results showed that the amplitude in the visual mismatch negativity (vMMN) at the most sensitive electrode Oz (occipito-central lead) was significantly reduced compared to the chronological-age-matched control as well as the reading-age-matched controls. While no such difference was seen between these three groups of children in the auditory mismatch negativity (aMMN) at Fz (sensor in the auditory cortex area). Wang et al.'s behavioral and electrophysiological results indicated that the orthographic processing skills were compromised in the Chinese Dyslexics, which in turn is linked to a deficit in the visual Magnocellular system, thus lending further support to the studies conducted by Qian et al. (2015) as well as Wei et al. (2014).

Another fMRI study conducted by Siok, Perfetti, Jin and Tan (2004) revealed the language specificity aspect of neural correlates during reading Chinese. The Chinese participants with/without dyslexia were asked to make (i) homophone judgements, (ii) font-size judgements, and (iii) and lexical decisions (whether the stimuli were real Chinese characters or not). It was found that reading impairment seen in the Chinese dyslexics is manifested by two deficits: one relating to the conversion of graphic form (orthography) to syllable, as measured in (i), and the other concerning orthography-to-semantics mapping, as measured in (ii). Both of these processes were critically mediated by the left middle frontal gyrus (LMFG), which "functions as a centre for fluent Chinese reading" (p. 5), and all the Chinese dyslexic participants revealed reduced activation in the LMFG, as shown in ***Fig-5a*** in the homophone judgements, and in ***Fig-5b*** in the lexical decisions.

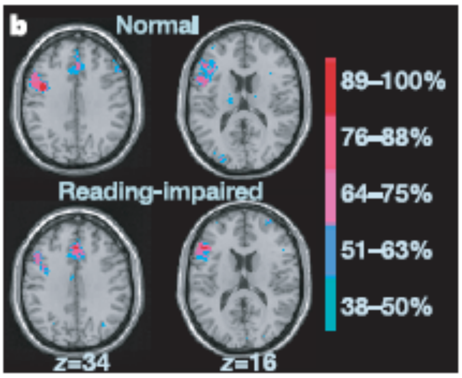


Figure 5a and 5b extracted from Siok et al. (2004), showing that the Chinese dyslexics showed significantly reduced activation in the LMFG compared to the Chinese normal readers.

Figure 5a Brain Regions with significant activity during Homophone Judgements

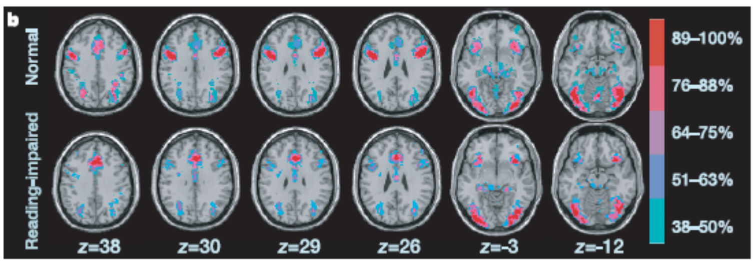


Figure 5b Brain Regions with significant activity during Lexical Decisions (contrasted with fixation)

Siok et al. thus demonstrated significant variations in the neural correlates of Chinese and English impaired reading. Again the neuroimaging studies of reading Chinese have direct relevance and important implication to the Japanese Kanji reading.
In conclusion the current paper argues that there are clear behavioural and neural differences in the way developmental dyslexia presents in alphabetic and non-alphabetic languages/orthographies.

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