Acquired Dyslexia in Japanese

: Implications for Reading Theory

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I, Hitomi Sato, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Acquired dyslexia research has been conducted mainly on English neurological patients. A limited number of dyslexia studies on non-alphabetic orthographies are available. Classical case studies for acquired dyslexia in Japanese, which has two distinctive scripts (morphographic Kanji and phonographic Kana), reported 'script-dependent' dyslexia patterns. Although recent case studies showed 'script-independent' dyslexia patterns for surface and phonological dyslexia, a 'script-independent' deep dyslexia pattern in Japanese has not yet been reported.

This study examined four Japanese aphasic patients, using psycholinguistically well-manipulated reading stimuli for both Kanji and Kana strings. YT, with phonological impairment, demonstrated the same effects of psycholinguistic variables as observed in English deep dyslexia, but semantic errors rarely occurred in Kana word reading. YT's concomitant deep dyslexia for Kanji, and phonological dyslexia for Kana fit the phonological impairment hypothesis, and this can be treated as a unique characteristic of Japanese deep dyslexia. HW, with semantic impairment, demonstrated a 'script-independent' surface dyslexia pattern. SO, with severe semantic impairment, demonstrated a surface dyslexia pattern in Kanji word reading, but showed substantial difficulty with Kanji nonword reading. ME, with phonological impairment and a visuo-spatial deficit, showed both lexicality and length effects on reading aloud Kana strings, thus suggesting phonological dyslexia for Kana. That is, the double dissociation between Kanji and Kana nonword reading was observed in SO and ME. These results suggest that Japanese acquired dyslexia patterns are not dependent on script-type, but are also not totally independent of script-type.

These outcomes of this study are discussed in terms of universality and orthographic-specificity in acquired dyslexia. Moreover, possible workings of the Japanese version of the DRC model (Coltheart et al., 2001) and the triangle model (Plaut, et al., 1996; Harm & Seidenberg, 2004) are presented in order to explain acquired dyslexia patterns in Japanese.

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Chapter 1

The importance of a cross-linguistic approach to acquired dyslexia research

1.1. Reading research and cognitive models

Language is a human, species-typical function that is attributable to the brain. While spoken language (natural language) is instinctive (e.g. Pinker, 1994; Chomsky, 1957), written language is acquired. Spoken language is based on the connection between phonology and meaning. Written language learning is the acquisition of additional links between orthography and phonology, and between orthography and meaning. In other words, written language is parasitically attached to spoken language. Reading research is crucial to understanding how this structural change influences language processing and the relationship between spoken and written language. There are two views. One considers that spoken language and written language are independent of each other, and the other considers that they are interrelated.

Cognitive models, which provide a hypothesis of language processing, reflect these two views. The dual-route model (e.g. Coltheart, 1985) represents the former view and regards reading processing as a written language-specific function. The triangle model (Seidenberg & McCelland, 1989; Plaut, McCelland, Seidenberg, & Patterson, 1996) represents the latter view and regards reading processing as a non-specific function of written language. These two cognitive models are also distinctive in terms of their way of representing information. Since cognitive processing is much more intricately driven into the fabric of representation than is usually acknowledged, the way in which information is represented in the brain is the key assumption for the cognitive model. The dual-route model is a module type model that assumes *'localist representation'*, whereas the triangle model is a non-module type model that assumes *'distributed representation'* (Lambon Ralph, 1998).

The term *module* has been defined as 'informationally encapsulated’ (Fodor, 1983) and/or as a 'functionally isolable sub-system' (Shallice, 1988). The traditional cognitive models of language processing (e.g. Morton & Patterson, 1980a; Coltheart, 1981; Patterson & Shewell, 1987) consist of module type components, in which single entities in the components (e.g. phonological lexicon, the semantic system, orthographic lexicon) represent a single word, where the representation and the representing item have a one-to-one correspondence. Due to its nature, this sort of representation is called ‘localist representation’. This notion is inherited from the concept of ‘*mental lexicon*' (or mental dictionary; Treisman, 1961), which is stored knowledge for individual words in the lexical memory.

Since the module type models are depicted as a box and arrow diagram, where boxes represent functional components (modules) and arrows are the metaphor of ‘accessing’ the stored representations in the box, they are sometimes known as *'the box and arrow' models.* The dual-route model belongs to this type of cognitive model and assumes specific reading routes (the lexical-semantic route, the lexical-nonsemantic route and the non-lexical route). Recently, the Dual Route Cascaded model (DRC), which is the computational realisation of the dual-route model, was proposed (Coltheart, Pastle, Perry, Langdon, & Ziegler, 2001). Although the DRC model is a computational model, this model belongs to the category of *nonconnectionist models,* in which elements of the model are defined as 'descriptions of a functional information-processing architecture' (Coltheart, 2004). So, the DRC model has the same functional components and 'localist representation' as the dual-route model. In this model, pronunciation of written strings is computed by processing the two reading-specific routes (i.e. cascaded-interactive processing of the lexical routes and rule-governed serial processing of the non-lexical route).

Meanwhile, non-module type models assume that lexical information is not represented as 'mental lexicon'. Semantic, phonological and orthographic information of language are distributed across the system. Due to its nature, this sort of representation is called 'distributed representation'. Since this type of cognitive model assumes parallel and interactive processing among the connections of neuron-like units with corresponding phonological, semantic and orthographic features, they are sometimes known as *connectionist models*. This is in contrast with the module type models which are serial and static in nature, and also contrasts with non-connectionist computational models such as the DRC model. The triangle model is of this type and consists of three domains or '*principal components*' (Lambon Ralph & Patterson, 2005) - Phonology, Semantics and Orthography - and intermediate units (or hidden units). The triangle model is a computational model but, unlike the DRC model, does not assume reading-specific processing routes. In this model, reading is calculated through bi-directional interactions between three principal components.

As briefly described above, the two types of cognitive model propose quite different hypotheses about reading processing. Cognitive models play a key role in reading research because they provide explanations for human reading performance by adults/children and neurological patients/deteriorated children. They also stimulate the conducting of computer simulation studies derived from recent technological advances, which also led to neuro-imaging studies that investigated the neuro-anatomical base of reading activity in both the intact and broken-down human brain. These various approaches to the study of reading (see Table 1) together contribute to developing our understanding of reading processes. Thus, cognitive models are critical for the theory of reading.

Table 1 Various approaches of the reading research

Approach	Target	Subjects	
Psychological	Human performance	a) Adult skilled readers b) Developmental readers	c) Patients with acquired dyslexia d) Children with developmental dyslexia
Computer simulation	Computer performance	a) Intact network	b) Damaged network
Neuro-imaging	Neural activation	a) Intact brain	b) Damaged brain

1.2. The cognitive neuropsychological approach to acquired dyslexia research

The basic goal of cognitive neuropsychological studies of reading is to understand the reading processing observed in neurological patients with acquired dyslexia and in children with developmental dyslexia. The research into reading disorders which occur after brain damage began within the neuropsychological framework, in which impaired reading performance is interpreted in relation to neuro-anatomical loci. According to Benson (1977), “With expansion of interest in aphasia during the 19th century, alexia was noted by a number of investigations but definitive discussion awaited the work of Dejerine in the 1890s.”(p.327). Dejerine’s two types of alexia - *alexia with agraphia* associated with dominant parietal-temporal damage, and *alexia* *without agraphia* associated with dominant occipital lobe damage - have been treated as written language-specific disorders since spoken language remains largely unimpaired in both types of disorder. Although these categorisations are still alive in use today (e.g. Lecours, 1999), the neuropsychological approach to acquired reading disorder does not allow us to understand in detail the psychological processing of the impaired reading. This is because such investigations focus on the relationship between loci of the neuro-anatomical damage and reading impairment and not on reading performance itself.

Two crucial papers by Marshall and Newcombe (1966, 1973) had a considerable impact on the study of acquired dyslexia and opened the cognitive neuropsychological approach to reading research. The excellence of their papers lay in revealing the psycholinguistic characteristics of the patient's reading performance using psycholinguistically manipulated reading stimuli, which led to the psycholinguistic categorisation of acquired dyslexia. After this epoch-making approach to reading disorders, a number of investigations about different patterns of acquired dyslexia have been published and these precipitated the development of the cognitive model for language processing[1].

The cognitive neuropsychological approach is motivated by various concerns. Theoretically, testing the reliability of the model is objective. In this regard, the cognitive neuropsychological approach allows us to test the hypothesised reading mechanism by using impaired performances which cannot be experimentally tractable for normal readers. Empirically, clarifying the characteristics of dyslexic

1 Coltheart et al. (2001) summarised the development the logogen model (word generation) (Morton, 1969), and identified the language-processing model proposed by Patterson and Shewell (1987) as generalisation of the final version of logogen model.

patterns (i.e. the effects of psycholinguistic variables and error patterns) is a main concern, and the impaired reading performance is interpreted using the model. Clinically, the cognitive neuropsychological approach is intended to gain a clue to therapeutic intervention. For these purposes, the cognitive models that can offer the framework of psycholinguistic evaluation are indispensable. Therefore, these three different concerns (i.e. theoretical, empirical and clinical concerns) of acquired dyslexia research are interrelated. The core assumption for this interrelation is that acquired dyslexia reflects damaged normal reading processing.

Damaged processing, however, is viewed differently depending on the framework of the cognitive model. In the module type model, there are two fundamental notions. One is the 'locality assumption' (Hills & Caramazza, 1992) which states that damage to one component of the functional architecture will have an exclusive 'local' effect. The other is the 'subtractive assumption' (Saffran, 1982; Caramazza, 1984) which states that the cognitive ability after brain damage is subtracted from the normal system function. Given these notions, the neurological cases with 'selectively' impaired processing have been paid much more attention, despite the fact that huge numbers of impairment patterns can be expected in module type models (Marshall, 1984).

Therefore, *double dissociation of deficits* has been treated as the reflection of the dissociation of two different sub-systems. Double dissociation is considered an important phenomenon because it helps us to understand the nature of each sub-system or processing route. For instance, if a patient has one damaged reading route, it is expected that an unimpaired alternative reading route(s) must be used for reading performance. So, in the module type model (the dual-route model), it is interpreted that patients' dyslexic patterns reflect selective impairment of the reading-processing route with isolation from the functional architecture of language processing as a whole.

In contrast, in the connectionist model (the triangle model), it is considered that cognitive deficits would be degraded; and that neurological patient's performance would be the result of interaction between the remaining cognitive functions in the damaged network and not just the combination of deficits in the module type models (the dual-route model). So, in this view, *association of deficits* in the system is important in the understanding of impaired processing. Reading disorder is interpreted as relation to other deficits. Using this type of model, the phenomenon of double dissociation is explained as a dynamic characteristic of the system (Plaut, 1997; Van Orden, Pennington, & Stone, 2001), not as the opposite combination of isolable processing routes.

In short, these two distinctive cognitive models provide quite different views on reading disorders, and therefore cognitive neuropsychological studies of acquired dyslexia have great potential to shed in-depth light on the nature of reading mechanisms by examining the reliability of cognitive models.

1.3. Cross-linguistic perspectives on acquired dyslexia research

The key question, using a cross-linguistic approach to the reading research, is whether different languages, which have different phonological structures and different orthographies, share the same mechanisms of reading processing. It is possible that different scripts are processed in a similar way, but also possible that the nature of the scripts may produce different reading strategies or different functional organisations. As Marshall (1976) and Henderson (1984) suggested, data and verification from many distinct orthographies are needed in order to consider this question. However, the fact is that the influential cognitive models (i.e. the dual-route model, the DRC model, and the triangle model) were originally designed to explain single word processing in the English language, and much of the reading research of both skilled readers and neurological patients has been carried out on readers of alphabetic scripts, particularly English. In the English writing system, an alphabetic letter basically corresponds to one phoneme but does not represent any meaning, and the relationship between spelling in English words and its phonology is quasi-regular including regular words (e.g. mint) and exception words (e.g. pint). Since there are other writing systems which do not share these characteristics in English, the current state of reading research prevents us from seeing the whole picture of normal and impaired reading processing.

In theory, whether the skilled readers can directly map from orthography to semantics is still an open question (Frost, 1998). So, a cross-linguistic approach to reading is critical in considering this question, because the relationships between orthography and phonology, and between orthography and semantics are different depending on script type: *phonogram* and *morphogram* (Fig.1).

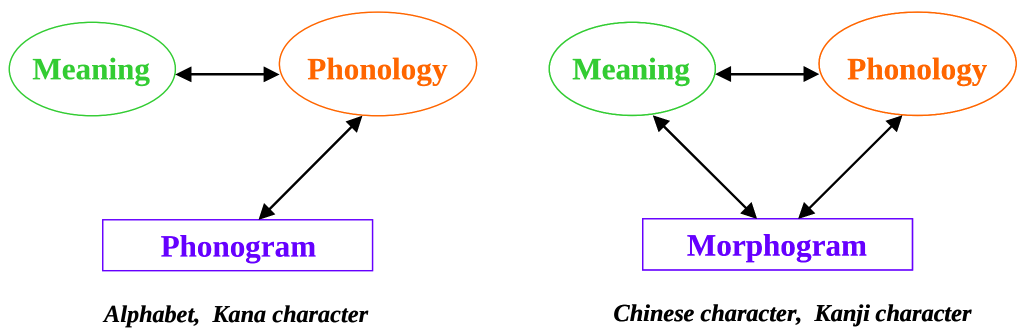

Fig. 1. The relationship between script types and lexical information.

While characters in most writing systems represent phoneme, sub-syllable, and syllable and they are known as ‘phonogram’, several writing systems use the characters which represent morpheme, and they are called as ‘morphogram’. In phonographic orthographies it can be considered that the link between orthography and phonology is strong, compared to the link between orthography and semantics, because there is no correspondence between phonogram and meaning. In general, empirical results suggest that access from phonographic orthographies to meaning via phonology is primal (e.g. Van Orden & Goldinger, 1994). Meanwhile, it is possible to postulate that there is a direct mapping from morphographic orthography to semantics, because there is a relationship between morphogram and meaning. Thus, the way of accessing meaning from orthography would be different, depending on the script type.

In this context, it is reasonable to expect that acquired dyslexic patterns in phonographic orthographies and morphographic orthographies would be distinctive.

It is worth noting that Marshall (1976) proposed a comprehensive view about the different nature of bi-script in Japanese reading processing. Taking the classical dual-route framework (i.e. phonological and semantic procedure), he suggested that semantic procedure (i.e. translation from orthography to phonology via semantics) was applied preferentially to morphographic Kanji because its operation most suited for Kanji, and phonological procedure was preferentially applied to phonographic Kana because of its efficient operation for Kana. Marshall also pointed out that "within the ‘two-script’ system of Japanese writing, we seem to have an analogue of the ‘two languages and two script’s situation’ "(p.123).

Though acquired dyslexia researches in non-alphabetic orthographies and morphographic orthographies have been reported (e.g. Sasanuma, 1980a, 1985, 1994; Karanth, 1985, 2002; Yin & Butterworth, 1992; Weekes & Chen, 1999; Law & Or, 2001), the way in which the nature of script affects reading processing is still not well known. This is mainly because it is easy to “confuse the formal nature of script with the psychology of script-processing” (Marshal, 1976, p.120). For example, within the framework of the dual-route model Karanth (2003) presumed that the reliance on the reading-processing route depended on script types, and phonemic/syllabic, morphemic and logographic scripts largely depend on the non-lexical route, the lexical-nonsemantic route, and the lexical-semantic route, respectively (p.113). Such presumptions often lead to the misinterpretation of cross-linguistic data on acquired dyslexia and provide little understanding of how script type affects reading processing. We therefore need as much comparative data as possible relating to acquired dyslexia in various types of scripts in order to explore psychological mechanisms of reading in our cognitive system.

In short, the cross-linguistic approach to acquired dyslexia is not only to describe acquired dyslexic patterns in different writing systems; rather it is also vital to discuss the script-specific and script-nonspecific nature of reading processing.

1.4. The significance of the study of acquired dyslexia in Japanese

From the cross-linguistic point of view, using the Japanese language for reading research is of considerable advantage, because the Japanese writing system is not only non-alphabetic but also bi-scriptal (Marshall, 1976; Karanth, 2003). Japanese orthography consists of both morphographic Kanji and phonographic Kana. The Kana character has a consistent character-sound correspondence, whereas the Kanji character has various degrees of character-sound correspondence. While the Kana character has no meaning, the relationship between the Kanji character and meaning has varied because the Kanji character is frequently used as a constitutional component of multiple-character Kanji words and is occasionally used as a single-character Kanji word. That is, both pronunciation and meaning of the Kanji character are dependant on the intra-word context. The difference between the Kanji character and the Kana character in terms of both character-sound correspondences and the character-meaning relationship is quite striking.

In terms of print-sound relationship, Kanji words are opaque like English words written by phonogram. In English, the 'word-body', which consists of the vowel and terminal consonant (i.e. nucleus and coda) in monosyllabic words, corresponds to the rhyme of the spoken syllable. Therefore, the ‘word-body’ is usually used for evaluating the spelling-sound correspondence, and it was pointed out that the pronunciation predictability of English words is determined by the degree of consistency of pronunciation of ‘word-body’ neighbours (Jared, 1990; 1997). Similarly, print-sound consistency in Kanji words can be evaluated using orthographic neighbourhoods of Kanji words, which share the same character in the same position (Fushimi, Ijuin, Patterson, & Tatsumi, 1999). It could be pointed out that print-sound consistency in Kanji words is more graded[2] than that of English words due to the nature of Kanji words. Because most Kanji words are two-character words and many Kanji characters have multiple pronunciations, orthographic neighbourhood statistics might be more complex than for English words. For instance, in the case of 根底 /koN-tei/, two-character Kanji word, there are 25 orthographic neighbours of the first constituent Kanji character 根: of these 14 are pronounced /koN/ and 11 are pronounced /ne/ for 根. There are 20

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2 Patterson (1990) pointed out that ‘various writing systems form a kind of continuum’ in regard to print-sound correspondence, ‘with Japanese kana at or near the rule-governed end, Japanese kanji at or near the opposite end, and the English alphabet somewhere in between’ (p.5).

orthographic neighbours of the second constituent Kanji character 底: of these 13 are pronounced /tei/ and 7 are pronounced /soko/. The print-sound consistency for 根底 can be calculated[3] as the average consistency of each constituent character (i.e. 14/25 for 根 and 13/20 for 底: [(14÷25) ＋(13÷20)] ÷ 2 =0.61). So, it appears that the pronunciation predictability of Kanji words is slightly lower than that of English words.

Furthermore, the pronunciation of Kanji words is less predictable than that of Chinese words. About 90% of Chinese characters are ideophonetic compounds which consist of 200 semantic radicals and 800 phonetic radicals, and about 40% of ideophonetic compounds correspond to the onsets and rhymes of their phonetic radicals[4] (Ho, 2003). Since most Chinese words are single-character words the print-sound consistency in Chinese has been defined as whether the phonology of words corresponds to their phonetic radicals (Yin and Butterworth, 1992). In the case of Japanese Kanji, the pronunciation of Kanji characters is determined by the intra-word context, because most Kanji words are two-character words. Thus, the pronunciation predictability of written Chinese words is much higher than that of Kanji words.

Figure 2 summarises the degree of pronunciation predictability in Japanese (Kanji and Kana), English and Chinese orthographies. Though Kana is phonographic script like English alphabet, the pronunciation of Kana words is transparent because the Kana character has a consistent character-sound correspondence. Though both Kanji

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3 Fushimi et al. (1999) proposed this procedure of calculating print-sound consistency for two-character Kanji words.

4 If tone is considered, 26% of ideophonetic compounds have the same onsets, rhymes and tones as their phonetic radicals. Tone connects with the meaning of the morpheme, because Chinese is a tonal language and changing the tone of a Chinese syllable leads to changing the meaning.

and Chinese characters are morphographic script, the degree of pronunciation predictability of Kanji words is much lower than written Chinese words. Therefore, it can be emphasised that Kanji and Kana are noticeably different in terms of script type (morphogram vs. phonogram) and pronunciation predictability of written strings.

Fig. 2. The degree of pronunciation predictability in Japanese, English and Chinese orthographies.

This sharp contrast between Kanji and Kana would provide a chance to examine whether script type influences the relationship between written and spoken language. If the strength of links between orthography and phonology and between orthography and meaning is different, depending on Kanji and Kana in skilled Japanese readers, distinguishable dyslexic patterns might be observed in Kanji and Kana strings. Research of acquired dyslexia in Japanese means studying monolingual-bi-scriptal readers with brain damage. This is different from the study of bilingual-bi-scriptal readers with brain damage (e.g. a neurological patient who is bilingual in English and Spanish), in which language type can be treated as an independent variable. Japanese acquired dyslexia research, however, can be applied to one of the two cross-linguistic methods, in which “language type is treated as a natural experiment, using the peculiar characteristics of a single language to answer a question that would be difficult to ask in (for example) English” (Bates, Wulfeck, & MacWhinney, 1991; p.124). The unique characteristic of the Japanese writing system would offer a rare opportunity to study the effects of script types on one language. This cannot be examined by using monolingual and mono-scriptal readers. In particular, the study of impaired reading performance in Japanese neurological patients provides a chance to examine whether the differential effects of identical damage in reading processing can be observed in dyslexic patterns in Kanji and Kana. In this respect, studying Japanese acquired dyslexia is significant in order to discuss script-specificity and universality of reading processing, which are connected with the fundamental question of how written language is appended onto spoken language.

For research of Japanese acquired dyslexia, it is a starting point to know the acquired dyslexia patterns in alphabetic scripts, particularly English, which were established in this research area and which were studied, in many cases, with interpretations from the cognitive models. Thus, the theories of the cognitive models (the dual-route model, the DRC model and the triangle model) are explained in detail, and acquired dyslexia studies with English neurological patients are mainly reviewed in Chapter 2.

Chapter 2

Cognitive models and acquired dyslexia in English

This chapter introduces the theory of influential cognitive models that have been used for the interpretation of acquired dyslexia, and presents a review of acquired dyslexia cases in alphabetic orthography, mainly in English. This chapter also provides interpretations of the three types of acquired dyslexia, using the distinctive cognitive models, and makes a critical comparison between the explanations of the two cognitive models. These reviews and clarification of theoretical issues are necessary in order to establish a context for exploring Japanese acquired dyslexia. Chapter 2 is organised in the following order:

i) The explanation of the dual-route model, some modifications to the model; and the DRC model;

ii) The review of case studies of three types of acquired dyslexia in English;

iii) Interpretations of each type of acquired dyslexia, using the dual-route model and the dual-route cascaded model (DRC model);

iv) The explanation of the triangle model;

v) Interpretations of each type of acquired dyslexia, using the triangle model;

vi) The comparison between the interpretations of the two cognitive models.

2.1. The dual-route model and the DRC model

1) The dual-route model

The dual-route model (Fig. 3) is a functional architecture for reading, and is a subpart of the module type model for language processing. The core assumption of this model is that there are two distinctive reading procedures: the lexical procedure and the non-lexical procedure. That is why this reading theory is well known as the dual-route model, despite the fact that three routes are acknowledged. Coltheart and his colleagues (Coltheart, 1981, 1985; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart & Rastle, 1994) have been the main proponents of the dual-route model, but many other authors have also expressed a similar view about reading processing (e.g. Paap & Noel, 1991; Bernstein & Carr, 1996; Herdman & Beekett, 1996).

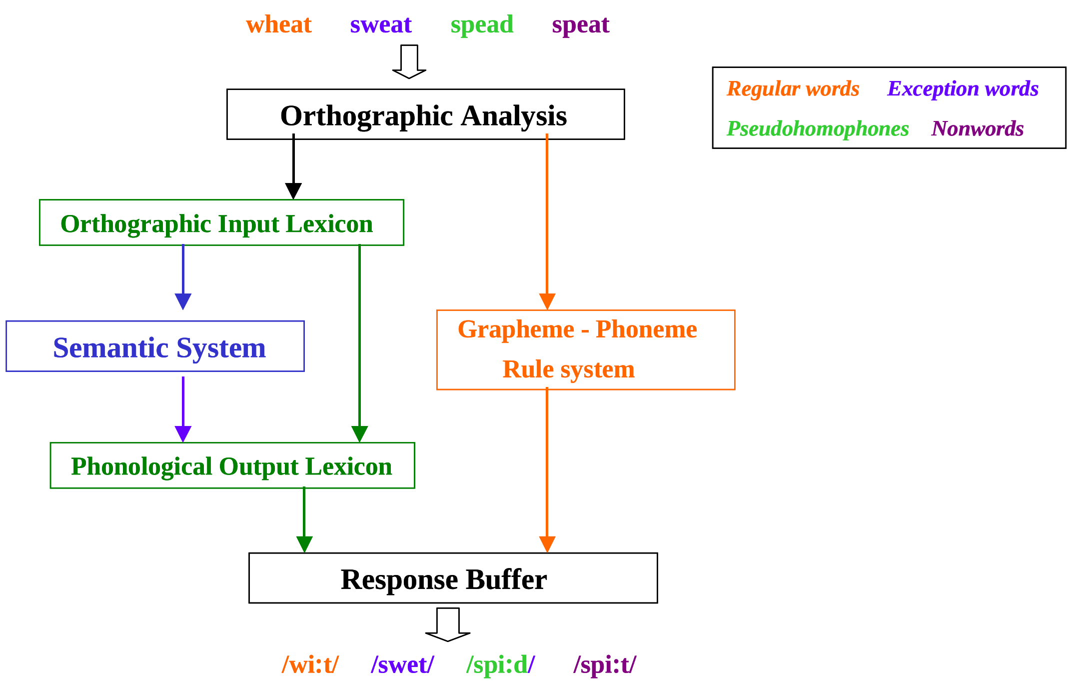

Fig. 3. The dual-route model.

This model assumes that lexical information for a word (i.e. a lexical item) is represented with phonological, orthographic and semantic representations, which have a one-to-one correspondence (i.e. localist representation), and that word-specific information is stored knowledge (i.e. lexical memory). Although nonwords are not represented in the system, normal adult readers can read aloud. So, this model needs to assume the non-lexical procedure for oral reading as sub-word processing.

The non-lexical route and the two lexical routes, which are processed after recognition of written strings by visual analysis, are postulated as follows:

i) The non-lexical route --- Recognised written strings are separated into orthographic subword constituents (or *graphemes*[1]) and they are translated by the rule (i.e. the grapheme-phoneme correspondence rule: hereafter the GPC rule) into phonological equivalents. Then, they are concatenated into the whole pronunciation corresponding to the whole strings. For example, the word *down* is divided into three graphemes *d*, *ow*, *n* (this stage is called 'graphemic parsing'), and the most common pronunciations of these graphemes (/d/, /au/, and /n/) are assigned by the GPC rule, and finally they are concatenated into /dá**u**n/. Then, this phonological information activates the response buffer.

ii) The lexical-nonsemantic route --- Recognised written strings activate its whole-word orthographic representation (i.e. orthographic input lexicon), which is directly translated into the whole-word phonological representation (i.e. phonological output lexicon). Then phonological representation activates the response buffer, which produces the pronunciation of the target word.

iii) The lexical-semantic route --- After activation of the whole-word orthographic representation (i.e. orthographic input lexicon), its word meaning (i.e. semantic representation) is activated and then it is transcoded into the phonological representation of the word (i.e. phonological output lexicon), which activates the

[1] Coltheart (1984) gave the definition of 'grapheme' following *Webster's Dictionary*, in which grapheme means any letter or letter cluster which corresponds to a single phoneme (e.g. sherry contains four graphemes: sh, e, rr, and y). He emphasised that the non-lexical route is not operated by using additional correspondences between letter groups and phoneme groups, as proposed by Shallice (1981).

corresponding phoneme in the response buffer (i.e. production of the pronunciation for the target word).

Hence, rule-based procedure (the GPC rule) and word-specific knowledge (or lexical stored representation) govern the dual-route model. Owing to the definition of the non-lexical route, this procedure will produce correct responses for ‘regular’ words and nonwords that can be applied to the GPC rule. ‘Regular’ words (e.g. *tent*) and regular-inconsistent words, which have typical spelling-sound correspondences (e.g. *hint*), are processed efficiently in all of the three reading routes. This is because the non-lexical route (i.e. the GPC rule) can produce correct pronunciations for this type of word, due to the ‘regular’ print-sound relationship, and the two lexical procedures (i.e. direct reading and semantically-mediated reading) also produce correct pronunciation since written strings are words.

In contrast, ‘irregular’ words or exception words (e.g. *pint*, *sweat*), which have atypical spelling-sound correspondences, are correctly read only by the lexical procedures, because the GPC rule in the non-lexical route cannot produce correct pronunciations for this type of word and potentially makes regularisation errors (e.g. *pint* /páint/ as /pint/; *sweat* /swet/ as /swi:t/). This reading error is the result of assigning more typical pronunciation to atypical spelling-sound correspondences. Thus, only the lexical route can produce the correct pronunciations for exception words. Though the non-lexical route can produce correct pronunciations for nonwords, the two lexical routes cannot read nonwords, because nonwords are not represented in the lexicon of the lexical reading routes (i.e. nonword letter strings cannot activate the orthographic input lexicon).

In short, reading procedure for correct oral reading is different depending on the word type (i.e. the non-lexical and lexical procedure for regular words, the lexical procedure for exception words, and the non-lexical procedure for nonwords). Therefore, this model can predict that print-sound regularity (i.e. ‘regular’ words vs. ‘irregular’ words/exception words) and lexicality (i.e. words vs. nonwords) directly affect oral reading processing.

In addition to a regularity effect, word frequency and imageability would be expected to influence the efficacy of the three reading routes[2]. In the lexical procedure, oral reading of high-frequency words is more efficient compared to that of low-frequency words, because efficient activation of the lexicon depends on frequency (i.e. how often the target word is processed). So, the pronunciation of high-frequency words with any degree of spelling-sound correspondence is processed more quickly than the pronunciation of low frequency words. In low frequency words it would take time to read irregular words, because such words emerge from the conflict between output of the non-lexical route (i.e. incorrect pronunciation) and output of the lexical procedure (i.e. correct pronunciation) at the response buffer. Thus, such words are processed more slowly than regular words. As far as imageability[3] is concerned, in the lexical-semantic route oral reading of high imageability words (e.g. *rose*) would be more efficient compared to that of low

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[2] The effects of these variables have been reported in the studies of the performance of adult readers with alphabetic orthography. A number of reading researches have shown 1) a regularity effect (mean RT and error rate: exception words > ‘regular’ words or consistent words); 2) a frequency effect (mean RT: low frequency words > high frequency words); and 3) a frequency by regularity interaction (a regularity effect is prominent in low frequency words, and a frequency effect is prominent in exception words). In the low frequency English monosyllabic words, the difference between exception words and regular-consistent words was from 20ms to 50ms in the mean RT and from 1% to 13% in error rate (Taraban & McCelland, 1987; Seidenberg, 1985; Seidenberg, et al. 1984). An imageability effect on oral reading (i.e. low imageability words > high imageability words in the mean RT and error rates) was also detected in low- frequency exception words (Strain, Patterson, Seidenberg, 1995; 2002; Strain & Herdman, 1999).

[3] Imageability is highly correlated with concreteness (r = 0.83: Pavio, Yuille, & Madigan, 1968) and ‘ease of predication’, which refers to the ease with which associated predicates can be evoked (r = 0.88: Jones, 1985), and also familiarity (r = 0.78: Sakuma, Ijuin, Fushimi, Tatsumi, 2000).

imageability words (e.g. *electricity*). Since imageability is a property of semantics and can be defined as the ease of retrieving a sensory image -which emerged from the word meaning, it can be assumed that high imageability words activate semantic representation more strongly than low imageability words.

Finally, it is worth noting the operation of the system, because this model does not explicitly define that. There are two views. One is 'either-or operation', based on the 'horse race' assumption (Paap & Noel, 1991), in which written strings are read by the most efficient (i.e. the fastest) reading route for the target written strings. The other is 'total' operation, in which the activation of phonological representation for oral reading is determined by the output from the three independent reading routes. According to the 'pooling' theory (Monsell, Patterson, Graham, Hughes, & Milroy, 1992), output from each reading route is pooled for the activation of speech output. The latter notion is generally accepted, and it has been considered that information from all three reading routes is combined at the response buffer.

2) Modifications to the dual-route model

<u>Contradictory experimental results to the dual-route model</u>

With regard to the contradictory results to the dual-route model, Patterson and Morton (1985) summarised 5 sets of experimental observations (p.341):

i) “Inconsistent” non-words are sometimes read aloud with an irregular pronunciation (e.g. *heaf* →/hef/ rather than /hif/);

ii) Pronunciation latencies may be significantly longer for inconsistent non-words like *heaf* than for consistent ones like *hean*;

iii) Pronunciation latencies may be significantly longer for regular inconsistent words like *leaf* than for regular consistent words like *lean*;

iv) Pronunciation of an inconsistent pseudoword can be significantly shifted towards irregularity (e.g. *yead* →/jed/ rather than /jid/) by prior presentation of appropriate irregular words;

v) The pronunciation assigned to an inconsistent non-word can be shifted towards irregularity by prior representation of a semantically related word, which would produce an irregular bias effect.

It is difficult for the dual-route model to explain these sets of data, because the GPC rule process all types of nonwords in the same manner and the GPC rule-based operation and independency of each reading route cannot explain the phenomena. This indicates involvement of lexical knowledge, such as a pseudohomophone effect. Similar criticisms are seen in Marcel (1980) and Humphreys and Evett (1985).

Modification of the non-lexical procedure

Shallice and his colleague (Shallice, Warrington, & McCarthy, 1983; Shallice & McCarthy, 1985) proposed *the multiple-levels approach*. In this theory, it was assumed that 1) phonological reading is processed, based on the various sizes of print-sound correspondences, including graphemes, consonant clusters, subsyllabic units, syllables, and morphemes; and 2) different levels of the process operate in parallel and in an integrated manner.

Meanwhile, Patterson and Morton (1985) proposed *the orthography-to-phonology correspondence (OPC) system*. They gave the two assumptions of the OPC system. First, there are two different sizes of orthography unit: graphemes and bodies, which are the vowel-plus-consonant segments of monosyllables (i.e. rhyme segment). Second, mappings at the grapheme levels are one-to-one translations like the GPC rule, whereas mappings of bodies are complex and sometimes require one-to-several translations. They argued that body routine processing accounts for oral reading of ambiguous words/nonwords (i.e. inconsistent and more complex orthographic patterns), which cannot be explained by the GPC rule.

Analogy theory

Analogy theory (Marcel, 1980; Kay & Marcel, 1981; Henderson, 1982) denies the non-lexical procedure, because this approach holds the view that the problem faced by the dual-route model came from the independency of the non-lexical and the lexical routes. This theory assumes that written letter strings are read by analogy, and with specific reference to known lexical items. Information about pronunciation of their segments in real words is used for nonword reading (e.g. nonword stimuli activate real words sharing letter sequences occurring in the same position), whereas information about pronunciation of their segments in other words and their own whole-word information are used for word reading. Thus, lexical knowledge applies to both words and nonword reading in the analogy theory, and nonwords can be read without postulating a non-lexical procedure.

The hypothesised interaction between phonological and semantic procedure

Hillis and Caramazza (1991) proposed the hypothesised interaction between sublexical and semantic information, which arose from the OPC mechanism and the semantic system, respectively, at the phonological output lexicon. This approach refers to *the Summation Hypothesis*, because it is assumed that the summation of even partial information from these two sources could lead to accurate oral reading. In their theory, both semantic and sublexical phonological information come together at the output phonological lexicon. They rejected the lexical-nonsemantic route. Thus, there are two reading routes: the semantic route and the phonological route (i.e. the OPC processing). This is very similar architecture to the ‘two-route’ model by Marshall and Newcombe (1973).

There is another theory that shares the interactive view with the summation hypothesis but admits the three reading routes of the dual-route model. Southwood and Chatterjee (1999) proposed *the Simultaneous Activation Hypothesis*, in which information from all three routes activates simultaneously upon encountering a letter string at the phonological lexicon. They assume that the non-lexical reading route reaches both the phonological output lexicon and the response buffer.

To summarise, these alternative theories as described above tried to modify the independence of each reading route in the dual-route model. All these approaches seek a sort of interaction between lexical and non-lexical procedures in order to explain experimental results which were difficult to explain through the dual-route model.

3) The DRC model

Coltheart and his colleagues (1993; 2001) proposed the dual-route cascaded model (DRC model), which is a computer simulation and 'nonconnectionist model' (Coltheart, 2004). As shown in Fig. 4, the DRC model shares the processing components[4] and the GPC rule with the dual-route model and has three reading routes, but this model operates in a cascaded manner in which processing is continuous until the final output is produced. So, activation of the phoneme system

4 The semantic system in the DRC model (Coltheart, et al., 2001) has not been implemented.

rises gradually as a result of information from the three routes. In the DRC model, as with the dual-route model, the GPC rule-based non-lexical route can read all nonwords and regular words and yields regularisation errors for all exception words, and the lexical routes can read all words.

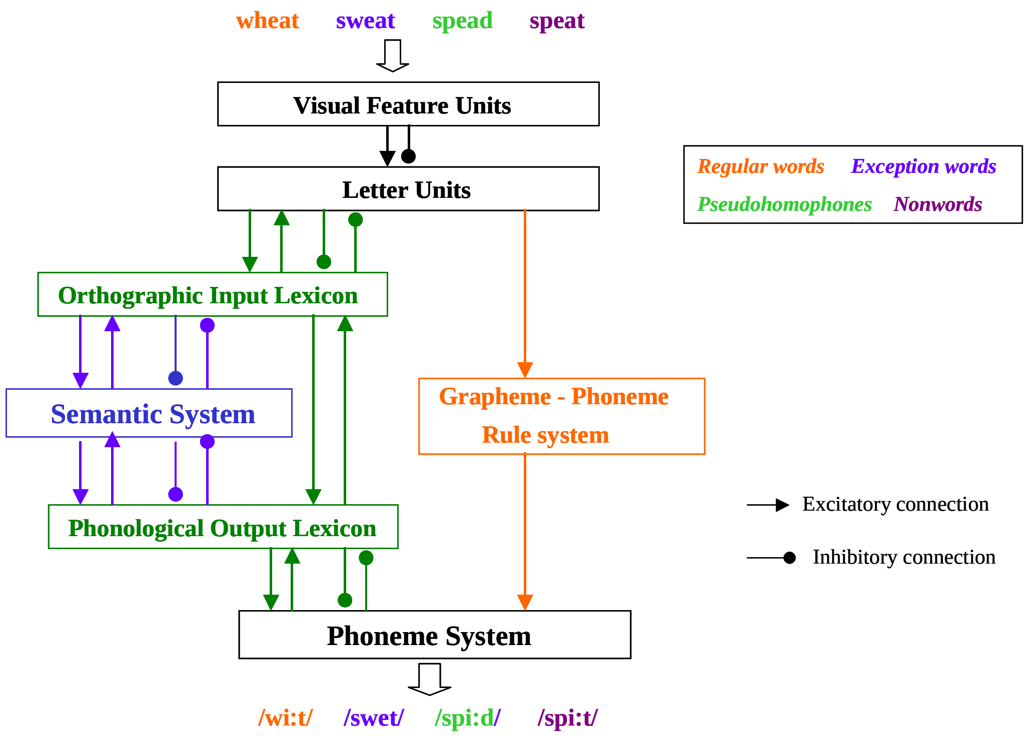

Fig. 4. The DRC model.

In the beginning of the reading process, written strings (e.g. wheat) activate visual feature units that represent the visual feature of a letter, and then corresponding letter units that represent each letter are activated (e.g. w, h, e, a, t). Processing from the visual feature units to the letter units is in one direction (i.e. serial processing). Then, the letter unit activations are transferred to the non-lexical route (which is serial rule-governed processing), and the lexical routes (which are parallel spreading activation processing).

In the non-lexical route, letter unit activation is transcoded into the phoneme system based on the GPC rule (e.g.. wh→/w /, ea→ /i:/, t→/t/) and then speech output is created (e.g. /wi:t/). The organisation of the phoneme units is similar to that of letter units. In the case of exception words like *sweat*, two phonemes are activated for the position with the exceptional GPC rule (e.g. /i: / and /e/ for the second and third position in *sweat*), and the two phonemes inhibit each other. This leads to longer processing of exception words for a correct response compared to that for regular words which have no such conflict. The nature of the non-lexical reading route in the DRC model is the same as for the dual-route model.

In the lexical routes (see Fig. 4), letter units activate the corresponding orthographic input lexicon (e.g. *wheat* as word unit or node), and then this activation is transcoded either directly or via the semantic system into the phoneme system, where phoneme units corresponding to word units (e.g. *wheat*→/wi:t/) are activated. And finally speech output is created through the phoneme system. In the non-semantic reading route, communication between the orthographic input lexicon units and the phonological output lexicon units is in a bilateral direction, but each unit inhibits all others within the orthographic input and phonological output lexicons. In both the orthographic lexicon and the phonological lexicon, identical spelling and phonology are represented in the same units. So, heterographic homophones (e.g. night and knight) have different units in the orthographic input lexicon but a common unit in the phonological output lexicon. In the lexical routes, the following interactions are operated with both excitation and inhibition: i) between the letter units and the orthographic input lexicon, ii) between the orthographic input lexicon and the semantic system, iii) between the semantic system and the phonological output lexicon, and iv) between the phonological output lexicon and the phoneme system. The lexical routes operate in parallel with the non-lexical route.

The lexical routes and the non-lexical route share the letter unit and the phoneme system, but ‘communicate between these levels separately’ (Coltheart, Langdon, & Haller, 1996, p.19). However, interaction between the lexical procedures and the non-lexical procedure in the phoneme system can be assumed in the DRC model, because this model operates the lexical routes in a cascaded manner. When letter strings are read aloud using the lexical routes and the non-lexical route simultaneously, reading processing is continuous until the final speech output is produced. Simultaneous operation of the two distinct procedures and cascaded processing in the lexical routes are the key features of the DRC model and the dual-route model. Furthermore, it is assumed that letter strings (both words and nonwords) excite an orthographically similar pattern to the target stimuli (i.e. orthographic neighbours) at the orthographic input lexicon (Coltheart et al., 1996).

The activation of orthographic neighbours at the orthographic input lexicon in the DRC model would offer an explanation of the graded consistency effect. The partial activation of orthographic neighbours at the orthographic input lexicon could facilitate or disturb oral reading of words and nonwords. When orthographic neighbours share typical pronunciation of word-bodies, their activation is helpful for a correct response, whereas when pronunciation of word-bodies is atypical their activation is harmful to the production of correct oral reading. In other words, the DRC model is sensitive to the consistency of word-bodies in the processing of oral reading. It is likely that the DRC model would interpret the consistency effect of word-body neighbours demonstrated by normal adult readers (Jared, 2002).

Thus, the DRC model would solve the problems of the weak explanatory power in the dual-route model which led to the various modifications of the dual-route model.

2.2. Different dyslexic patterns and their interpretation using the dual-route model and the DRC model

Based on oral reading error, Marshall and Newcombe (1973) presented three types of dyslexia: visual dyslexia, surface dyslexia, and deep dyslexia. Although there are several types of dyslexia that can be described as '*peripheral dyslexia*'[5], the main investigations have been of surface and deep dyslexia, and phonological dyslexia (Beauvois & Derouesné, 1979; Derouesné & Beauvois, 1979). This study does not focus on 'peripheral dyslexia'. Therefore, surface, phonological, and deep dyslexia in alphabetic orthographies are reviewed in this section.

2.2.1. Previous research on surface dyslexia in alphabetic orthography

1) 'Pure' surface dyslexia pattern

<u>Oral reading errors in surface dyslexia</u>

The firstly reported two cases of surface dyslexia (Marshall and Newcombe, 1973), JC and ST, whose speech was fluent and grammatical, made predominantly reading errors described as ‘partial failures of grapheme-phoneme conversion’ (p.183). In their oral reading of 878 individual words, the vast majority of reading errors were of this type. JC and ST had found it troublesome to read words containing ambiguous consonants (e.g. incense→increase, phase→face), silent graphemic consonants (e.g. listen→liston, reign→region), words where the ‘rule of

[5] The patients with l*etter-by-letter reading* (also called *pure alexia*) make visual errors (e.g. soft →sort), but the major defining features are i) reading aloud the letters of a stimulus word one-by-one, and ii) a linear relationship between reading latency and word length (e.g. Patterson & Kay, 1982; Warrington & Shallice, 1980; Staller, Buchana, Singer, Lappin, & Webb, 1978; Shallice & Saffran, 1986). Patients with *neglect dyslexia* make distinctive visual errors in which the initial letters are replaced by other letters (e.g. wine →mine, yellow→pillow) or deleted (e.g. ran→an) (e.g. Kinsbourne & Warrington, 1962; Ellis, Flude, & Young, 1987; Patterson & Wilson, 1990). The patients with *attentional dyslexia* (Shallice & Warrington, 1977) show difficulty in identify letters, words and familiar shapes when a number of items are presented and have to be identified one after the other (e.g. win fed →fin fed), despite having preserved single-word reading.

e' lengthens the vowel (e.g. bike→bik, unite→unit), and so on. JC also made stress-shift errors (e.g. begín→béggin; omit→ómmit) and often gave sequences of responses (e.g. broad: broke, break…. braid. …broad). ST did not show these sorts of attempts, but sometimes tried to spell out the stimulus word ('spelling-reading'). Both cases made neologisms (about 25%), whereas there was no semantic error within their reading errors.

Marshall and Newcombe (1973) interpreted surface dyslexics' main errors as 'partial failures of grapheme-phoneme conversion'. But, Marcel (1980) pointed out that the vast majority of errors made by JC and ST were with visually similar real words and only about 25% of their errors were neologisms. Patterson (1982) wrote that reading errors of surface dyslexia were 'either neologistic pronunciation (e.g. *broad* → 'brode') or production of a similar but incorrect real word (e.g. *insect* → 'insist') or both (e.g. *placebo* → 'place-bo')'.

Meanwhile, Shallice and Warrington (1980) found that regularity of print-sound correspondence affected reading performance in surface dyslexia cases, and explained that most reading errors were 'partial failures of grapheme/phoneme correspondence rules'. Their patients, ROG and EM, demonstrated regular word advantage over irregular words (ROG: 92% > 64%; EM: 72% > 13%). This effect was confirmed in JC, who is one of the firstly reported surface dyslexics (Newcombe and Marshall, 1984). JC's accuracy of regular/irregular word reading was 50% vs. 30% and 54% vs. 28% in the two word lists. With regard to error type, Shallice, Warrington and McCarthy (1983) presented the detailed analysis of HTR's reading errors in oral reading words, including both regular words and irregular words. Sixty percent of HTR's errors were nonwords. In a set of irregular words, of

HTR's errors 60% were '*regularisation errors*' [6] (e.g. *gauge* →gorge, *prove* →proave) and 33% were lexicalisation errors.

Although the term regularisation error has been used for describing signature error type of surface dyslexia, Patterson, Plaut, Seidenberg, Behrmann, and Hodges (1996a) pointed out that surface dyslexia patients made not only 'pure' regularisation errors but also alternative pronunciation of each component of the word even for regular word reading (e.g. named *hoot* to rhyme with 'foot', *hear* like 'bear'). They found that many of the regular words yielding *LARC error,* short for Legitimate Alternative Reading of Components (Patterson, Suzuki, Wydell, and Sasanuma, 1995), which refers to the most typical pronunciation of its body neighbourhood, were regular inconsistent words (e.g. hoot). In exception words considerable LARC errors occurred in their patients, PB and FM. For example, PB pronounced *sweat* to rhyme with 'great' not to rhyme with 'treat' (i.e. regularisation of *sweat*). The concept of LARC error includes regularisation errors. Indeed, Patterson et al. (1996a) noted that the quintessential LARC error is a regularisation.

Defining features of 'pure' surface dyslexia

Through the cognitive neuropsychological investigations, it is accepted that 'pure' surface dyslexia has four defining features as follows:

i) Oral reading of words with an atypical spelling-sound correspondence ('irregular' words or exception words) is in a substantially deteriorated condition and this impairment is modulated by word frequency.

ii) The vast majority of reading errors are LARC errors in which the pronunciation of a component(s) is incorrect but is appropriate for that component(s) in other

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6 According to Shallice (1988), Coltheart (1981) created this succinct term, which is based on the dual-route model.

words (e.g. *pint* is misread as /pínt/ with typical pronunciation for orthographic neighbors like *mint*, *hint* and *print*), including regularisation errors.

iii) Accuracy of both regular word and nonword naming is in the normal range, or near normal.

iv) Oral reading latencies are within the normal range.

For example, MP (Bub, Cancelliere, & Kertesz, 1985) showed all these characteristics. While her oral reading accuracy of regular words was 96% (out of 707 words), her accuracy of exception words was 41% (out of 224 words). This regularity effect was strongly modulated by word frequency. Her reading accuracy of exception words reduced dramatically as word frequency diminished (over 200 per million: about 80%, 25-100 per million: about 60%, 0-25 per million: about 40%), but her reading performance of regular words remained at a high level of accuracy (over 100 per million: 100%, 0-100 per million: over 90%). The proportion of MP's correct reading was 95% for high frequency regular words, 97.5% for low frequency regular words, 92.5% for high frequency exception words, and 72.5% for low frequency exception words. MP produced a substantial number of regularisation errors (e.g. steak →/stik/; flood → /flud/). In contrast, MP read all 86 nonwords taken from Glushko (1979). MP's mean naming latencies were 588-594 msec, which was a normal range of speed[7].

KT (McCarthy & Warrington, 1986) was tested using 9 word lists manipulated by regularity. He read regular words more accurately than irregular words in all word lists. For example, in a word list taken from Glushko (1979), which consists of 43

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[7] For instance, in 20 University undergraduates (Taraban & McClelland, 1987) the mean naming latencies of exception words with a high frequency band and with a low frequency band were 573 msec and 623msec, respectively.

regular and 43 exception words controlled by word frequency and word length, KT's accuracy of regular and exception words was 100% and 34%, respectively, at the first testing session, and 93% and 34%, respectively, at the second and the third testing session. Seventy one percent of KT's errors were categorised as 'perfect' regularisations in which the most frequent letter-sound translation was assigned, 11% were acceptable but less common pronunciations, 8% were stress errors, and 10% were visual errors or uncategorised errors. So, 82% of KT's errors in word naming were LARC errors. KT also read nonwords taken from Glushko (1979) without errors.

The degree of consistency effect

With regard to the effect of spelling-sound correspondence, Shallice, Warrington, and McCarthy (1983) found that the degree of regularity affected patients' reading performance. Their surface dyslexic patient, HTR, read 74% of regular words, 49% of 'mildly irregular' words, and 29% of 'very irregular' words. Kay and Lesser (1985) also reported that their surface dyslexic patient, PT, demonstrated a degree of regularity effect using the same word list as Shallice et al. (1983) had used.

While these levels of regularity were described on the basis of their definition, Patterson and Behrmann (1997) demonstrated a body-level neighbourhood consistency effect on words and nonwords in MP, who has also been intensively investigated by other studies with different focuses (Bub, Cancelliere, & Kertesz, 1985; Bub, Black, Hampson, & Kertesz, 1988; Behrmann & Bub, 1992). Patterson and Behrmann (1997) manipulated spelling-sound consistency based on "the ratio of the number of words in a specified orthographic neighbourhood that have a regular spelling-sound relationship to the number of words in that neighbourhood that have an exceptional spelling-sound relationship” (p.1220). The reading stimuli comprise body-matched regular words (REG) by the GPC rule (e.g. *hoot*), exception words (EXC) by the GPC rule (e.g. *soot*), and nonwords (e.g. goot, noot). In condition 1, the ratio of the mean number of REG to the mean number of EXC was 9.9 to 1.6 (REG > EXC). In condition 2, they were 3.6 to 4.6 (REG < EXC). MP’s reading accuracy of regular words is higher than for exception words in conditions 1 and 2 (100% > 38%, 90% > 57%, respectively). MP’s reading accuracy of nonwords was also influenced by body level consistency (90% in condition 1, 78% in condition 2). MP’s results suggested that word-body neighbour consistency is a more sensitive means of predicting MP’s oral reading deficit than spelling-sound regularity.

2) Subtypes of surface dyslexia

Taking the description of subtypes[8] of surface dyslexia by Shallice and McCarthy (1985), Patterson, Seidenberg, and McClelland (1989) divided previously reported surface dyslexic patients into two types. Type I is ‘pure’ surface dyslexia, which is explained above, including MP (Bub, Cancelliere, & Kertesz, 1985), KT (McCarthy & Warrington, 1986), and HTR (Shallice, Warrington, and McCarthy, 1983). Type II is considered to include more heterogeneous cases than Type I. Type II patients show the following characteristics:

i) Detectable deterioration for regular words as well as a remarkable deficit in the reading of exception words;

ii) The proportion of regularisation errors/LARC errors is sometimes not dominant;

iii) Nonword reading is impaired but with a tolerable level of accuracy; and

iv) Oral reading latency is slow, and the patient may show a number of attempts to

[8] Shallice and McCarthy (1985) labeled the ‘pure’ type of surface dyslexia (i.e. Type 1) as ‘semantic dyslexia’ and called Type II as ‘surface dyslexia’.

read aloud the stimulus word.

JC and ST (Marshall & Newcombe, 1973), PT (Kay & Lesser, 1985), and EST (Kay & Patterson, 1985) were considered to belong to this type. Among Type II patients, for instance, EST showed an advantage of regular words over irregular words (69% > 56%) in oral reading, though there was no statistical significance. The average number of his attempts to read aloud each regular word was lower than for each irregular word (1.5 vs. 2.3). Regularisation errors were EST's main reading error for irregular words (8/17, 47%), but he also made visual errors in oral reading of both regular words (5/12, 42%) and irregular words (3/17, 18%). EST's visual errors, which involved either letter changes or letter additions or deletions, always corresponded to existing words (e.g. rob → rub, scarce → scare). EST's accuracy of nonword reading was 84%, which was better than regular word reading. EST's reading speed for nonwords was much faster than his oral reading of words (while he took about 14 minutes to read 80 nonwords, he spend over 1 hour reading 80 words that were the base word for nonwords).

There is another view of sub types of surface dyslexia. While the categorisation of Types I & II is based on the nature of the surface dyslexic pattern itself, Ellis, Lambon Ralph, Morris, and Hunter (2000) proposed the three subtypes of surface dyslexia based on hypothesised loci in the dual-route model. According to their rationale, damage to the orthographic (or visual) input lexicon, to the impaired semantic system, and to the phonological (or speech) output lexicon lead to output surface dyslexia, central (semantic) surface dyslexia, and output dyslexia, respectively. The relationship between these two distinct categorisations can be considered as follows: Type I (i.e. 'pure surface dyslexia') corresponds to central (semantic) surface dyslexia, and Type II corresponds to both input and output surface dyslexia. This is because it was pointed out that the semantic function in Types I and II was distinctive (e.g. Patterson, Seidenberg, and McClelland, 1989a). Type I patients show severe impairment of language comprehension and semantic knowledge, whereas Type II patients are heterogeneous in terms of the relationship between word comprehension and reading. For instance, MP (Bub, Cancelliere, & Kertesz, 1985), who belongs to Type I, showed substantial semantic impairment. MP's accuracy in the card-sorting task, which comprised 105 exemplars from 25 semantic categories, was 47%. MP also performed poorly in semantic relatedness judgment (9/26, 35%) and picture-word semantic categorisation (7/20, 35%), which required the patient to choose the word that was, conceptually, most similar to the picture (e.g. tree: picture, *shoe*, *flower*, *pen*, *hand*).With EST (Kay & Patterson, 1985), and EE (Howard & Franklin, 1987), their written word comprehension corresponded strongly to correct oral reading, though occasionally they could understand written words which were mispronounced. Meanwhile, MK (Howard & Franklin, 1987) showed a quite different pattern in the relationship between word naming and written word comprehension. Although MK demonstrated a regularity effect (his reading accuracy of regular words and irregular words was 90% and 67%, respectively), he showed good comprehension of both types of written words in the task of defining written words with homophone presentation (his comprehension of regular words and irregular words was 96% and 92%, respectively). That is, MK could understand written words that he mispronounced.

Taking this heterogeneity of Type II, it might be possible to subdivide this type. Indeed, Ellis et al. (2000) presented JC (Newcombe & Marshall, 1984) and EE

(Howard & Franklin, 1987) as input surface dyslexia, and EST (Kay & Patterson, 1985) and MK (Howard & Franklin, 1987) as output surface dyslexia. However, they acknowledged the difficulty of distinguishing between input surface dyslexia and output surface dyslexia. They wrote that “the situation with output surface dyslexia is rather like that with input surface dyslexia: No case has yet been reported that matches all the requirements of a pure case, but patients have been reported who come fairly close” (p.97).

3) Semantic function in 'pure' surface dyslexia

With the exception of a few studies (e.g. Deloche, & Andreewsky, 1982; Coltheart, Masterson, Byng, Prior, & Riddoch, 1983), early research of surface dyslexia had not systematically investigated dyslexic patients’ reading comprehension and semantic knowledge. However, studies of semantic dementia[9] accompanied by surface dyslexia changed this conventional situation.

Patterson and Hodges (1992) reported that all six patients with progressive deterioration of semantic impairment, ranging from moderate to very severe, demonstrated a regularity effect, which was highly modulated by word frequency. For example, in a severe case, PP, who could not name any objects and showed severe comprehension deficit (35% correct in spoken word-picture matching with five choices), could read regular words with high and medium frequency bands fairly well (86% and 82%, respectively), but her accuracy reduced in low-frequency regular words (62%) and dramatically declined in exception words with three frequency bands (high frequency: 36%, medium frequency: 18%; and low

[9] Semantic dementia is a progressive, selective disorder of semantic memory connected with focal atrophy of the anterior, inferior temporal lobes in both hemispheres (Snowden, Goulding, & Neary, 1989; Hodges, Patterson, Oxbury, & Funnell, 1992).

frequency: 8%). A moderate case, PB, whose accuracy of the same spoken word-picture matching task was 75% and whose naming ability was modulated by word frequency (high frequency vs. low frequency was 37.5% and 8%), could read regular words well (his accuracy for high, medium and low frequency bands was 98%, 90%, and 93% respectively). PB's oral reading performance for exception words, however, was most impaired at a low frequency band and showed frequency by regularity interaction (his accuracy for high, medium, and low frequency bands was 86%, 71%, and 48%, respectively). Both PP and PB made a high proportion of regularisation errors on exception words (74% and 80% respectively). These results indicated that severity of semantic impairment was related to accuracy of word reading and the degree of regularity effect.

Funnell (1996) presented a longitudinal investigation of EP, who is one of the patients with semantic dementia reported by Hodges et al. (1992). EP demonstrated a progressive deterioration of irregular word naming coupled with preserved oral reading for regular words and nonwords over 30-months. EP's comprehension of the irregular words read correctly was better than that of the irregular words read incorrectly in written/spoken word-picture matching tasks with an unrelated condition (i.e. the target picture and an unrelated distractor were presented). This result suggests that successful oral reading of irregular words is related to knowing word meaning. Using identical words, Graham, Patterson, and Hodges (1994) directly examined the relationship between semantic knowledge and oral reading of words and found that three patients[10] with semantic dementia demonstrated an item-specific correspondence between comprehension and exception word naming.

[10] FM, one of the three cases in Graham et al. (1994), was later classified as progressive pure anomia due to her mildly impaired and stable performance on various tasks of semantic knowledge over 3 years being revealed (Graham, Patterson, & Hodges, 1995).

Thus, a) correlation between the severity of the surface dyslexic pattern, and b) an item-specific relationship between exception word reading and comprehension, suggest that there is a link between semantic impairment and surface dyslexia. However, there are some semantically impaired patients, who did not manifest surface dyslexia, like WLP (Schwartz, Saffran, & Marin, 1980) [11], DRN (Cipolotti & Warrington, 1995), DC (Lambon Ralph, Ellis, & Franklin, 1995), EW (Gerhand, 2001), and EM (Blazely, Coltheart, & Casey, 2005). So, whether semantic impairment is a source of surface dyslexia is an open question.

2.2.2. Interpretations of surface dyslexia using the dual-route model and the DRC model

1) The interpretation of surface dyslexia using the dual-route model

An advantage of regular words over irregular words or exception words, coupled with preserved nonword reading, which is a characteristic feature of surface dyslexia, can be interpreted as the preserved non-lexical reading route and the impaired lexical reading routes. Since surface dyslexic patients showed sub varieties, the loci of impairment in the lexical reading routes should vary. Based on the processing model from Funnel (1983a), which postulates a single set of orthographic codes and phonological codes, Coltheart and Funnell (1987) presented seven different possible patterns of impairment in the lexical routes for the manifestation of surface dyslexia (p.318), as follows:

i) pathway from Visual Analysis to Lexical Orthographic codes impaired;

ii) entries within Lexical Orthographic Codes inaccessible or deleted;

iii) pathway from Lexical Orthographic Codes to Lexical Phonological Code, and

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[11] WLP ‘s oral reading was preserved in an earlier stage of her disease, but WLP showed a surface dyslexic pattern in a later stage of her disease (Schwartz et al., 1980).

pathway from Lexical Orthographic Codes to Cognitive System both impaired;

iv) pathway from Lexical Orthographic Code to Lexical Phonological Codes impaired, and entries within the Cognitive System inaccessible or deleted;

v) pathway from Lexical Orthographic Codes to Lexical Phonological Codes, and pathway from Cognitive System to Lexical Phonological Codes both impaired;

vi) entries within Lexical Phonological Codes inaccessible or deleted;

vii) pathway from Lexical Phonological Codes to Response Buffer impaired.

They also mentioned that a visual lexical decision task would be used for distinguishing impairment iii) from impairments i) and ii). If a patient with surface dyslexia shows good lexical decision performance that implies impairment of iii). Furthermore, they pointed out that if *homophone confusion errors* (Coltheart et al., 1983) is observed in a reading comprehension task, variants iv), v), vi) and vii) will not occur and variants i), ii) and iii) will occur.

This view is different from the proposal by Ellis et al. (2000), who assumed pre-semantic impairment, post-semantic impairment, and impairment of the semantic system. Using this proposal, all hypothetical loci made by Coltheart and Funnell are categorised as pre-semantic impairment, but the non-semantic lexical route (i.e. the pathway from Input Orthographic lexicon and Output Phonological Lexicon) must be impaired in all cases. In this rationale, surface dyslexia is attributable to multiple-deficits in the lexical routes.

For instance, EST (Kay & Patterson, 1985), who showed good comprehension and good performance in lexical decision judgment, though there was a regularity effect (the proportion of correct response was 100% for regular words and 87% for irregular words), would have i) impairments of the pathway from the orthographic input lexicon to the semantic system, or post-semantic impairment; and ii) impairment of the pathway from the orthographic input lexicon to the phonological output lexicon. KT (McCarthy & Warrington, 1986), who showed deteriorated comprehension of both spoken and written words accompanied by anomia, would show damage of i) the semantic system and ii) the lexical-nonsemantic route. Bub, Black, Hampson and Kertesz (1988) explored the semantic function of their surface dyslexic patient, MP, and concluded that ”MP’s comprehension deficit must arise beyond the actual pathways to meaning, and the most reasonable option is that the damage has occurred within the semantic mechanisms itself” (p.49). So, the source of surface dyslexia in MP should be the semantic system and the non-semantic lexical route. The same loci are attributable to the surface dyslexic pattern observed in the patients with semantic dementia who have semantic memory impairment.

With regard to the degree of regularity effect (Shallice et al., 1983), the degree of consistency effect (Patterson & Behrmann, 1997), and the predominant occurrence of LARC errors, the dual-route model cannot provide a clear explanation due to the GPC rule-base and independent processing. The GPC rule is applied in an all-or-nothing manner. In other words, regularity is treated in dichotomy (i.e. regular vs. irregular). So, the dual-route model fails to offer the explanation of the degree of the regularity and the consistency effects. Although the dual-route model can interpret regularisation errors as the outcome of a dominant of use the GPC rule, this model cannot explain the LARC errors that involve not only regular one-to-one correspondence but also other correspondences, and which are seen in irregular words (or exception words) and regular inconsistent words.

2) The interpretation of surface dyslexia using the DRC model

In the DRC model surface dyslexia is interpreted as being the result of impairment of the lexical reading routes, which is the same as in the dual-route model. The DRC model, however, can provide an explanation of a graded consistency effect (Patterson and Behrmann, 1997) and LARC errors (Patterson et al., 1996) that cannot be explained by the dual-route model.

As explained in the previous section (2.1.), given the assumption that letter strings excite an orthographically similar pattern to the target stimuli (i.e. orthographic neighbours) at the orthographic input lexicon (Coltheart et al., 1996), the activation of orthographic neighbours could facilitate or disturb reading aloud of the target stimuli. If orthographic neighbours of the stimuli consist of many friends and a few enemies, oral reading of the stimuli is facilitated, but it is disturbed when orthographic neighbours of the stimuli consist of a few friends and many enemies. So, oral reading of regular inconsistent words, which have enemies, is more prone to creating errors compared to oral reading of regular consistent words, which have no enemies. LARC errors occur when the pronunciation of orthographic neighbours is activated instead of the target's pronunciation, due to the deterioration of the lexical reading routes. Thus, the DRC model can provide a coherent explanation for a surface dyslexic pattern, including a consistency effect and LARC errors.

Finally, computer simulation studies should be mentioned. Coltheart and his colleague showed that the data from the lesioned DRC model, and quantitative data from the two surface dyslexic patients, MP (Bub et al., 1985) and KT (McCarthy & Warrington, 1986), are very close. In one simulation (Coltheart et al., 1996), the lesion site was the pathway from letter units to the orthographic input lexicon, and letter-to-word excitation was reduced to 25% or 21% of its normal value, which were appropriate for MP’s reading performance and KT’s reading performance, respectively. In another simulation, (Coltheart et al., 2001), the orthographic input lexicon itself was chosen as a locus of impairment. The different computer simulation study[12] by using the connectionist dual-process model also presented a successful simulation for KT's dyslexic pattern.

However, these computer simulation studies, which only examined the effect of the impaired lexical-nonsemantic route (i.e. computation from the input orthographic lexicon and the phonological output lexicon), still appear to be insufficient to examine the mechanism of the surface dyslexic pattern. This is because cognitive neuropsychological investigations suggest that the semantic system and the lexical-nonsemantic route were loci of impairment of both MP and KT, who are 'pure' surface dyslexia.

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[12] While the DRC model keeps explicit GPC rule-based serial processing, Zorzi, Houghton, and Butterworth (1998) presented the connectionist dual-process model, in which the sublexical assembly process is implemented in the connectionist network by containing both the direct connections from orthography to phonology and the orthography →hidden units →phonology connections. They called this mechanism *the Two-Layer Assembly (TLA) model*. When the hidden unit-mediated pathway was selectively impaired (they treated this as lesion of the non-semantic lexical route), their model’s performance was similar to the performance of surface dyslexia patient, KT (McCarthy & Warrington, 1986).

2.2.3. Previous research on phonological dyslexia in alphabetic orthography

1) Phonological dyslexia pattern

Basic characteristics

The key characteristic of phonological dyslexia is a marked 'lexicality' effect, where reading aloud of nonwords is severely impaired despite relatively preserved real word reading. Beauvois and Derouesné (1979) first described this type of acquired dyslexia in French. MF and RG can read words (i.e. nouns) without errors, whereas their nonword reading was significantly impaired (42% correct in MF and 25% correct in RG). The dominant type of reading error for words/nonwords in these patients was in the visual (and therefore phonological) resemblance to the target words. Furthermore, both cases' accuracy of reading aloud of pseudohomophones (which are orthographic nonwords with a familiar phonological pattern like BRANE) was better than of non-homophonic nonwords like FRANE (MF: 76% > 43%; RG: 78% > 36%). In a detailed analysis of LB's performance, Derouesné and Beauvois (1985) found interaction between visual similarity and psedohomophony. In nonword reading, visual error occurred more frequently when the stimuli were pseudohomophone but visually not similar to a word (8/19, 42%) than when the stimuli were non-homophonic nonwords but were visually similar to a word (2/11, 18%).

After the first report of phonological dyslexia pattern in French, a number of phonological dyslexia cases have been reported (e.g. GRN and BTT: Shallice & Warrington, 1980; WB and FL: Funnell, 1983b). This was not limited to English cases. Italian-speaking patients (AMM: De Bastiani, Barry, and Carreras, 1988; RR: Bisiacchi, Cipolotti, & Denes, 1989) and a Spanish-speaking patient (AD: Cuetos, Valle-Arroyo, & Suarez, 1996) were also reported. That is, phonological dyslexia has been reported in opaque or deep orthographies such as English and French, and transparent or shallow orthographies such as Italian and Spanish.

Pseudohomophone advantage

Some phonological dyslexia cases demonstrated a pseudohomophone advantage over nonhomophonic nonwords like MF and RG (Beauvois and Derouesné, 1979). For example, in the study by Derouesné and Beauvois (1979) two cases (B and C) showed a pseudohomophone effect. In the study by Berndt, Haendiges, Mitchum and Wayland (1996), out of 11 phonological dyslexics 5 patients showed this effect, which was not related a patient's severity of reading impairment. Patterson and Marcel (1992), who investigated 6 phonological dyslexic patients, reported 4 cases (BBO, DPR, RTI and TWA) which demonstrated a pseudohomophone effect (oral reading pseudohomophone > oral reading nonhomophonic nonwords: BBO- 82% > 33%; DPR- 69% > 10%; RTI- 74% > 30%; TWA- 68% > 17%), and one case, WBA, showed a numerical advantage for pseudohomophone reading (88% > 77%). Southwood and Chatterjee (2000) also reported that 2 cases (VD and SE) out of 5 phonological dyslexic patients demonstrated a pseudohomophone effect.

Lexicalisation errors in nonword reading

With regard to nonword reading errors, Funnell (1983b) pointed out that most errors made by her phonological dyslexic, WB, were real words with a strong orthographic resemblance to the stimulus nonword (e.g. SWEAL → *sweet* DUBE→*tube*, BAME→*blame*). This type of nonword reading error is called as lexicalisation error and this phenomenon was later termed '*lexical capture*' by Funnell and Davison (1989) in their study of a woman with developmental phonological dyslexia and dysgraphia.[13] Patterson and Marcel (1992) found that out of 6 phonological dyslexic patients who showed radical dissociation between words, including function words and nonwords (over 90% vs. 5% in 4 cases or over 90% vs. 20% in two cases), 5 cases made a considerable number of lexicalisation errors (63-88%). Southwood and Chatterjee (2000) also found a superiority of lexicalisation error over visual/phonological error in 4 out of 5 phonological dyslexic patients (VA: 64% > 21%; VD: 69% > 15%; NS: 61% > 33%; SE: 43% > 21%). Although the phonological dyslexics, who demonstrated a superiority of lexicalisation errors, tended to show a pseudohomophone effect, Berndt et al. (1996) reported that pseudohomophone reading was not significantly correlated with the rate of lexicalisation error for 11 patients, ranging from 35% to 58% ($r = 0.21$, $p > 0.1$).

Function word reading

Patterson (1982) pointed out a deteriorated oral reading of function words in phonological dyslexia. In AD, who showed a lexicality effect and pseudohomophone advantage over control nonwords (60% > 37.5%), his accuracy of function words was 72% which was less accurate than that of content words (92% correct). Although there are phonological dyslexic patients who did not show this dyslexic pattern (e.g. WB: Funnell, 1983b; JD: Farah, Stowe, & Levinson, 1996), the inferiority of function words over content words has been pointed out in other studies. For instance, AN (Goodall & Phillips, 1995), and CJ (Patterson, 2000a) demonstrated this characteristic (AN: 48% < 85%; CJ: 65% < 95%).

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13 Out of 50 nonwords, her lexicalisation errors were 22% in oral reading, 14% in spelling, and 10% in repetition.

Imageability effect

The effect of imageability and/or concreteness on oral reading performance has been also noted in phonological dyslexia patients (CJ and JG: Funnell, 1987; AN: Goodall & Phillips, 1995; JD: Farah, Stowe, & Levinson, 1996). For instance, AN read 82% of high imageability words, but 43% of low imageability words. CJ (Patterson, 2000a), also studied by Funnell (1987), was able to read 86% of high imageability/high concreteness words, but 55% of low imageability/low concreteness words. Patterson examined CJ's word naming, using word stimuli that manipulated three variables (word frequency, regularity, and imageability) and confirmed a highly reliable advantage of high imageability words over low imageability words (92% vs. 61%, $p < 0.001$). She also found a marginal effect of word frequency (high frequency words: 82% vs. low frequency words: 71%, $p = 0.056$). But there was no effect of regularity (regular words: 76% vs. irregular words; 76%), and no interaction between these three variables.

Taking all the above together, the reading characteristics of phonological dyslexia are summarised as follows:

The cardinal features of phonological dyslexia are

i) Impaired nonword reading coupled with preserved word reading (lexicality effect); and

ii) The dominant error type of nonword reading is visual (and therefore phonological). Resemblance to the target, and lexicalisation errors can be observed.

Many phonological dyslexic patients also show

iii) A pseudohomophone effect (pseudohomophones > nonhomophonic nonwords).

Some phonological dyslexic patients show

iv) Inferiority of function word reading over content word reading; and

v) An imageability/concreteness effect (high imageability/concreteness words > low imageability/concreteness words).

As the review of deep dyslexia will show later (2.2.5), deep dyslexia share these characteristics. But there is general agreement that an absence of semantic errors is the diagnostic feature of phonological dyslexia (e.g. Patterson, 1981). It has been recognised that phonological dyslexia is ‘a convenient shorthand term indicating that one of the symptoms seen in the person referred to will be selectively impaired nonword reading’ (Coltheart, 1996, p.750).

2) Subtypes of phonological dyslexia

Friedman (1995) proposed subtypes of phonological dyslexia, using her ‘original’ reading model (p.399, Fig.2) which does not postulate the non-lexical route. She argued that oral reading of words and pseudowords depends on the proper activation of the phonological lexicon, and she assumed two types of deficit: a) an impaired orthography-to-phonology route, and b) impairment of the phonological lexicon. In her logic, the former deficit leads to an impaired function of word reading and pseudohomophone reading, coupled with preserved content word reading, which is due to a preserved semantic route. In the latter deficit, repetition that relies on phonological processing should be impaired and other features, such as difficulty of holding onto a phonological code, should also be apparent because impairment of the phonological lexicon is not specific to oral reading. On the basis of her rationale, Friedman surveyed the previously reported phonological dyslexic patients who were divided into the two groups. Type I patients can repeat nonwords, but their oral reading of function words is less accurate than that of content words (AM: Patterson, 1982; LB: Derouesné and Beauvois, 1985). Type II patients do not show an impaired function word reading, but they have difficulty with nonword repetition (WB: Funnell, 1983b; HR: Friedman & Kohn, 1990). Friedman (1996a) added two Type II patients (MS and BR).

However, these subtypes of phonological dyslexia suggested by Friedman have not been accepted widely (Patterson, 2000a). Since almost all phonological dyslexic patients demonstrated a clear disturbance of general phonological ability, which is described in the next section, it appears that Friedman's distinction is not reliable, and is not useful in the understanding of the source of phonological dyslexia.

3) Phonological function and phonological dyslexia

Although phonological dyslexia cases without phonological impairment were reported (LB: Derouesné & Beauvois, 1985; RR: Bisiacchi, Cipolotti, & Denes, 1989; RG: Caccappolo-van Vliet, Vliet, Mizzo, & Stern, 2004a; MO & IB: Caccappolo-van Vliet, Vliet, Mizzo, & Stern, 2004b), there is consensus that almost all phonological dyslexics have phonological impairment, even in non-reading tasks that do not use orthographic stimuli (see Coltheart, 1996, for review).

<u>Phonological manipulation</u>

Earlier works were focused to test patients' ability in hypothesised non-lexical route processing (i.e. 'graphemic parsing', grapheme-phoneme conversion, and phonological blending), because the dual-route model gives the definition that nonword reading is only processed by the non-lexical route. As far as the hypothesised three stages of the non-lexical route are concerned, the deficit pattern is different across reported patients. Derouesné and Beauvois (1985) found that their phonological dyslexic LB was poor at the task required to decide the number of phonemes for the target grapheme (27/40, 68%), suggesting an impairment of graphemic parsing. LB, however, showed a good performance of phonological segmentation (53/60, 88%) and could pronounce, fairly well, the phoneme of presented strings of letters that corresponded to a single graphemic unit (35/40, 88%), thus indicating preserved grapheme-phoneme conversion.

On the other hand, Patterson and Marcel (1992) drew attention to a relationship between phonological impairment and phonological dyslexia. Indeed, their paper's title was written as 'Phonological ALEXIA or PHONOLOGICAL Alexia?' All of their 6 patients with phonological dyslexia were good at orthographic segmentation (or graphemic parsing), in which the patients were required to find matching single letters, or digraphs, in pairs of words or nonwords. However, their performance varied in the phonological segmentation task which required the patients to delete the first sound of a single-syllable spoken stimulus (both words and nonwords). While two patients were unable to do this task, the accuracy of the other patients ranged from 25% to 88%. In contrast, all 6 patients were impaired in the phonological blending tasks, which required them to assemble a single phoneme onset and the rhyme of a single-syllable (e.g. /v/, age →vage), and to blend the 3 individually presented phonemes (e.g. /kə/, /æ/, and /tə/ →cat). All 6 cases showed more difficulty in three-phoneme blending than in onset/rhyme blending. Four patients demonstrated a significant advantage for words over nonwords in the blending tasks. For example, BBO's accuracy for words and nonwords in onset/rhyme blending was 88% and 42%, respectively, and in the three-phoneme blending task BBO's proportion of correct responses was 30% for words and 0% for nonwords.

Goodall & Phillips (1995) also reported that their phonological dyslexic, AN, showed preserved ability of graphemic parsing (38/40, 95%), but a deteriorated ability of sounding-out single letters (201/300, 67%), and severe impairment of phonological blending (3/10 for words, and 4/10 for nonwords). Cuetos, Valle-Arroyo & Suárez, (1996) reported a Spanish speaking phonological dyslexic patient, AD, who showed preserved processes of orthographic segmentation, syllabic segmentation and sounding-out single letter (15/15, 100%; 14/15, 93; 20/21, 95%, respectively), but demonstrated severe impairment in phonological blending for words (11/50, 22%) and for nonwords (6/30, 20%).

These results indicate that phonological blending appears to be the most difficult phonological manipulation for phonological dyslexic patients. More importantly, the vast majority of cases demonstrate a better performance for words than nonwords across various kinds of non-reading phonological tasks. That is, a lexicality effect is not specific to reading aloud of words in phonological dyslexia, suggesting that there is a general phonological impairment in phonological dyslexics.

<u>The view of a causal relationship between phonological impairment and phonological dyslexia</u>

There are two intensive studies (Farah, Stowe & Levinson, 1996; Patterson, 2000a) dealing with causal relationship between a general phonological impairment and phonological dyslexia.

Farah, et al. (1996) used a repetition task for extensive testing of phonological processing. They showed that their phonological dyslexic, JD, was impaired in the 5 different tasks: 1) single nonword repetition, 2) triple word repetition, 3) triple nonword repetition, 4) delayed repetition of triple words, and 5) delayed repetition of triple nonwords. In the delayed conditions the patients counted aloud from 1 to 5 after the targets were presented phonologically, and then repeated them. The average proportion of correct performance by ten age- and education-matched normal subjects, with the same order of the 5 conditions, was 88%, 89%, 80%, 88% and 76%. JD's accuracy was 87%, 85%, 66%, 66%, and 35% in each condition. Though it has been reported that many patients with phonological dyslexia have preserved single nonword repetition (e.g. Patterson & Marcel, 1992; Goodall & Phillips, 1995), their study revealed that JD had impairment in more demanding repetition, suggesting a general phonological ability in both reading and repetition. They concluded that a damaged phonological function led to phonological dyslexia.

Patterson (2000a) presented an in-depth study of her phonological dyslexia case, CJ, who was also studied by Funnell (1987), offering an explanation for how a general phonological deficit could impact on nonword reading, based on the triangle model's framework. She emphasised that CJ, and every one of the 17 patients with phonological dyslexia who were presented in a special issue on the topic of phonological dyslexia (*Cognitive Neuropsychology*, 1996, vol. 13), showed an associated phonological deficit, and she argued that a general phonological impairment is the source of phonological dyslexia. She pointed out that the two exceptional cases - LB (Derouesné & Beauvois, 1985) and RR (Bisiacchi et al., 1989) - did not demonstrate the marked lexicality effect, which is the key feature of phonological dyslexia.

A different notion about the source of phonological dyslexia

There is a view that considerable difficulty in nonword reading in phonological dyslexia is not attributable solely to phonological impairment. Berndt et al. (1996) take this position using the dual-route model's framework. Their 11 cases had problems in all three stages of hypothesised non-lexical route processing based on the dual-route model. The patients' blending ability was influenced by segment size and lexicality. The probability of grapheme-to-phoneme correspondence of nonword strings also affected nonword-reading performance in some patients whose accuracy of word reading was over 90%. Out of the 11 patients, four patients (WE, BK, JH, & JD) showed an advantage of the high GPC nonwords - which were CVC strings that combined a number of consonants with word bodies (e.g. NEEP, FEEP) - over the low GPC nonwords, which were strings with a lower probability of correspondence to any single phoneme and with several alternative pronunciations (WE: 85% >50%, BK: 70% > 25% JH: 76% > 10%; JD: 24% > 0%). One patient, HC, showed a numerical advantage of the high GPC nonwords (27% > 10%). But, 6 patients, whose accuracy of word reading was under 70%, were severely impaired in both the high and low GPC nonwords and did not show this effect. Based on these results, they concluded that selective impairment of nonword reading “arise(s) from pervasive problems in the representations and processes necessary to derive phonology from print nonlexicality” (p.797).

4) Preserved implicit phonological knowledge

Some studies have indicated that implicit phonological knowledge of nonwords was relatively well preserved in phonological dyslexia. In the silent judgment of homophony test, both AM (Patterson, 1982) and AN (Goodall & Phillips, 1995) showed a relatively preserved performance. The proportions of correct judgments for regular words, irregular words and nonwords were 84%, 92% and 64%, respectively, in AM, and 100%, 92% and 74%, respectively, in AN. In auditory-visual matching of nonwords - which required the patient to indicate which of the three spoken items corresponded to a given single printed nonword - AM's proportions of accuracy were 79% in a phonologically distinct condition and 60% in a phonologically similar condition. It is worth noting that Patterson (1982) mentioned that AM's accuracy was significantly above that of the two deep dyslexic patients, DE and PW (Patterson, 1978), in a phonologically similar condition (60% > 44% and 36%, respectively), though their scores were similar in a phonologically distinct condition (79% ≒ 80% and 75%, respectively). This appears to suggest that patients with phonological dyslexia have a more reliable implicit phonological knowledge about nonwords compared to that of patients with deep dyslexia.

Preservation of implicit phonological knowledge in phonological dyslexia might be treated as data to support the view that a general phonological impairment leads to phonological dyslexia. This is because implicit knowledge about nonwords indicates that the non-lexical route has not been totally abolished in phonological dyslexia cases.

2.2.4. Interpretations of phonological dyslexia using the dual-route model and the DRC model

1) The interpretation of phonological dyslexia using the dual-route model

Selective impairment of nonword reading is the key feature of phonological dyslexia. So, phonological dyslexia can be explained as impairment of the non-lexical route coupled with preservation of the two lexical routes.

Phonological dyslexia and surface dyslexia show a 'double dissociation' in terms of the substantial discrepancy between real word and nonword reading. Given the assumption that all reading routes are functionally independent, the dual-route model can easily explained this double dissociation. While selective impairment of the lexical routes leads to surface dyslexia, selective impairment of the non-lexical route leads to phonological dyslexia. So, the double dissociation between surface and phonological dyslexia perfectly fits the dual-route model's prediction, and this has been taken as firm evidence to support the reliability of the dual-route model (e.g. Coltheart, 1985; Coltheart et al., 1993).

Indeed, previously reported phonological dyslexic patients demonstrated various problems in these distinctive processes of the non-lexical reading route: i) *graphemic parsing*, ii) *phoneme assignment*, and iii) *phoneme blending*. But the fact was that almost all patients in the previous studies were impaired in the final stage (i.e. *phoneme blending*), though there were two exceptional cases (LB: the impaired graphemic parsing with the preserved phoneme assignment - Derouesné & Beauvois, 1985; RR: the impaired phoneme assignment with the preserved grahemic parsing - Denes, Ciplotti, & Semenza, 1987). Therefore, the process of assembling phonological sequence into a blended response is potentially relevant to the patient's nonword reading deficit.

The dual-route model, however, cannot explain why impairment of this phonological ability leads to deficit of nonword reading. The following phenomena, observed in the vast majority of phonological dyslexic patients and appearing to be important qualitative characteristics, are also hard to explain through the dual-route model. First, the patients produced lexicalisation errors (real words that are visually similar to the stimuli nonwords) in nonword reading. Second, they showed a pseudohomophone effect in nonword reading (superiority of pseudohomophones over nonhomophonic nonwords).

Since the dual-route model assumes that the non-lexical reading routes can only process nonword letter strings without reference to the representations of words, it is difficult to explain these lexical influences in nonword processing. The lexical status of pseudohomophones (phonologically, they are words) could not be known after the process of assembling phonological sequence in the non-lexical route. So, a pseudohomophone effect would have to arise at the level of response buffer. But any lexical information from the phonological output lexicon is not supplied in the response buffer, because orthographic nonwords cannot be processed in the lexical reading routes. Thus, there is no reason for a pseudohomophone advantage or lexicalisation errors to occur.

2) The interpretation of phonological dyslexia using the DRC model

The DRC model can interpret phonological dyslexia as a result of the substantial impairment of the non-lexical route, and also can explain both a pseudohomophone advantage and lexicalisation errors. This is "because nonword letter strings that are orthographically very close to real words partially excite the entries for those words in the orthographic input lexicon" (Coltheart et al., 1996, p.33), as was already explained in the previous section (2.1). Coltheart et al. (1996) called this 'the orthographic proximity effect'. So, activation of real words, which are visually similar to the target nonwords in the lexical reading routes, will facilitate nonword reading by the interaction between the phonological output lexicon and the phoneme system. This will result in i) lexicalisation errors, and ii) superiority of pseudohomophone over nonhomophonic nonwords that are both orthographically and phonologically nonword strings and which cannot excite any lexical entries.

Coltheart et al. (1996, 2001) presented the simulation of phonological dyslexia, with effects of pseudohomophony and orthographic similarity to the base words, which was observed in French phonological dyslexic, LB (Derouesné & Beauvois, 1985). Much greater advantage of the pseudohomophones that are visually close to the base words (e.g. *galo* from galop) over visually less similar pseudohomophones (e.g. *kacé* from cassé) can be explained as superiority of an ‘orthographic proximity effect’ in the former compared to the latter. In summary, the DRC model, can offer a coherent explanation of a phonological dyslexic pattern in relation to a damaged non-lexical route.

2.2.5. Previous research on deep dyslexia in alphabetic orthography

1) Deep dyslexia pattern

The first deep dyslexia cases were GR and KU (Marshall and Newcombe, 1973), whose spontaneous speech was non-fluent and characterised as 'telegrammatic'. GR showed differing accuracy of oral reading depending on a word's grammatical category. In GR's correct responses out of the reading of 4000 individual words i) concrete nouns were more accurate than abstract nouns (45-50% > 10%), ii) adjective and verbs (5-15%) were less accurate than concrete words, and iii) function words were the least accurate (2/111, 1.8%). GR's error patterns showed a) a striking response bias toward nominalisation (e.g. entertain→entertainment), in which 90% of stimulus verbs and 72% of stimulus adjectives were read as nouns; b) predominant semantic errors (e.g. city→town; daughter→sister; cheer→laugh; employ→factory); c) the co-occurrence of semantic and visual errors (the ratio of semantic to visual errors was 8 to 2 for nouns and 5 to 5 for verbs); d) occasional occurrence of 'visual then semantic errors' in which a visual error was apparently followed by a semantic error (e.g. sympathy→[symphony]→orchestra; resign→[reign]→crown); and e) derivational errors, which are morphologically related to the target word (e.g. heat→hot; depth→deep; furnish→furniture). GP seldom produced neologisms (2 or 3 out of 4000 responses).

In the case of KU, the vast majority of reading errors were visual errors (e.g. sour→soup; shallow→shadow), but semantic errors (e.g. diamond→necklaces; news→paper) were very limited (4/170, 2.4%). Although this pattern is dissimilar to GP's reading errors, KU was classified as deep dyslexic because of a substantial number of derivational errors - which are a type of semantic error sharing with a common root (e.g. truth→true; prefer→preference; invite→invitation).

Although heterogeneity of deep dyslexic patients was pointed out (Marshall and Newcombe, 1980), it was generally agreed that deep dyslexia shared four main features, as follows (e.g. Nolan & Caramazza, 1982):

i) Nonword reading is worse than word reading (lexicality effect);

ii) Concrete/high imageability word reading is superior to abstract/low imageability word reading (concreteness/imageability effect);

iii) A part of speech effect (noun > adjective > verb > function words);

iv) The production of semantic, visual and deviational errors[14] in word reading.

For example, JA (Katz & Lanzoni, 1992) was able to read 15 out of 30 high imageability words (50%), but 6 out of 30 low imageability words (20%), and was unable to read any nonwords. JA's accuracy for 20 words made up of nouns, adjectives, verbs and functors was 80%, 40%, 30% and 0%, respectively. JA's error patterns fit the characteristics of deep dyslexia. In his oral reading performance for 420 words, including nouns that were manipulated by imageability, concreteness, regularity, word length and frequency, and verbs, adjectives and function words, the proportion of error types was as follows: out of 265 errors 20.7% were semantic errors, 6.4%, were circumlocutions, 1.5% were visual then semantic errors, 3.7% were visual/semantic errors, 4.5% were visual errors, 5.2% were derivational errors,

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14 Derivational errors are related to the target words both visually and semantically, these types of errors were known as 'visual completion errors' (Marshall & Newcombe, 1966), and also as 'derivational semantic errors' (Shallice & Warrington, 1975). Several studies suggest that derivation errors are not a type of semantic error. According to Funnell (2000), Moody (1984) reported that 4 patients who made derivational errors made more errors in truly suffixed words (e.g. officer → office) than in the pseudo-suffixed words (e.g. corner → corn), suggesting that derivational errors are morphological. This was supported by Job and Sartori (1984), in whose research prefixed words and pseudo-prefixed words were matched for word frequency and word length. Funnell (1987), however, found that there was not a significant difference between suffixed words and pseudo-suffixed words in the reading accuracy of the deep dyslexic patient JG when both word frequency and concreteness/imageability were controlled.

and 36.6% were no responses.

With regard to the defining feature of deep dyslexia, Coltheart (1980a) concluded that semantic error guarantees that the other features will occur, based on the internal logical structures of the symptom-complex. However, as Shallice (1988) mentioned, the proportion of semantic errors , varied depending on the patients. For instance, PW (Patterson, 1978) produced a high proportion of semantic errors (54%) followed by derivational errors (22%), but the proportion of his visual errors was 13%. In contrast, PS (Shallice & Coughlan, 1980) produced a low proportion of semantic errors (10%) and derivational errors (9%), and the majority of her errors were visual errors (51%). In DE (Patterson, 1978), the proportion of visual errors (35%) was higher than of semantic errors (23%), but many derivational errors (32%) were also produced. Furthermore, there is the case (KF: Shallice & Warrington, 1975), which only produced a small proportion of semantic errors (4%), being under the cited chance level of around 8% (Ellis & Marshall, 1978).

As seen in these examples, the semantic error is not always the prominent error type - rather, the co-occurrence of semantic and visual errors appears to be the unique nature of deep dyslexia. There are some studies[15], which showed that the

[15] Patterson (1978) examined 2 deep dyslexic patients using 3 types of confidence rating (sure, maybe, no) of their own reading responses. While both DE and PW selected the ‘sure’ category for a high proportion of their correct readings (83% and 94%, respectively), their confidence varied depending on the error type. PW showed much confidence about both visual and derivational errors (83% of his visual errors and 88% of his derivational errors were rated as ‘sure’, but none of his visual errors and only 9% of derivational errors were rated as ‘no’), whereas he was less confident in relation to semantic errors (57% of his semantic errors were rated as ‘no’, though 38% of his semantic errors were rated as ‘yes’). DE showed a similar pattern to PW. DE was less confident about his semantic errors (he rated 54% of his semantic errors as ‘no’), but he was more confident about both derivational and visual errors (59% of his derivational errors and 52% of his visual errors were rated as ‘yes’). The same was also reported in BL (Nolan & Caramazza, 1982). BL rated 62% of his semantic errors as wrong, but only 14% of his visual errors were rated as wrong.

awareness of error was considerably more sensitive for semantic errors than for visual and derivational errors, indicating that semantic errors and visual errors might come from a different source.

Although deep dyslexia[16] and phonological dyslexia have been treated as independent dyslexic types, in which the presence and absence of semantic errors in word reading are hallmarks of deep and phonological dyslexia respectively, both types of dyslexia share a lot of characteristics. Some phonological dyslexics showed a concreteness/imageability effect (Funnell, 1987; Goodall & Phillips, 1995; Farah et al., 1996) and a part-of-speech effect (Derouesné & Beauvois, 1985; Patterson, 1982). Some deep dyslexic patients also showed a superiority of pseudohomophone reading over nonhomophonic nonword reading (e.g. Katz & Lanzoni, 1992) and a lexicality effect on repetition (e.g. Buchanan Hilderbrandt, & MacKinnon, 1994, 1995; Nolan & Caramazza, 1982).

Recently, Crisp, Howard and Lambon Ralph (2003) directly compared twelve patients with phonological or deep dyslexia using the same test battery and found that all patients demonstrated most of the symptoms of deep dyslexia such as an imageability effect, with the exception of semantic errors. They suggested that there were overlapping characteristics of the two types of dyslexia, in which the severity of co-occurring characteristics varied with the overall degree of reading impairment.

2) The evolution from deep dyslexia to phonological dyslexia

As already pointed out, deep dyslexia and phonological dyslexia shared many characteristics in oral reading. In this regard, the studies that reported evolution from

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16 In the 1970’s, deep dyslexia was also called ‘phonemic dyslexia' (e.g. Shallice & Warrington, 1975).

deep dyslexia to phonological dyslexia (Glosser & Friedman, 1990; Laine, Niemi, & Marttila, 1990a; Friedman, 1996b; Southwood & Chatterjee, 2000) are crucial. For example, RL (Klein, Behrmann, and Doctor, 1994), who was evaluated at 6 month post-onset and 18 month post-onset without any formal intervention between the two assessment points, demonstrated the following changes in his oral reading performance.

i) Words vs. nonwords: 21/32 (66%) vs. 1/32 (3%) →28/32 (88%) vs. 5/32 (16%);

ii) Pseudohomophones vs. nonhomophonic nonwords: it was too frustrating for him to read and the task was discontinued: (1/21 in both types of nonwords) →8/20 (40%) vs. 2/20 (10%);

iii) High imageability words vs. low imageability words: 27/28 (96%) vs. 19/28 (68%) → 60/63 (95%) vs. 92/96 (96%);

iv) Content words vs. function words: 21/25 (84%) vs. 8/25 (32%) →25/25 (100%) vs. 24/25 (96%);

v) The proportion of error types: semantic 24%, visual 38%, derivational 9%, mixed 6%, other types of error 23% → no semantic error, only semantic/visual error (here→there). The proportion of other types was not reported.

The general recovery pattern from deep dyslexia to phonological dyslexia is that i) semantic errors disappear first; ii) then performance for abstract, adjectives, verbs and function words improves in this order; and iii) finally, the patient remains unable to read nonwords aloud (Friedman, 1996b). The order of recovery pattern for different word classes corresponds to the rank order of a part-of-speech effect, and the remaining difficulty of nonword reading can be considered as the effect of the lowest imageability 'word', because nonwords have no semantic information. Thus, evolution from deep dyslexia to phonological dyslexia might be governed by concreteness/imageability. In other words, this evolution indicates a severity-based continuum between two types of dyslexia. Friedman (1996b) emphasised this continuity[17] and pointed out that "it is the degree of semantic impairment, not phonologic impairment, that determines the continuum" (p.123). Then, she argued that the distinction between deep and phonological dyslexia may be 'an accident of history' (p.127), which means that deep dyslexia was discovered before phonological dyslexia.

In short, there is a view that phonological dyslexia and deep dyslexia are not independent reading disorders (e.g. Friedman, 1996b; Klein et al., 1994; Crisp, Howard, & Lambon Ralph, 2003), though this view is still controversial.

3) Semantic variables and deep dyslexia

<u>The core characteristics of deep dyslexia</u>

Barry and Richardson (1988) found that a part-of-speech had no effect on the reading accuracy of a deep dyslexic patient, GR, when concreteness and associative difficulty which is akin to *ease-of-prediction* (Jones, 1985), as well as word frequency, were statistically controlled. This suggests that a part-of-speech might be a compound variable. Indeed, some studies suggest that the rank order of word class in a part-of-speech effect is highly correlated with ease of prediction and imageability (Jones, 1985; Harm, 1998), and so it would perhaps be correlated with

[17] Klein et al. (1994) basically followed Friedman's explanation about the continuity between deep dyslexia and phonological dyslexia based the notion that semantic errors arise from an impaired semantic function in the framework of the serial staged model. Southwood and Chatterjee (2001) proposed a distinctive explanation using *the Simultaneous Activation Hypothesis* (Southwood & Chatterjee, 1999), which assumes that all three reading routes of the dual-route model activate simultaneously. They considered that the disappearance of semantic errors was only explained by complete recovery of the lexical-nonsemantic route.

concreteness. For example, the mean results of the ease-of-prediction score for high-imagery nouns, low-imagery nouns, adjectives, verbs and the function words were 6.62, 5.17, 3.89, 3.80 and 2.12, respectively (Jones, 1985). In consideration of this phenomenon, and the assumption that nonwords are types of ‘words’ of the lowest imageability, an inability of nonword reading and a part-of-speech effect might be reducible to a concreteness/imageability effect. In other words, deep dyslexic pattern is governed only by concreteness/imageability.

A number of studies investigated the semantic function of deep dyslexia. The results are summarised as follows: i) semantic errors occurred in words with greater concreteness/imageability, whereas visual errors occurred in words with less concreteness/imageability; ii) semantic associative knowledge was well preserved; iii) comprehension of abstract words was fairly well preserved; and iv) semantic knowledge of function words was preserved. The studies, which pointed out these characteristics of deep dyslexia, are reviewed in below.

<u>The relationship between concreteness/imageability of the target word and oral reading errors</u>

Shallice and Warrington (1975) had pointed out that in deep dyslexic patient KF, semantic errors occurred in less concrete nouns rather than in more concrete nouns. KF’s visual errors occurred in more concrete nouns rather than in less concrete nouns. Shallice and Coughlan (1980) had noted that their deep dyslexic case, PS, more frequently produced visual errors in abstract words (21/100) than in concrete words (7/100).

Newton and Barry (1997) demonstrated this pattern using a different analysis. In their deep dyslexic case, LW, the concreteness rating of the words in which she made semantic errors (5.14) was lower than for the words she read correctly (5.65), but was considerably higher than the rating for the words in which she made visual errors (2.53). Barry (1984) also calculated the mean concreteness value of GR's reading responses collected by Marshall and Newcombe and found that the words in which he made semantic errors was less concrete than the words he read correctly (4.55 < 5.52). Gerhand and Barry (2000) further reported on the nature of LW's semantic errors. The words where LW made semantic errors were acquired earlier than the target words (2.32 < 2.99: mean age of acquisition of semantic error and the target words, respectively), and were less concrete (5.63 < 5.88), more frequent (1.54 > 1.09), and shorter (4.81 < 5.76) than the target words.

Semantic associative knowledge and written word comprehension

Howard (1985) tested the 4 deep dyslexic patients (DE, PW, HRM and BB) with 3 versions of the Pyramids and Palm Tree Test (i.e. 3 words, 1 word 2 pictures, and 3 pictures) which is a semantic associative task. They performed well in all 3 versions (mean accuracy was about 93%), indicating that the verbal and nonverbal semantic functions of the 4 deep dyslexic cases were preserved.

Using several semantic tasks Newton and Barry (1997) tested LW who showed superiority of concrete word reading over abstract word reading. In the lexical decision task, LW's accuracy for concrete/high frequency words, concrete/low frequency words, abstract/high frequency words and abstract/low frequency words was 95%, 75%, 90% and 70%, respectively (c.f. her reading accuracy of the target words was 55%, 20%, 10% and 0% with the same rank order as the comprehension task). In the synonym-matching task LW's accuracy of concrete words and abstract words was 95% and 90% respectively for high frequency words, and 75% and 55% respectively for low frequency words. The difference between concrete and abstract words did not show statistically significant difference.

Newton and Barry further tested LW's comprehension using the task required to match the spoken definition and a written word. LW's accuracy for high frequency words in the 3-band of concreteness (highly concrete, moderately concrete and highly abstract) was 88%, 81% and 81%, respectively (c.f. her reading accuracy of the target words was 50%, 19%, 6%, with the same rank order of concreteness).

So, LW demonstrated her preserved comprehension of written abstract words in a high frequency band, despite her difficulty of oral reading graded by concreteness. In relation to low frequency words, LW's accuracy of written word comprehension had deteriorated more for abstract words (38%) than that for highly concrete and moderately concrete words (88% and 94%, respectively). Since LW's accuracy of target word reading was 0% for highly abstract words, 31% for highly concrete words, and 25% for moderately concrete words, LW showed semantic activation of words which she is not able to read.

The results above suggest that deep dyslexia cases have a well-preserved semantic function and also fairly good comprehension of abstract words.

Function word reading and comprehension

With regard to function word substitutions (i.e. function word paralexia), Morton and Patterson (1980b) explored the comprehension of function words in a deep dyslexia case, PW[18]. PW was examined using various kinds of comprehension tasks

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18 PW, who was also investigated in other studies (Patterson & Marcel, 1977; Patterson, 1978; 1979), was only able to read 23% out of 406 function words, including prepositions and conjunctions, adverbs and quantifiers, interrogatives, auxiliary verbs, personal pronouns,

such as picture-word assignment, and judgment of appropriateness about 17 function words describing the position (e.g. above, under, beside, etc,). PW showed his preserved semantic knowledge of function words. By re-examining PW's reading errors in function words, using data presented in Coltheart (1980a) and Coltheart, Patterson, and Marshall (1987), Funnell (2000) had noted that there was a strong relationship between PW's reading errors and his comprehension.

4) Implicit phonological processing

Some studies have indicated that implicit phonological knowledge of written strings was relatively preserved in deep dyslexia.

Nolan and Caramazza (1983) reported that a deep dyslexic patient, PS, was able to match a spoken word (e.g. queen) to a pseudohomophone (e.g. *quean*), though PS's matching to a control nonword (e.g. *queam*) was at above-chance level.

Katz and Lanzoni (1992) examined JA who showed deep dyslexia patterns (e.g. his reading accuracy of concrete words vs. abstract words vs. nonwords was 50% vs. 20% vs. 0%) using content word reading with two conditions which manipulated rhyming and visual similarity. As with normal subjects, JA's reaction time for oral reading of rhyming and similarly spelled words (e.g. *bribe-tribe*) was faster than that for non-rhyming dissimilarly spelled words (e.g. *couch-touch*).

Hildebrandt and Sokol (1993) reported that their deep dyslexic patient, GR, demonstrated the normal regularity effect for low-frequency words on a lexical decision task. With low frequency exception words GR's accuracy was significantly

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and relative pronouns. PW made a high proportion of function word substitution errors (39%), followed by omission errors (21%) and non-functional word substitution errors (17%). Function word paralexia consisted of semantically related errors (e.g. me → I, often → sometimes, before → front of), visually similar errors (e.g. his → is, beside → because, about→ out), and other errors (e.g. both → perhaps, nor → and).

lower and his reaction time was significantly longer than in his performance in low frequency regular words.

Buchanan, Hildebrandt, and MacKinnon (1994) showed that JC, who was able to read 31% of words and 0% of nonwords and who produced semantic errors (21% out of total errors), had preserved implicit knowledge of nonword phonology. JC took more time to reject pseudohomophones than control nonwords. The two other deep dyslexic patients, PB and GZ, also demonstrated a significant pseudohomophone effect in a lexical decision task (Buchanan, et al., 1995).

2.2.6. Interpretations of deep dyslexia using the dual-route model

1) Classic interpretation

Deep dyslexia was considered to be a combination of severe impairment of the non-lexical route and partial impairment of the lexical route. This was because inability in nonword reading implies that impairment of the non-lexical route is almost eliminated, and deterioration of word reading implies a significant impairment of lexical-nonsemantic route. Furthermore, semantic errors, a concreteness/imageability effect and a part-of-speech effect imply partial impairment of the lexical-semantic route. Morton & Patterson (1980a) presented the hypothesised four loci of deep dyslexia (i.e. multiple-deficits view) as follows:

i) the non-lexical reading route (grapheme-to-phoneme conversion to the response buffer);

ii) the lexical-nonsemantic route (the orthographic input lexicon to the orthographic output lexicon);

iii) the processing from the semantic system to the orthographic output lexicon;

iv) the semantic system itself – i.e. the characteristics of a deep dyslexic pattern need to assume multiple loci of impairment.

With regard to the co-occurrence of semantic and visual errors in deep dyslexic patients, the classic interpretation assumes different loci of impairments. The source of visual errors is the damaged processing from visual analysis to the orthographic input lexicon or the damaged orthographic input lexicon. Semantic errors occurred as a result of either damaged processing from the semantic system to the phonological output lexicon or the damaged semantic system itself.

However, this multiple deficits view of deep dyslexia faced unanswerable questions. If deep dyslexia reflects multiple damage of independent reading routes, why do they not dissociate, and why do semantic errors and visual errors occur together? Coltheart et al. (1987) presented an anatomical explanation of this question. They wrote, “perhaps the dissociations are not seen because certain processing components, whilst functionally independent, are anatomically adjacent and so cannot be independently damaged” (p.415). In short, the multiple-deficits view can explain deep dyslexic patients’ performance, but cannot explain the co-occurrence of semantic and visual errors in deep dyslexia.

2) **Alternative interpretations**

While the classic interpretation assumed that all three reading routes were impaired, alternative explanations of deep dyslexia have been proposed.

‘The right hemisphere hypothesis’

This hypothesis (Coltheart, 1980b; Saffran, Bogyo, Schwartz and Marin, 1980) postulates that reading processing by deep dyslexic patients occurs in the right hemisphere and that normal readers with right-handedness have the right-hemisphere reading system as standard equipment. However, there is limited direct data relating to the right-hemisphere reading in deep dyslexic patients (e.g. Saffran, Bogyo, Schwartz, & Marin, 1980). Zaidel & Schweiger (1984) reported that their patient with deep dyslexia and deep dysgraphia showed a) a significantly faster RT in the left visual field (hereinafter LVF) in a lexical decision task, though her accuracy for the right and left visual fields was equal; b) in oral reading tasks, in which the stimuli were flashed for 90msec, 55% of hercorrect responses were to the right visual field (hereinafter RVF) presentations. Also, 73% of her semantic errors occurred in LVF presentations, but 73% of her visual errors occurred in RVF presentations. Zaidel & Schweiger argued that the left hemisphere controls correct oral reading and semantic errors are due to the right-hemisphere reading.

Patterson and Besner (1984b) criticised Zaidel & Schweiger'shemisphere-effect interpretation of the LVF advantage in a deep dyslexic patient, pointing out that it is difficult to find evidence that LVF advantage in oral reading and lexical decision tasks is attributable to right-hemisphere dominance rather than to deficits of the left-hemisphere. Patterson and Besner (1984a) emphasised that they found little evidence for a right-hemisphere reading system. Then Patterson and Besner (1984b) wrote “the notion that both hemispheres contribute to deep dyslexic reading is such a general and reasonable one that we will not argue logically against it” (p.376). This view that deep dyslexia pattern occurs using processing by both hemispheres was also noted in another study (Patterson, Vargha-Khadem, & Polkey, 1989). It was also supported by a recent functional neuro-imaging study (Price, Howard, Patterson, Warburton, Friston, & Frackowaik, 1998), which revealed that the two dyslexic patients showed increased activation in their intact regions of the left hemisphere and also in some areas of their right hemisphere (right inferior occipital gyrus and right para-hippocampal gyrus).

Despite of these criticisms, Coltheart et al. (2001) still considered that deep dyslexia should be interpreted using the right-hemisphere hypothesis, and stated that "it is fruitless to seek to interpret deep dyslexia in relation to a model of normal reading system" (p.246). Since both 'the adjacent explanation' and 'the right hemisphere hypothesis' are anatomical explanations of deep dyslexia, it is a theoretical disaster if the dual-route model cannot provide an explanation for the co-occurrence of the characteristics of deep dyslexia.

'The isolated-semantics view'

Some researchers (Newcombe & Marshall, 1980; Newton & Barry, 1997) claimed that the lexical-semantic route is inherently so inefficient as to give rise to reading errors when operating in isolation without support from the other two routes. This view considers that all characteristics of deep dyslexia occur due to an inherent inefficiency of the lexical-semantic route in isolation, even when the semantic system is intact.

The isolation of the lexical-semantic route is based on the assumption of the complete unavailability of both the non-lexical route and the lexical-nonsemantic route (e.g. Coltheart et al., 1987). Therefore, exaggerated reliance on the lexical-semantic route leads to the influence of semantic variables such as concreteness/imageability which are observed in deep dyslexia. According to the explanation by Newton and Barry (1997), the semantic representations for concrete/high imageability words are highly specific for addressing phonological representation, whereas the semantic representations of abstract/low imageability words are under-specific for addressing phonological representation, resulting in a concreteness/imageability effect in deep dyslexia. They also explained the occurrence of semantic errors in terms of less specified semantic representations - which activate many related semantic representations - resulting in error-prone selection. This is in contrast to the classic interpretation of deep dyslexia which assumes that semantic errors result from the malfunctioning semantic system.

The isolated semantic view is based on the assumption that the semantic system is functional. Indeed, the preserved semantic system in deep dyslexic patients was intentionally demonstrated in some studies (Howard, 1985; Newton & Barry, 1997) as mentioned in the review of previous deep dyslexic cases (2.2.5). Among other studies of deep dyslexia, Laine, Niemi, Niemi, & Koibuselkä-Sallinen (1990b) uniquely used drawing to examine semantic knowledge and found that a Swedish-speaking deep dyslexic patient, VJ, could make accurate drawings of the target words that produced semantic errors. According to Newton and Barry (1997, Appendix 1), the majority of reported deep dyslexia cases showed good performance in comprehension tests such as word-picture matching, synonym matching and categorisation. It is worth noting that RL, who showed deep dyslexia and moved to phonological dyslexia one year later, also did not show a deficit in input to semantics nor in the semantic system itself - these had been examined using lexical decision, synonym judgment and semantic judgment (Klein et al., 1994).

With regard to the co-occurrence of semantic errors and visual errors, Newton and Barry (1997) did not explain this at all. But the isolated-semantics view might have the potential to explain the co-occurrence of semantic and visual errors, and a concreteness/imageability effect. Since the semantic system is isolated, visual errors arise from orthography-to-semantic activation, and semantic errors arise from semantic-to-phonological activation. This explanation fits the fact that visual errors frequently occur in abstract/low imageability words and semantic errors occur frequently in concrete/high imageability words, and that the mean concreteness of words producing semantic errors is less concrete than that of words read correctly (Shallice & Warrington, 1975; Shallice and Coughlan, 1980; Barry & Richardson, 1988; Newton & Barry, 1997; see 2.5.5.).

Moreover, if one follows the notion that a part-of-speech effect and a lexicality effect are reducible to a concreteness/imageability effect (see 2.5.5.), this alternative view that assumes the isolated semantics with complete damage of both the non-lexical and lexical-nonsemantic routes appears to provide an interpretation of all characteristics of deep dyslexia.

<u>The damage to the phonological output lexicon</u>

Buchanan et al. (1994) proposed that the source of deep dyslexia is impairment of the phonological output lexicon. This is a single-deficit view, which is clearly different from both the classic interpretation and the isolated-semantics view.

For interpretation of deep dyslexia pattern, Buchanan et al. (1994) used the reading model (p.176, Fig.2) that is slightly different from the ‘original’ dual-route model, because the non-lexical route pathway reaches the phonological output lexicon, not the phonological output buffer. In their model, the phonological output lexicon has a number of nodes, including the target, and phonological, visual and semantic neighbours. Moreover, they postulate communication between the phonological output lexicon and the semantic system.

In their logic, visual errors occur when phonological/visual neighbours (e.g. *light* when the target words is *life*), activated from both the non-lexical route and the lexical routes, are incorrectly selected in the phonological output lexicon due to impaired ‘selection mechanisms’. Semantic errors occur because phonological neighbours (e.g. *light*) spread back to the semantic system and activate the corresponding semantic representation (e.g. *light*) and its semantic neighbours (e.g. *bulb*), and then they feed forward to the phonological representation, resulting in occasional semantic errors. In Buchanan, McEwen, Westbury, & Libben (2003), semantic errors were explained by the lack of inhibition of semantic neighbours. But they did not explain a concreteness/imageability effect in their proposed model. So, their interpretation does not offer a full account of deep dyslexia pattern.

To summarise alternative interpretations, the isolated-semantics view within the dual-route model has the potential to explain all characteristics of deep dyslexia. However, on the basis of the experimental results which suggested preserved implicit phonological processing, it was thought that complete damage of the lexical-nonsemantic route and the non-lexical route was unlikely to occur in patients with deep dyslexia. Therefore, it appears that the dual-route model needs to be modified in order to explain the co-occurrence of semantic and visual errors.

3) The interpretation of deep dyslexia using the DRC model

Within the framework of the DRC model, which assumes interaction between independent components in the lexical routes, both the phoneme system and the phonological output lexicon would be the source of a deep dyslexic pattern. This is an original interpretation by the author, because the DRC model has not been used for interpretation of deep dyslexia.

Since nonwords are processed in the non-lexical route, inability in nonword reading and preserved implicit phonology of nonwords imply impairment of the phoneme system. Patients with deep dyslexia performed well in lexical decision tasks, so the orthographic input lexicon seem to be intact. Many (but not all) patients with deep dyslexia also showed good comprehension, the semantic system appears to be relatively preserved (even some patients have partial impairment).

From these facts, the main source of deep dyslexia pattern seems to be impairment of the phonological output lexicon. Effects and reading errors observed in deep dyslexia are explicable assuming the impairment of the phonological output lexicon, because this component communicates with the semantic system, the orthographic input lexicon, and the phoneme system. Semantic errors occur when there is failure to inhibit semantic neighbours due to a reduced activation of the phonological output lexicon. Visual errors occur in either the non-lexical route or the lexical-nonsemantic routes, in which visually similar neighbours are not inhibited due to impairment of the phoneme system and impairment of the phonological output lexicon. These explanations fit the fact that deep dyslexic patients were less confident about their semantic errors, but were confident about visual errors (Patterson, 1978; Nolan & Caramazza, 1982). Patients with deep dyslexia know that their semantic errors are not correct but they cannot inhibit the activation of semantically similar responses. Furthermore, visual errors occur more frequently on abstract/low imageability words (Shallice and Coughlan, 1980; Newton & Barry, 1997), because semantic activation of abstract/low imageability words is not sufficient to inhibit the activation of visual errors in phonological output lexicon. This might be consistent with the view that “visual errors are an emergent property of the bias towards concreteness/imageability in this sensory semantic system” (Funnell, 2000, p.52).

A concreteness/imageability effect might be considered as follows: impairment of the phonological output lexicon leads to increased reliance on the semantic system during the interaction between the two components. Then this communication reflects the activation role of the semantic system (concrete/high imageability representation has stronger activation than that of abstract/low imageability representation), resulting in a concreteness effect. Funnell (2000) offered a similar view - that a concreteness/imageability effect in deep dyslexia could be a normal attribute of the sensory semantic system.

Thus, the DRC model can offer the interpretation that deep dyslexia is attributable to impairment of both the phonological output lexicon and the phoneme system. However, the question remains as to why these deficits do not dissociate, as in they do in the classic interpretation (i.e. the multiple-deficits view).

Unfortunately, there are no simulation studies of deep dyslexia, using the DRC model, because Coltheart et al. (2001) considered that “it is fruitless to seek to interpret deep dyslexia in relation to a model of the normal reading system” and argued that “the explanation of any symptom of deep dyslexia is outside the scope of the DRC” (p.246).

2.3.Triangle model

The triangle model (Fig.5) is one of the parallel-distributed processing (PDP) models (or connectionist model).

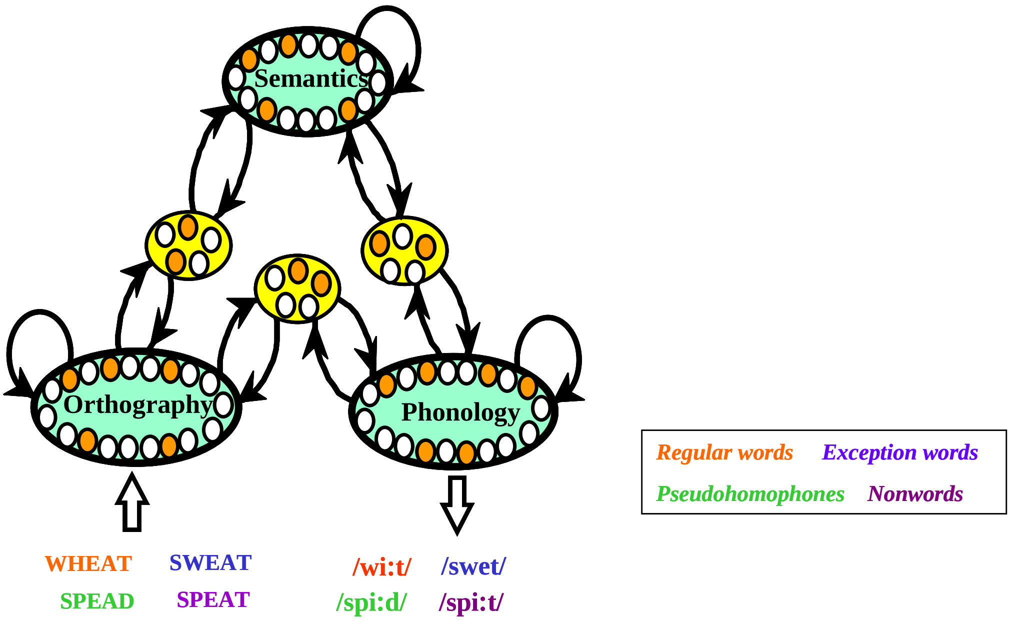

Fig. 5. The triangle model.

Seidenberg and McCelland (1989) originally proposed this model[19] which was designed to compute any mental activities that used different types of information (orthography, phonology and semantics) and it consists of three primary components: Orthography (O), Phonology (P), and Semantics (S). Hidden units which mediate the computations allow the model to encode complex relations between codes. In this model, the components of Orthography and Phonology, and the hidden units between them, were implemented and the network was trained to

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19 Similar notions were also seen in other authors (e.g. Kawamoto & Zamblidge, 1996; Van Orden & Goldinger, 1994).

read by the back-propagation learning algorithm. Then Plaut, McCelland, Seidenberg and Patterson (1996) developed the model. Although their model did not have Semantics (i.e. the ‘bi-angle’ architecture: Patterson, 2000b) as did Seidenberg and McClelland's model (1989), an artificial pathway from Semantics and Phonology was created by external input to Phonology, and this was treated as mimic input from Semantics to Phonology. Recently, Harm and Seidenberg (2004) implemented Semantics (i.e. ‘full’ triangle architecture)[20], which is referred to as the full-triangle model hereinafter.

The basic assumptions of the triangle model

The triangle model assumes that i) a representational unit is a not one-to-one correspondence and that similar words are represented by similar patterns of activity (i.e. *distributed representations*) over neuron-like processing units in the three domains; ii) activation in any one domain propagates automatically to both of the others; iii) any transformation among three domains is accomplished via the cooperative and competitive interactions among simple neuron-like processing units; iv) units interact until the network as a whole settle into a stable pattern of activity, which is termed as *an attractor*, corresponding to an interpretation of the input; and v) unit interactions are governed by *weighted connections* between them, which encode the system's knowledge determined during learning.

These are the principles of computation in the triangle model. In other words, any mental activity that used three types of information is processed in the same architecture with the same principles of computation. Harm and Seidenberg (2004)

[20] Their model contained both Orthography →hidden→Phonology connections and direct connections from Orthography to Phonology, which were not implemented in the Plaut et al. (1996) model.

called this nature ‘architectural homogeneity’. Since the triangle model does not have a word-specific representation (i.e. lexicon) like the dual-route model and the DRC model, so it departs from the view of ‘accessing stored representations’ in lexical processing. In the triangle model lexical knowledge is stored in the network, and representations of each word are computed.

The degree of reliance on the computations between different domains depends on *weighted connections* arising from learning and experience based on the system’s exposure to written and spoken words and word meaning, in which one pathway may experience less pressure to learn because of the efficient computation of the other pathway. This is called *division of labour* between components and that is affected by factors of a word’s property such as frequency, spelling-sound consistency, homophony (where different spelling strings share a common phonology), and imageability through learning process. Therefore, the differential efficiency of a processing pathway arises through the leaning mechanism. The nature of the triangle model is remarkably different from that of the dual-route model and of the DRC model, where the contributions of the reading routes (i.e. rule-based non-lexical processing and localist lexical processing) are determined by the nature of written input.

<u>The mechanism of oral reading</u>

In the triangle model, the phonological pathway (O→P computation) and the semantic pathway (O→S→P computation) work together to achieve normal skilled reading, but the phonology of given written strings (both words and nonwords) is computed primarily through the phonological pathway connecting the two domains (O→P). Because the direct computation (O→P) involves more consistent mapping from Orthography to Phonology, it should dominate, with considerable reliance on oral reading performance. In word reading, contribution of meaning is also important. The phonological procedure (O→P) receives support from Semantics, i.e. activation via Semantics (O→S→P), or communication between Semantics and Phonology that was activated by Orthography (O→P⇔S). That is, word meaning participates in oral reading. Thus, the computation of reading words aloud is jointly determined by the phonological and semantic procedures.

The division of labour between the phonological pathway and the semantic pathway is affected by spelling-sound consistency and word frequency, because spelling-sound consistency primarily affects ease of learning of oral word reading. The words that have the same shared-body pronunciation (e.g. *hint, mint,* and *tint*) facilitate learning of oral word reading that have the same spelling patterns, but this type of word interferes with learning of reading the words aloud with atypical pronunciation for the same shared-body (e.g. *pint*). So, learning regular words (e.g. *tent, bent*) is easiest, followed by regular-inconsistent words (e.g. *hint, mint*), and oral reading exception words (e.g. *pint, sweat*) are the most difficult to learn (i.e. regular words > regular-inconsistent words > exception words). This difference, however, is not prominent for high frequency words which have a lot of learning experiences resulting in stronger connection weights. Thus, the efficiency of the O→P computation reflects these graded connection weights through leaning. As a result, the reliability of the phonological pathway is greater for oral reading of high frequency words with a higher spelling-sound consistency than that of the semantic pathway. In contrast, the semantic contribution (O→S→P or O→P⇔S) becomes important and the reliability of the semantic pathway increases for computing the pronunciation of low frequency words with low spelling-sound consistency. Indeed, adult readers demonstrated an imageability effect on low frequency exception words (Strain, Patterson, & Seidenberg, 1995).

In simulation of the full-triangle model, Harm and Seidenberg (2004) observed that the activation of semantic information arrived more rapidly from O→S than from O→ P→ S in the computation of meaning, but there is significant input from both pathways to Semantics over more time. Thus, semantic activation from both pathways can support the computation of a word's phonology through the link between Semantics and Phonology. In this way, both O→S→P and O→P⇔S have an important role for oral reading.

In reading aloud of nonwords which have no semantic representations and no experience for oral reading, the computation of phonology relies on phonological procedure (i.e. O→P computation). If a person has acquired the base words that share the same body with the target nonwords, nonwords can be read, but this processing is less efficient than that for real word reading. Meanwhile, pseudohomophones (i.e. homophonic nonwords) should be read more efficiently than nonhomophonic nonwords. This is because pseudohomophones, which are, phonologically, words and are visually similar to their base words, activate semantic patterns that overlap with the meaning of the base words. So, a semantic contribution is expected for oral reading of pseudohomophones, though support from semantics is modulated by the density of the body-neighbours of the base words and pseudohomophones. In contrast, a semantic contribution does not occur for nonhomophonic nonwords. Seidenberg et al. (1996) also pointed out that a pseudohomophone advantage might arise from an articulatory advantage in initiating familiar pronunciation.

With regard to semantic activation for pseudohomophones, phonologically mediated activation of semantics is generally accepted. But Harm and Seidenberg (2004) showed that the pseudohomophones, which were visually similar to the base words, activated semantic information directly from orthography by simulation of the full-triangle model. So, some pseudohomophones benefit from both phonologically and directly mediated semantic activation for oral reading.

In summary, the triangle model can provide an alternative mechanism for oral reading processing without explicitly assuming the different mechanisms that apply to different types of words (i.e. the non-lexical route can read regular words and nonwords, whereas the lexical routes can read words in the dual-route model and the DRC model). In this model the efficiency of phonological and semantic procedures is determined by the word properties with a set of computational principles such as an atractor network, connection weight and division of labour.

2.4. Interpretations of different dyslexic patterns using the triangle model

2.4.1. The interpretation of surface dyslexia using the triangle model

In the triangle model, surface dyslexia arises from either from semantic impairment (Patterson & Behrmann, 1997) or from a disruption of connections from semantics to phonology (Watt, Jokel, & Behrmann, 1997). The signature deficit in surface dyslexia (i.e. impaired performance of oral reading words that have atypical spelling-sound correspondences) is explained by reduced semantic support (i.e. O→S→P, or O→P⇔S) for oral reading. While a direct O→P computation is sufficient for correct oral reading of the words/nonwords with a higher consistency of spelling-sound correspondences, the correct pronunciation of the lower spelling-sound consistency words (i.e. exception words), especially low-frequency words, needs additional semantic support. If semantic activation or communication between Semantics and Phonology is reduced or abolished, the low frequency words with lower consistency of print-sound correspondences should be error prone.

Therefore, the triangle model offers the interpretation that the source of surface dyslexia is Semantics itself, or a disruption in the links between Semantics and Phonology. In this respect, this interpretation can be called the '*semantic impairment hypothesis*' (Patterson & Lambon Ralph, 1999). This is consistent with the suggestion from cognitive neuropsychological studies (e.g. Hodges et al., 1992; Patterson & Hodges, 1992; Graham et al., 1994; Funnell, 1996; Ward et al, 2000) of a link between semantic impairment and 'pure' surface dyslexia. According to Patterson et al. (1996a), 'Hillis and Caramazza (1991), Howard and Franklin (1988) and Marshall and Newcombe (1973, 1980) all implicated word meaning in their accounts of surface dyslexia' (p.182).

With regard to the degree of regularity effect and graded consistency effect demonstrated by surface dyslexic patients, they reflect a characteristic of the triangle model, in which the direct O→P translation is not governed by the rule of print-sound correspondences. The reliability of the O→P computation is graded by spelling-sound consistency and word. So, oral reading performance in the network, which has reduced semantic supports, reflects the graded function of the phonological pathway.

LARC errors occurred in oral reading of regular inconsistent words, and exception words are also explained by the sensitivity of graded degrees of consistency and frequency in the phonological pathway. It is the nature of an exception word is that one of its components has a different, legitimate and more common pronunciation, and of regular inconsistent words that they take the most typical pronunciations of their body neighbourhood, and it is the case that one or more words with the same body have a conflicting pronunciation, LARC errors are of the same quality in both types of word. Obviously the proportion of LARC errors for exception word reading should be larger than that for regular inconsistent words, as was demonstrated in PB and FM (Patterson et al., 1996a).

Plaut et al. (1996) simulated surface dyslexia by deleting the semantic contribution that is external input to phonology (i.e. mimic input from semantics). Given the triangle model's principle, in which unit interactions are governed by *weighted connections* determined during learning and by the *division of labour*, they manipulated the number of training epochs in order to simulate the impact of semantic support. In this rationale, the reliability of the semantic pathway is greater in the network with 2000 training epochs than that with 400 training epochs. So, the impact of deleting the semantic contribution should be greater in the former than in the latter. The data of these simulations in the two models, which have different training epochs, are consistent with the reading performance by severe surface dyslexic patient, KT (McCarthy & Warrington, 1986) and mild surface dyslexic patient, MP (Bub et al., 1985), respectively.

However, the findings in relation to several neurological patients (DRN: Cipolotti & Warrington, 1995; DC: Lambon-Ralph, Ellis, & Franklin, 1995; EW: Gerhand, 2001, EM: Blazely, Coltheart, & Casey, 2005) who showed impaired comprehension of low frequency words but normal oral reading of low-frequency exception words, challenge the triangle model's explanation of surface dyslexia that takes a causal relationship between semantic impairment and phonology. Since the relative capacities of the phonological and semantic pathways in the triangle model are open to individual differences (Plaut et al., 1996), it is possible for the triangle model to explain these cases. Plaut (1997) presented the simulation that can account for both DRN's and DC's performance[21] on low-frequency exception words in terms of an individual difference of division of labour between the phonological and the semantic pathways. Plaut manipulated two parameters: *semantic strength* (the strength of external input to phonology) and *weight decay* (the magnitude of the pressure to keep weights small in the phonological pathway). Plaut observed preserved exception word reading after a lesioning semantic procedure (i.e. deleting external input to phonology) in the network, with a low level of weight decay and stronger semantic strength, and in the network with a high level of weight decay but weaker semantic strength. It was interpreted that the former network may correspond to DRN, a biological scientist with a high degree of education, and the latter network may correspond to DC, a patient with little formal education (DC attended school until the age of 14). In this rationale, their different educational backgrounds were treated as a remarkable difference in their reading experience. It was considered that DRN might have a highly developed phonological pathway, corresponding to low levels of weight decay, whereas DC might have developed both weak phonological and semantic pathways.

As seen in this simulation, the triangle model has the capacity to explain the individual differences in oral reading that reflect premorbid differences of reading experience.

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[21] The proportions of DRN's correct responses in oral reading and generating definitions for low-frequency exception words were 95% (20/21) and 14% (3/21), respectively. In the case of DC the proportions were 95% (40/42) correct responses in oral reading, and 31% (13/42) correct responses in definitions.

2.4.2. The interpretation of phonological dyslexia using the triangle model

According to Patterson and Lambon Ralph (1999), a general phonological impairment results in phonological dyslexia in the triangle model. This hypothesis can be called *'the phonological impairment hypothesis'*.

When phonological activation is reduced by the damage of the phonological system itself, the reliance on the semantic procedure (O→S→P and O→P⇔S) is exaggerated in oral reading of written strings. So, nonwords (which have no semantic information and no learning experience), and less concrete/imageability words (which have less weighted connection in the semantic system), should be prone to errors. When phonological impairment is mild, phonological activation is sufficient to inhibit semantic errors, but is insufficient to inhibit visual (i.e. phonological) errors. So, visual errors are dominant in phonological dyslexia.

Furthermore, this model can interpret superiority of pseudohomophones reading over nonhomophonic nonword reading in phonological dyslexia. This is because pseudohomophones are, phonologically, words and are visually similar to their base words, and they activate semantic patterns that correspond to the meanings of the base words. Therefore, pseudohomophone can receive the additional support from semantics, and this advantage leads to better oral reading of pseudohomophones compared to oral reading of nonwords which cannot receive semantic support.

With regard to the lexicality effect on various kinds of non-reading phonological tasks (e.g. phoneme blending, repetition), which was observed in many phonological dyslexic patients (e.g. Patterson & Marcel, 1992), the triangle model can also offer an explanation based on the phonological impairment hypothesis. If there is a general phonological impairment, the interaction between phonology and semantics (i.e. semantic support) should be especially important for settling on the correct response in any phonological tasks. So, any phonological performance with nonwords - which have no semantic representations - is prone to errors.

Harm and Seidenberg (1999) simulated developmental phonological dyslexia by lesioning the representations of phonological information before training the model to read, and their simulation data suggested that phonological impairments have an impact on nonword generalisation. Harm and Seidenberg (2001) also presented a computational account for the effects of graphemic complexity and visual similarity observed in MJ, a developmental dyslexic patient (Howard & Best, 1996), and LB, an acquired phonological dyslexic patient who had preserved phonological function (Derouesné & Beauvois, 1985). Their simulation data suggested that phonological impairment that interacts with orthographic properties of stimuli led to these 'orthographic' effects. They supported 'the phonological impairment hypotheses' through the results of their simulation, and argued that "the case of patient LB does not provide convincing evidence against 'the phonological impairment hypothesis'" (p.89). In addition, Harm and Seidenberg pointed out that LB's weak dissociation between word reading (ranging from 74% to 98%) and nonword reading (85%) clearly indicated that LB's reading impairment was not attributable to a selective impairment of the non-lexical route within the dual-route framework.

In short, the triangle model explains that the source of a phonological dyslexic pattern is a general phonological impairment, not a selectively impaired reading route.

2.4.3. The interpretation of deep dyslexia using the triangle-model

Computer simulation studies of deep dyslexia were presented in the early 1990's (Hinton & Shallice, 1991; Plaut & Shallice, 1993) and they lesioned the mapping from Orthography to Semantics. In the simulation by Plaut and Shallice (1993)[22], the phonological pathway was not implemented, based on the notion O→P had been completely abolished in deep dyslexia, and only the semantic pathway (O→S→P) was implemented. Damage to any part of the pathway between Orthography and Semantics (O→Intermediate units; Intermediate units→S; Intermediate units→S; S→Cleanup units; Cleanup units→S) resulted in the co-occurrence of semantic and visual errors and visual-then-semantic errors (e.g. SYMPATY → (symphony) →Orchestra). This simulation for deep dyslexia seems to be successful and completed damage to O→P and partial damage to O→S appears to be the source of deep dyslexia. However, there are problems with this simulation. Empirically, some studies demonstrated that deep dyslexics preserve implicit phonological processing (Nolan & Caramazza, 1982; Katz & Lanzoni, 1992; Hildebrandt & Sokol, 1993; Buchanan et al., 1994; 1995), which challenges the claim that the O→P computation is abolished.

Theoretically, no implementation of the phonological pathway is a source of trouble. The triangle model assumes that division of labour between components, which is one of the principle computations in this model, arises through the learning process. So, no implementation of O→P - which is different from lesioning the phonological pathway after training of O→P computation - ignores this principle of the triangle model. Therefore, further research using the full-triangle model is necessary for verifying this simulation study.

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22 De Mornay Davies and Funnell (2000), and Funnell (2000), pointed out that their simulation model's assumption of semantic representation based on 'ease of predicates' (Jones, 1985) was under question. Their main criticisms were questions about explanatory power of 'ease of predicates', and about the means of simulation based on this hypothesised variable, in which predicates turned to semantic features and a concrete word has more semantic features than does an abstract word. However, Jones (2002) refuted their criticism about 'ease of predicates', pointing out that predicates and features were not assumed to be the same, but rather that 'predicates appear to be almost synonymous with the more inclusive characterization of semantic features' (p.164).

In contrast, Patterson and Lambon Ralph (1999) proposed the interpretation that deep dyslexia is attributable to a general phonological impairment, and that deep dyslexia is a severe type of phonological dyslexia. In other words, they apply '*the phonological impairment hypothesis*' to deep dyslexia. In the triangle model, more severely reduced phonological activation leads to a stronger reliance on the semantic procedure, in which a remarkable impairment of nonword reading and a more prominent concreteness/imageability effect, and substantial semantic errors in word reading, should emerge. This is because nonwords have no semantic representations, and the connection weight between semantics and phonology for concrete/high imageability words is greater than that for abstract/low imageability words. While more concrete/imageability words can receive semantic support (O→S→P and O→P⇔S) in oral reading, abstract words /low imageability words receive less semantic support and nonwords cannot receive semantic support at all. Thus, severe phonological impairment leads to an inability in nonword reading and a concrete/imageability effect on word reading. Since abnormally reduced phonological activation cannot inhibit items which are semantically related to the target, the occurrence of semantic errors increased to become a noticeable proportion of errors.

As mentioned in an earlier section (2.2.5.), a part-of-speech effect (nouns > adjectives > verbs > function words) is reducible to an imageability effect, because ordering these word classes is highly correlated with imageability (Harm, 1998) or 'ease of prediction' (Jones, 1985), which is akin to associative difficulty. In this respect, the phonological impairment hypothesis can explain a part-of-speech effect as a concreteness/imageability effect.

More importantly, the phonological impairment hypothesis, based on the triangle model, can explain the co-occurrence of semantic and visual (i.e. phonological) errors in deep dyslexics. Patterson et al. (1996b) suggested that the phonological system of the triangle model is an attractor network where, in disruption, phonological representations of unfamiliar nonwords and less familiar words are easier to capture erroneously than those of phonologically similar and more familiar words. Disruption of the phonological representations themselves is expected to produce semantic errors, because the relationship between orthography and semantics resembles the relationship between phonology and semantics in the alphabetic writing system. Reduced input to the semantic system drives to turn off the normal trajectory in semantic space, resulting in an activation of phonologically (i.e. visually) or semantically related words. Thus, the impairment of phonology drives the capture of the wrong words, related either visually or semantically to the input stimulus. Since concrete/higher imageability words have a stronger connection weight in Semantics, it is likely that semantic errors are produced more in concrete/higher imageability words, reinforcing reduced phonological activation by the interaction between Phonology and Semantics. This prediction fits the experimental results, which showed that the words which produced semantic errors were more concrete/had higher imageability compared to the words which produced visual errors (Shallice and Coughlan, 1980; Newton and Barry, 1997).

The phonological impairment hypothesis also fits the lexicality effect on non-reading phonological tasks (e.g. phoneme blending, repetition) which was observed in some deep dyslexic patients (Buchanan, et al., 1994; 1995; Laine et al., 1990a; Nolan & Caramazza, 1982; Patterson & Marcel, 1977; Southwood & Chatterjee, 1999). This phenomenon can be also explained in terms of semantic support. Due to the interaction between Phonology and Semantics, phonological activation from Semantics (i.e. semantic support) is important for settling on the correct response in any phonological tasks. So, any phonological performance with nonwords, which have no semantic representations, is prone to errors.

Taking above together and using the triangle model, it is plausible that severe phonological impairment is the source of deep dyslexia. That is, deep dyslexia and phonological dyslexia arise from a common source (i.e. phonological impairment), and in this model deep dyslexia is a severe form of phonological dyslexia. This view is consistent with the results that both deep and phonological dyslexics showed[23]. Given the 'phonological impairment hypothesis', the issue of continuity, or overlapping characteristics between deep and phonological dyslexia (Friedman, 1996b; Glosser & Friedman, 1990; Klein et al., 1994) becomes non-debatable.

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[23] In the literature nonword reading accuracy in phonological dyslexia was much greater than that in deep dyslexia (e.g. a phonological dyslexic patient, MF: Beauvois & Derouesné, 1979: 42%; a deep dyslexic patient, JA: Katz & Lanzoni, 1992: 0%; a patient showed evolution from deep to phonological dyslexia, RL: Klein et al., 1994: 3% → 16%). The size of the lexicality effect (the accuracy of word reading − the accuracy of nonword reading) was larger in phonological dyslexia than in deep dyslexia (e.g. phonological dyslexic patients, MF and RG: Beauvois & Derouesné, 1979: 100% >42% and 100% > 23%, respectively; AD: Patterson, 1982: 92% > 37.5%; a deep dyslexic patient, JA: Katz & Lanzoni, 1992: high imageability words > low imageability words > nonwords: 50% > 20% > 0%; a patient showed evolution from deep to phonological dyslexia, RL: Klein et al., 1994: 66% > 3% → 88% > 16%). So, these empirical data suggest that the distinction between deep dyslexia and phonological dyslexia may reflect the degree of phonological function.

2.5. Different interpretations of acquired dyslexia in the DRC model and the triangle model, and unresolved issues

Both the DRC model (Coltheart et al., 2001) and the full-triangle model (Harm & Seidenberg, 2004) - referred to just as the triangle model hereinafter for convenience sake - are computational models. The former is a nonconnectionist model in which the elements of the system are treated ‘as descriptions of a functional information-processing architecture’, whereas the later is a connectionist model in which the elements of the system are treated ‘as brain-like and develop via a connectionist learning algorithm’ (Coltheart, 2004). This different character of the system led to a distinctive interpretation of acquired dyslexia patterns. While the DRC model explains them as damage to the reading route(s) whose function is defined by modellers, the triangle model explains them as a result of the principal impairment.

For the DRC model, dissociation between two classes of stimuli within oral reading tasks observed in surface dyslexia (regular words vs. irregular words) and phonological dyslexia (words vs. nonwords) is critical evidence of hypothesised independent reading routes (i.e. the lexical routes and the non-lexical route). This is because each reading route is assigned a specific function (i.e. the non-lexical route can read regular words and nonwords, whereas the lexical route can read words but not nonwords) in a nonconnectionist model. In other words, dissociation is transparently related to the damage of specific processing in the DRC model. On the other hand, dissociation is not related to the network's structure in the triangle model. This is because functions are distributed across the network in a connectionist model. Dissociation depending on regularity and lexicality is a direct consequence of the representational status of written strings in the network that learned 'functional specialisation' (Plaut, 1995; 2003).

For the triangle model, association between the damage to the primary component and dyslexia pattern is critical evidence of the specific hypotheses (i.e. semantic impairment hypothesis and phonological impairment hypothesis) about how the interactive system operates after damage. Thus, the relationship between semantic impairment and surface dyslexia and the relationship between phonological impairment and deep/phonological dyslexia are causal in this model. In contrast, these relationships are coincidental in the DRC model, and anatomical proximity is considered as the source of these associations. In this model, semantic impairment (i.e. the damage of the semantic system) does not always lead to surface dyslexia, because there is also the lexical-nonsemantic route. The DRC model can predict that if the lexical-nonsemantic route is intact the patients with semantic impairment do not manifest surface dyslexia. Likewise, phonological impairment does not always lead to phonological dyslexia, because the damage of the non-lexical route can lead to phonological dyslexia without phonological impairment. In the case of deep dyslexia, phonological impairment (i.e. the damage of the phoneme system) cannot explain the different degrees of impairment for the non-lexical route and the lexical routes, which are considered as the source of deep dyslexia in the DRC model. These are essential differences in the two models' interpretation of acquired dyslexia and these are important points for evaluating a model's reliability. They are also associated with the following unsolved problems:

i) The DRC model cannot explain the co-occurrence of semantic impairment and surface dyslexia;

ii) The DRC model cannot explain the co-occurrence of phonological impairment and deep/phonological dyslexia;

iii) The modellers of the DRC model abandoned attempts to interpret deep dyslexia, arguing that an explanation of deep dyslexia is theoretically fruitless and outside the scope of the DRC model (Coltheart et al., 2001);

iv) There is no simulation study for deep dyslexia, based on the DRC model;

v) It is difficult for the triangle model to explain why the patients with semantic impairment did not show surface dyslexia (Schwartz et al., 1985; Lambon Ralph et al., 1995; Cipolotti & Warrington; Gerhand, 2001;Blazely et al., 2005);

vi) It is difficult for the triangle model to explain why the patients with phonological impairment did not manifest phonological dyslexia (Derouesne & Beauvois, 1985; Bisiacchi, et al., 1989; Caccappolo-van Vliet et al., 2004a,b);

vii) A phonological impairment hypothesis for deep dyslexia, based on the triangle model, has not yet been verified by both case studies and simulation studies;

viii) There is little empirical proof that phonological impairment for deep dyslexia is more severe than for phonological dyslexia.

In short, both the DRC model and the triangle model, which have developed using the English language, have not yet provided fully coherent explanations for acquired dyslexia in English. Therefore, the interpretation of acquired dyslexic patterns in a non-alphabetical orthography like Japanese, using the DRC model and the triangle model, is theoretically important for developing reliable reading models.

Thus, the reading models proposed for Japanese, including a possible Japanese version of the DRC model and the Japanese version of the triangle model, are explained, and acquired dyslexia studies with Japanese neurological patients are reviewed in Chapter 3.

Chapter 3

A critical review of Japanese acquired dyslexia research

This chapter critically reviews Japanese acquired dyslexia research. Before reviewing these studies, the Japanese spoken language is introduced and the Japanese writing system is explained in detail, from a psycholinguistic point of view. The review of Japanese acquired dyslexia research is organised as follows:

i) The neuropsychological approach to acquired dyslexia in Japan;

ii) Cognitive neuropsychological studies of Japanese acquired dyslexia;

iii) An explanation of the reading models for Japanese, and their interpretation of the reported patterns of Japanese acquired dyslexia;

iv) The comparison between the interpretations of the two distinctive cognitive models, and unresolved issues in Japanese acquired dyslexia research.

3.1. Characteristics of the Japanese language and writing system

3.1.1. A brief introduction to spoken Japanese

Japanese has no relatives[1] in the language family tree. The structure of Japanese phonology is quite simple because i) the basic phonological unit for the Japanese spoken languages is a mora (i.e. a subsyllabic unit); and ii) morae consist of only 5 types: a single vowel (V); a consonant-vowel compound (CV); a consonant-semivowel-vowel compound (CjV: j is glide and 3 vowels /a//u//o/ follow j); the

[1] There are several theories. Some researchers argue that Japanese belongs to the Ural-Altai Language group.

nasal coda (N: this represents the sounds [n][m] or [ ] depending on the following phonetic context); and a geminated (double) consonant (Q: its acoustic entity is a prolonged silent period before the following plosive or fricative consonant). There are 108 distinct morae in the corpora of Japanese speech, and more than 70% of morae are CV (Otake, 1990).

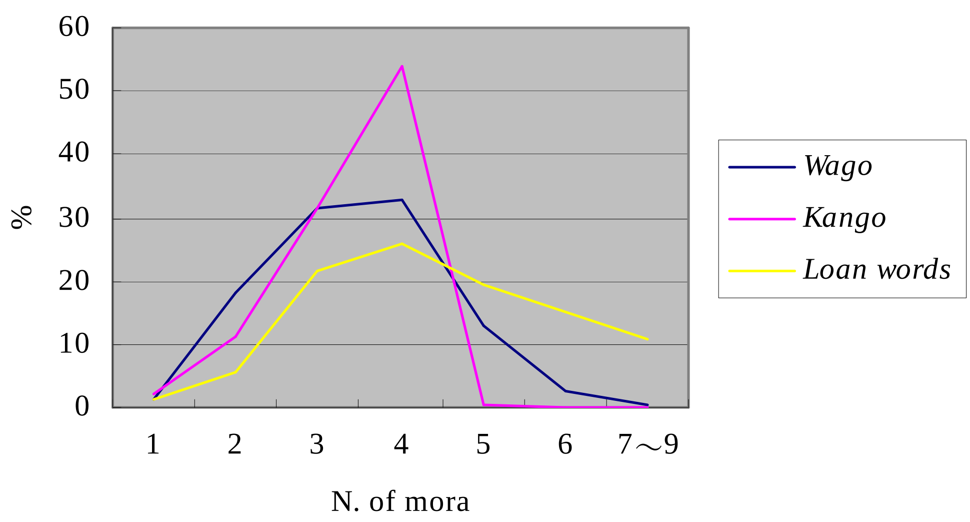
Since the mora is the basic phonological unit of spoken Japanese, this characteristic affects the prosody of spoken Japanese. That is, the rhythm of spoken Japanese is based on the morae and this is described as mora-timed language (Kubozono, 2002). For instance, it takes twice as long to pronounce 4-mora words (e.g. /ka-mi-na-ri/ meaning *thunder*) as to pronounce 2-mora words (e.g. /so-ra/ meaning *sky*). This characteristic is in stark contrast with English which is based on stress-timed rhythm. For example, strike and station, which belong to the loan words in Japanese, are monosyllabic and two-syllabic respectively in English. However, they are pronounced with mora-timed rhythm (/su -to -ra-i -ku/: 5 morae and /su-te-i-ʃo-N/: 5 morae) in spoken Japanese. Therefore, speech segmentation by the native Japanese listener is based on mora (Otake et al., 1993).

In short, there are three characteristics of spoken Japanese: i) a simple or restricted phonological structure, ii) dominance of open syllables (CV), and iii) mora-timed rhythm. These are in contrast with the nature of spoken English which has a complex phonemic structure and stress-timed rhythm.

With regard to the phonological characteristics of words, the number of morae and the phonological nature varies depending on the type of Japanese vocabulary, which can be divided into four categories: *Wago* or *Yamato-kotoba*, *Kango*, *Gairaigo*, and mixed type (Takashima, 2001). *Wago* is the term for Japanese words having their origins in the time before the import of Chinese characters/words. *Kango* consists of imported Chinese words and coined words, which were used the word-forming capacity of Chinese characters and created by Japanese people, mainly in the Meiji era (1868-1912) in order to translate western foreign words (e.g. 法律 for law, 社会 for society, and 政治 for politics). *Gairaigo* is the loan word from a foreign language (e.g. バナナ for banana). The mixed-type is for the words created by combining these types of words (e.g. 駅ビル for station building: 駅 *is Kango* and ビル is *Gairaigo*). The proportion of words in each type in common Japanese vocabulary is about 85% for *Wago* and *Kango*, 10% for the loan word, and 5% for mixed typed words (Takashima, 2001). The more recent trend has been to increase loan and mixed-type words.

Fig. 6 shows the distribution of the number of morae for these three types of Japanese words in the text of a daily newspaper (Nakano, 1973).

Fig.6. The distribution of morae for three types of Japanese vocabulary (Nakano, 1973).



In *Wago* (original Japanese words) 3- and 4-mora words are in the majority. In *Kango* 4-mora words are typical. Although *Gairaigo* (the loan word) has many 3-, 4- and 5-mora words, words of more than 6-mora are not unusual. This distinctive characteristic appears to arise from the mora-timed rhythm of spoken Japanese. There are also some different phonemic characteristics of these types of words.[2]

Thus, the origin of vocabulary affects the phonological characteristics of Japanese words and word length.

3.1.2. A brief introduction to written Japanese

The Japanese ancestors did not have their own orthography. From the 3rd to the 10th century they imported Chinese characters, mainly from the Tang era (618-907) of Chinese, and created a Japanese writing system. The Han Chinese, who lived in the area downstream from the Yellow River, used the Chinese language and the Han Chinese orthography was systematised during their era (206 BC and AD 221). Although the origin of Chinese orthography is very old, it remains essentially unchanged[3] today (Jean, 1992). Since the Japanese language has no relatives in the language family tree and the Chinese language belongs to the Sino-Tibetan Language (i.e. Japanese and Chinese language are unrelated each other), the way, in which Chinese characters were adapted as Japanese script was unique.

Firstly, Japanese ancestors invented two types of phonogram - **Kana -** by i) simplifying Chinese characters as a whole (e.g.以→い; 呂→ろ; 波→は), and ii)

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2 According to Nakano’s analysis (1973), /r / is not used as onset for *Wago* and high, frequently used consonants are /k//r//m/ for *Wago*. Frequently used consonants for onset are /k/ for *Kango* and /b/, /p/, and /k/ for the loan words. *Wago* does not include the consonant-semivowel-vowel compound (CjV), because this phonology did not exist before the introduction of Chinese.

3 According to Ho (2003), the average number of strokes for c. 2000 commonly used Chinese characters was reduced from 11.2 to 9.0, by a Chinese writing reform which began in 1956.

by taking part of a Chinese character (e.g. 阿→ア; 伊→イ; 宇→ウ) to represent a Japanese mora. As a result, the former became the cursive form - **Hiragana**, and the latter became the square form - **Katakana**. Each type of Kana comprises 75 characters and its pronunciation corresponds to the reading of the base Chinese character. Hiragana and Katakana are exact phonological equivalents (e.g.あ/a/ and ア/a/; ね/ne/ and ネ/ne/).

Secondly, Japanese ancestors borrowed the Chinese characters to represent Japanese spoken words based on the meaning of Chinese characters. In other words, spoken Japanese words were assigned to the reading of Chinese characters, with the words being based on the meaning of the characters. For example, 心, which means soul in Chinese, was read as /ko-ko-ro/ which is the spoken Japanese word (i.e. *Wago*) for soul. We call this pronunciation *KUN-reading* of **Kanji**, which in Japanese means the Hun Chinese character.

Thirdly, they imported Chinese characters/words, because *Wago* (i.e. original spoken Japanese words) could not cover the meaning of all Hun Chinese characters. In this adaptation (i.e. imported Chinese vocabulary), approximated Chinese pronunciation with Japanese phonology was assigned to the reading of Chinese characters. We call this Japanese pronunciation *ON-reading* of **Kanji**. Due to a long period of importing Chinese characters (mainly from the 7th to the 10th century), some Kanji characters have multiple ON-readings. For example, 男 *man* has three pronunciations: /o-to-ko/ (KUN-reading), /da-N/ (ON-reading), and /na-N/ (ON-reading).

This adaptation had a strong impact on Japanese vocabulary and there are a lot of *Kango*, which was explained in the previous section (3.1.1.).

It is worth noting that there are many heterographic homophones in *Kango*. These arose from ON-reading (i.e. Japanese pronunciation of Chinese characters). It often happened that the same ON-reading was assigned to different Chinese characters which have different Chinese phonology (e.g. 少, 小, 松, 消, 勝, 商, 焦, 尚, 章, 賞, 症, 称, 省 have ON-reading /ʃo/). As a result, *Kango* came to have many homophones. For example,電線 and 伝染, (which mean *electric wire* and *infection*, respectively), have the same pronunciation /de-N-se-N/, though the original Chinese pronunciations of these words are different.

Thus, for these historical reasons there are two types of reading for Kanji characters. About 75% of the basic Kanji characters have both ON-reading and KUN-reading (Morioka, 1974)[4]. For instance, 心 has KUN reading /ko-ko-ro/ and ON reading/ ʃi-N/. Learning Kanji characters, which have both ON-reading and KUN reading, means knowing the morphemic nature[5] of Chinese characters.

The following helps explain this point and the relationship between ON-reading and KUN-reading. (A) is part of a Chinese poem by 張継, who lived in the Tang era, and it can be pronounced by ON-reading of each character (①).

月 落 烏 啼 霜 満 天 ----(A)

/ge-tu/ /ra-ku/ /u/ /te-i/ /so-u/ /ma-N/ /te-N/ ----①

If a native Japanese speaker were to hear these sequences of ON-reading without seeing their orthography, she/he would not understand the meaning. This Chinese

4 According to the analysis by Morioka (1974), among 1850 Kanji characters that were selected as standard Kanji by the national language council, 1383 Kanji characters (74.7%) have both ON-reading and KUN-reading, 449 characters (24.3%) have just ON-reading, and only 18 characters (1%) have KUN-reading.

5 Using the morphemic nature of Chinese characters, Japanese people created some new Kanji characters, which are known as '*Kokuji* ' or 'State characters'. For instance, 雫, which means *drop*, was created by synthesizing 雨 (*rain* or *water* in general) and 下 (*down* or *under*).

poem, however, can be translated into a written Japanese sentence (B) by using KUN-reading of each character except 天/te-N/, which is frequently used as ON-reading (②).

月　落ちて　烏　　啼いて　霜　天に　満つ　----(B)

/tu-ki/ /o-chi-te/ /ka-ra-su/ /na-i -te/ /ʃi -mo/ /te-N-ni/ /mi-tu/ ----②

If a native Japanese speaker were to hear this sentence they would easily be able to understand the meaning without seeing the written sentence (B). As for seeing the written Chinese (A), a Japanese adult reader would be able to understand the broad meaning, because they would know the meaning of each character through the acquisition of KUN-reading. Thus, KUN-reading and ON-reading can be explained as morphophonemic 'allophones'.

In short, the above three points were the procedure for creating the Japanese writing system through borrowing Chinese characters. As a result, the Japanese writing system has Kana characters which consist of Hiragana and Katakana, and Kanji characters which have KUN-reading and ON-reading.

3.1.3. The psycholinguistic characteristics of Japanese scripts

1) The relationship between character and meaning

Phonographic Kana characters have no meaning, whereas morphographic Kanji characters are related to meaning. The vast majority of written Kanji words are two-character Kanji words, followed by three-character Kanji words and then single-character Kanji words (Amano & Kondo, 1999). Kanji characters, which can constitute a single character Kanji word (e.g. 犬 /inu/ *dog*; 雪 /yuki/ *snow*; 花 /hana/ *flower*; 夏 /natu/ *summer*, 東 /higashi/ *east*), have one-to-one correspondence between character and meaning. Likewise, Kanji characters that can constitute Kanji-Kana compound words (e.g. 学ぶ /mana-bu/ *learn*; 柔らか /yawa-ra-ka/ *soft*) have a strong connection to meaning. However, Kanji characters, which only constitute multiple-character Kanji words (e.g. 由→自由 /ji-yu/ *freedom*; 理由 /ri-yu/ *reason*; 曖→曖昧 /ai-mai/ *ambiguity*; 尚→高尚 /kou-ʃo/ *noble*), have no one-to-one correspondence between character and meaning. Thus, the relationship between Kanji characters and meaning varied.

2) The relationship between character and pronunciation

Transparent Kana characters have a consistent character-sound correspondence, whereas Kanji characters have various degrees of character-sound correspondence. That is, consistency, which is a critical psycholinguistic variable for oral reading, is radically different depending on the script type in Japanese.

Both forms of Kana characters (i.e. Hiragana and Katakana) have an almost one-to-one correspondence between character and sound, and they comprise 75 characters. Single Kana characters are conventionally divided into three groups: i) the basic set comprising 46 Hiragana and 46 Katakana characters, which corresponds to C or CV (e.g. あ for /a/, ぬ for /nu/); ii) the diacritical set comprising 25 Hiragana and 25 Katakana characters which have a diacritical mark representing a phonetic distinction (e.g. ぎ/gi/; ズ/zu/) and iii) the complex set comprising 36 Hiragana two-character compounds and 36 Katakana two-character compounds, corresponding to CjV mora (e.g. きゅ/kju/; ビョ/bjo/). In the third group, the way of modifying the pronunciation in the two-Kana character context is deletion of the vowel of the first Kana character (e.g. きゅ: /ki/＋ゆ/ju/ → kju/), so the pronunciation of such Kana characters is totally predictable.

Thus, both Hiragana and Katakana have an entirely regular and transparent relationship between a character and its pronunciation.

In contrast, the relationship between Kanji characters and their pronunciation is quasi-regular because for historic reasons (see 3.1.2), many Kanji characters have multiple pronunciations (or readings). According to Fushimi et al. (1999), in a sample of 1,945 '*Jyoyo Kanji*' characters (Kanji for daily usage; see 3.1.4. -4), the average number of common-usage pronunciations per Kanji character is 2.94. Among these, 34% of Kanji characters have a single pronunciation (of which 32% are classified as ON-reading and 2% as KUN-reading), and the remaining 66% have multiple pronunciations (of which 43% have a single ON-reading and a single KUN-reading, and 57% have multiple ON-readings and/or KUN-readings). Thus, the Kanji characters have a quasi-regular correspondence between orthography and its pronunciation.

3.1.4. The psycholinguistic characteristics of Japanese written words

1) Pronunciation predictability

Due to the difference in character-sound correspondence, there is a great contrast in the pronunciation predictability of Kana words and Kanji words. The pronunciation of Kana words is always predictable, whereas the pronunciation of Kanji words is determined by the intra-word context, and the pronunciation predictability of Kanji words[6] is clearly lower than that of Kana characters.

The following is an example of how the pronunciation of constituent Kanji characters is determined by the intra-word context. Kanji character 水, which has an ON-reading /sui/[7] and a KUN-reading /mizu/, appears in a single-character Kanji word (i.e. 水 meaning *water*, is pronounced /mizu/) and in multiple-character Kanji words such as 水筒(/<u>sui</u>-to/, *water bottle*),水着 (/<u>mizu</u>-gi/, *swimming costume*), 防水(/bo-<u>sui</u>/, *waterproof*), 清水(/shi-<u>mizu</u>/, *spring water*), 水族館(/<u>sui</u>-zoku-Kana *aquarium*), 水道水(/sui-do-<u>sui</u>/, *tap water*), 水菓子(/<u>mizu</u>-gashi/, *fruit*) and 水陸両用 (/<u>sui</u>-riku-ryo-yo/, *amphibious*). The position of 水 does not provide a clue for its appropriate pronunciation as a constituent character in these multiple-character Kanji words. The pronunciation of 水 is determined by specific knowledge of the target words (i.e. the intra-word context).

It is worth noting that there are very few[8] true exceptions known as '*Jukuji KUN*'', i.e. where Kanji words are not pronounced with the readings for each constituent Kanji character, but have one KUN-reading for the target Kanji word as a whole. For

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6 Many Kanji characters consist of phonemic and semantic radicals. The ON-reading of a Kanji character is sometimes identical to the pronunciation of the phonemic radical. But, this correspondence is weak. Saito et al. (1995) examined 1,668 Kanji characters and found that only 32% have an ON-reading, which is identical to their phonemic radical.

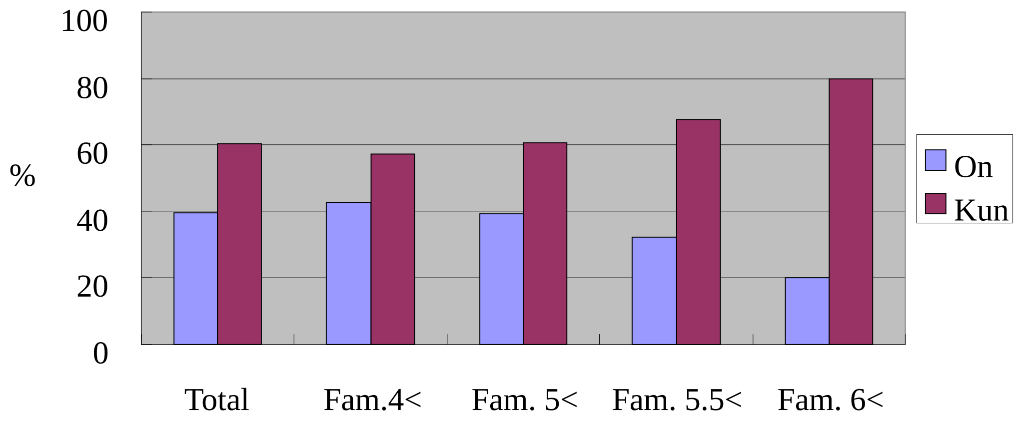
7 For several phonotactic reasons, the ON-reading /sui/ is altered by changing the consonant to /zui/ as in 洪水 ko-zui/ *flood*. If we count this alteration, 水 has three pronunciations.

8 Only 110 words are listed in the appendix of the list of *Toyo Kanji* (i.e. the standard Kanji).

instance, 大 has one ON-reading /dai/ and one KUN-reading /ou/, which means *big*. 人 has two ON-readings /jiN/ and /niN/ and one KUN-reading /hito/, which means *human being* or *person*. The pronunciation of 大人 is /o-to-na/, which is called '*Jukuji KUN*', and cannot be predicted by the pronunciation of each constituent character. In short, pronunciation of Kanji words is opaque. This is contrasted with transparent Kana words.

Furthermore, it is worth noting that both ON-reading and KUN-reading are assigned to single-character Kanji words. Figure 7 depicts the analysis of the pronunciation for 1,657 single-character Kanji words as a function of familiarity (Amano & Kondo, 1999). Although the majority of high familiarity words have a KUN-reading, in lower familiarity words where the mean familiarity is below 5.5 on a 7-point scale, about 40% are pronounced using ON-reading.

Fig.7. The distribution of reading types in single-character Kanji words (Amano & Kondo, 1999).



Native Japanese adult readers would be surprised by this data, because at primary schools they have been taught the 'general rule' that KUN-reading is assigned to single-character Kanji words, and ON-reading is assigned to multiple-character Kanji words. Although many of them believe that this ‘rule’ is true[9], the facts were different. The point is that adult readers do not appear to read written Kanji words based on the general ‘rule’ of ON/KUN-reading which was taught in primary education - instead, they read Kanji words based on word-specific knowledge.

Definition and manipulation of print-sound consistency for Kanji words

A way of evaluating the character-sound consistency of Kanji words had not been tackled until the mid 1990’s, even though this variable is critical for oral reading performance. Chronologically, Wydell, Butterworth and Patterson (1995) first defined this variable for Kanji words as follows:

i) 'Consistent' words are those in which each constituent character has only a single ON-reading and no KUN-reading (i.e. 'consistent-ON' words); and

ii) 'Inconsistent' words are those in which both constituent characters have multiple pronunciations, and where either one or both characters have a KUN-reading, but a target word takes an ON-reading (i.e. 'inconsistent-ON' words).

Patterson et al. (1995) added two new types of Kanji words for the manipulation of consistency.

iii) 'Inconsistent-KUN' words are those in which each constituent character has both an ON-reading and a KUN-reading, but a target word takes an atypical KUN-reading; and

iv) '*Jukuji KUN*' words, in which each constituent character does not correspond to any ON- or KUN-reading of the constituent Kanji characters, and has unique

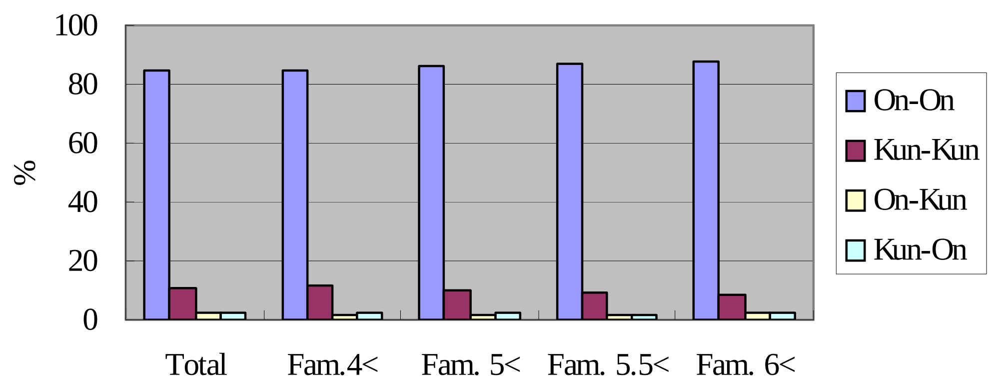
9 For instance, it appears that many adult readers incorrectly believe that /e/ for 絵 *picture*, /i/ for 胃 *stomach*, and /e-ki/ for 駅 *station*, are KUN-reading, though all are ON-reading.

pronunciation as a whole word, as explained above.

So, they proposed the 4 types of 2-character Kanji words: i) consistent-ON, ii) inconsistent-ON, iii) inconsistent-KUN, and iv) *'Jukuji KUN'*. According to the approximate analogy with English words they treated them as consistent words, inconsistent-‘*regular*’ words, inconsistent-‘*irregular*’ words and exception words, respectively. In this respect, their definition of consistency for Kanji words is categorical (this is referred to as *'categorical consistency'* hereinafter).

Their logic was based on both the number of pronunciations of each constituent Kanji character and also the general 'rule' that ON-reading is assigned to the vast majority of two-character Kanji words.

Fig. 8. The distribution of reading types in two-character Kanji words (Amano & Kondo, 1999).



As shown in Fig.8, which depicts the analysis of the pronunciation for 32,220 two-character Kanji words as a function of familiarity (Amano & Kondo, 1999), the vast majority of Kanji words have an ON-reading (i.e. the pronunciation of each constituent Kanji character is an ON-reading: On-On in Fig.8). Only about 10% of two-character Kanji words have a KUN-reading (i.e. the pronunciation of each constituent Kanji character is a KUN-reading: Kun-Kun in Fig.8). So, this analysis confirms that each constituent character of two-character Kanji words is typically pronounced using ON-reading.

It is rational that the difference between ON-reading and KUN-reading is associated with typicality of pronunciation of Kanji words. In this sense, inconsistent-ON words are inconsistent-typical and inconsistent-KUN words are inconsistent-atypical. However, no statistically significant RT difference was found, though a numerical RT difference between the four types of Kanji words with a different 'categorical consistency' was found in normal readers' oral reading performance (i.e.. for high-familiar words: consistent words = consistent-ON words = inconsistent-KUN words < Jukujikun words; for low-familiarity words: consistent words = inconsistent-ON words < inconsistent-KUN words < Jukujikun words) (Wydell, 1997; 1998).

On the other hand, Fushimi et al. (1999) defined print-sound consistency of two-character Kanji words using the ratio of friends/neighbours as follows:

i) Consistent words are those in which each constituent character has identical pronunciation across the neighbours; ii) Inconsistent-typical words are those in which each constituent character has more than one legitimate pronunciation across the neighbours but a where a target word takes the statistically typical pronunciation of each character; and

iii) Inconsistent-atypical words are those in which each constituent character has more than one legitimate pronunciation across the neighbours and where one or both constituent characters of a target word takes a statistically atypical pronunciation.

Their definition is based on the notion that orthographic *neighbours* of Kanji words that are the words sharing the same Kanji character at the same position[10](i.e. shared-character Kanji words). This definition is comparable to the notion of shared word-body neighbours in English words (see 3.1.5). For instance, 会 has two ON-readings (/kai/ and /e/) and one KUN-reading (in Kanji-Kana compound word 会う/a-u/ *meet*). In 29 two-character Kanji words sharing 会 in the first position (in a Japanese dictionary, *Kadokawa Kokugo Jiten*: Hisamatu & Sato, 1984), 会 is pronounced as /kai/ in 27 words (e.g. 会計/kai-kei/ *accounts*, 会社/kai-ʃa/ *company*, 会話/kai-wa/ *conversation*) and as /e/ in only 2 words (会釈/e-ʃaku/ *bow*, 会得/e-toku/ *master*). So, /kai/ is typical (27÷29=0.93) and /e/ is atypical (2÷29=0.07) for the pronunciation of 会 in the first position of two-character Kanji words. To use a similar analogy to that spelling-sound consistency in English, Kanji words like 会話 and 会得 are categorised as ‘regular-inconsistent’ words like *hint*, and ‘exception’ words like *pint*, respectively.

Thus, the definition of print-sound consistency in Kanji words is statistical. The definition refers to *'statistical consistency'* hereafter. Using a corpus of about 31,000 words, Fushimi et al. (1999) firstly calculated the average consistency of two-character Kanji words using the consistency of each constituent character at the first and the second position, by the ratio of friends/neighbours. Then, they classified two-character Kanji words into three types (i.e. 'consistent', 'inconsistent-typical' and 'inconsistent-atypical') on the basis of this ratio. They found a graded consistency effect on Kanji word reading as performed by Japanese adult readers.

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10 According to their definition, 手紙 (/te-gami/ *letter*) and 手段 (/sju-daN/ *procedure/*) are orthographic neighbourhoods, but 手紙 and 右手 (/migi-te/ *right hand*) are not.

In short, both 'categorical consistency' and 'statistical consistency' for Kanji words have been proposed, and the latter had a statistically reliable effect on normal readers.

2) General rules, and the flexibility of writing Japanese words, and lexicality

There are some rules for written Japanese, using Kanji and Kana (Hiragana, and Katakana), as follows:

i) *Kango* is written using Kanji (e.g. 位置 /i-.chi/ *position*; 気象 /ki-ʃo/ *weather*),

ii) *Wago* is written using Kanji, Hiragana and a Kanji-Kana compound (e.g. 鈴 /su-zu/ *bell*; のんびり /no-N-bi-ri/ *take it easy*; 鮮やか /a-za-ya-ka/ *vivid*),

iii) *Gairaigo* (i.e. loan words from a foreign language) is written using Katakana (e.g. レモン/re-mo/N/ *lemon*; キャラメル /kja-ra.me-ru/ *caramel*),

iv) Hiragana is used for function words (e.g. だから/da-ka-ra/ *so,* が/ga/, に/ni/: postpositional particle of Japanese),

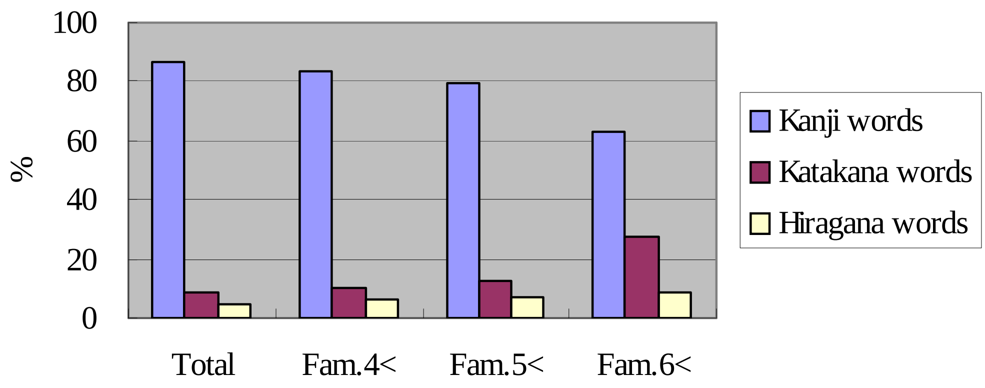
v) Kanji and Kana are used as morphemic components and the inflections of Kanji-Kana compound verbs and adjectives, respectively (e.g. verbs: 話す /ha-na-su/ *talk;* 書く /ka-ku/ *write*) (e.g. adjectives: 美しい/u-tu-ku-shi-i/ *beautiful*; 楽しい/ta-no-shi-i/ for *joyful* or *delightful*).

That is, both the type of vocabulary (*Kango*, *Wago,* and *Gairaigo*) and the syntactic categories (i.e. nouns, verbs, adverbs, adjectives and function words) constrain Japanese 'spelling'.

The vast majority of Japanese vocabulary consists of Kanji words (i.e. *Kango* and *Wago*), followed by Katakana words (*Gairaigo*) and Hiragana words (i.e. *Wago*).

Fig.9 displays the proportions of these three sorts of written Japanese words (N=68,732) as a function of word familiarity (Amano & Kondo, 1999). Kanji words are dominant in any familiarity band. In highly familiar words (N=4,564), where the mean familiarity is above 6 in the 7-point scale, the proportion of Katakana words is about 30%, which is much higher than that for Hiragana words.

Fig. 9. The distribution of types of orthography for written Japanese words (Amano & Kondo, 1999).



If one cannot remember Kanji character(s) in one's spontaneous writing for Kanji words, phonographic Kana is used for writing (e.g. 高邁 /kou-mai/ *loftiness*→高まい; 瑠璃 /ru-ri/ *lapis lazuli*→るり). These Kana transcriptions are acceptable for informal documents. So, the Japanese writing system is not only diverse but also flexible. This flexibility[11] led to a range of lexicality for Kana strings. Kana pseudohomophones consist of Hiragana/Katakana transcriptions of Kanji words, Hiragana transcriptions of Katakana words, and Katakana transcriptions of Hiragana words. As a result, the lexicality of Kana strings is very varied compared to that of

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[11] This flexibility is measurable as '*orthographic plausibility*' (Amano & Kondo, 1999) or '*orthographic acceptability*', which is recognised as a psycholinguistic variable by the Japanese research community.

Kanji strings.

3) Word-length

Basically, ON-reading for Kanji characters has bi-mora, because they are Japanese pronunciation of imported Chinese monosyllabic words. The majority of KUN-reading also has bi-mora. The number of mora for Gairaigo (loan words) is greater than for Kango and Wago (see Fig.6). The former is written using Katakana characters (Katakana words), and Kango and majority of Wago are written using Kanji characters (Kanji words). Therefore, word-length for Katakana words is greater than that for Kanji words. The vast majority of Hiragana words, which represent some of Wago, also have greater word-length, compared to Kanji words.

Thus, word-length for Kana words is greater than that for Kanji words.

4) The learning process for Japanese orthography, and age-of-acquisition, familiarity, and frequency

Kana characters are taught as part of the curriculum in the first year of primary school (between the ages of 6 and 7). But many children learn Hiragana before their formal education[12], and it has been pointed out that having a phonological manipulation of mora segmentation is an important preparation for Kana learning (Amano, 1970).

Learning Kana is about understanding the relationship between each single Kana script and their correspondent morae. Generally speaking, there are two learning procedures for Kana script. One is that the phonology of a single Kana characteris

[12] Leaning Hiragana has taken priority over leaning Katakana since 1945. Before that time, Katakana was learned first (i.e. before 1945 the language text book for the first grade of primary school was written in Katakana).

taught by using the shortest familiar words (e.g. い/i/ for /i -nu/ *dog*, か/ka/ for /ka-ki/ *persimmon*). Another learning procedure is the use of a Japanese syllabary list (i.e. '*Gojyu-On-Hyou* 五十音表'), in which Kana letters are arranged in order (i.e. 5 vowels /a//i//u//e//o/ are followed by a consonant-vowel compound, in which the order of consonants is /k//s//t//n//h//m//j//r//w//g//z//d//b//p/). Children practice reading (and sometimes writing) of Kana script in this order by vocalising the phonology of each character. So, in both procedures, the learning process of Kana is to assign Japanese morae to Kana characters and to acquire the two-way translation between Kana and its phonology, in which the role of semantics is quite limited. Once one has learnt this translation, the transparent nature of Kana characters allows us to really, orally, any Kana written strings, including both words and nonwords.

In contrast, Kanji characters are learned as words by knowing the meaning and phonology of the target Kanji words (e.g. 石 /i-shi/ *stone*, 手紙/te-ga-mi/ *letter*, 自転車/ji-te-N-sja/ *bicycle*). In other words, learning Kanji characters is about understanding the relationship between the written Kanji word, its phonology and its meaning (i.e. word-specific). So, the Kanji learning process relies heavily on the meanings of words.

Since so many Kanji characters (about 3000) are used in daily newspapers, a government organisation selected the basic and standard Kanji characters and proposed guidelines for learning. Children aged between 6 and 12 learn *'Kyoiku Kanji'* (educational Kanji; The Ministry of Education, 1948), which consists of 996 basic Kanji characters, and is allocated Kanji characters for each grade of primary school education. *'Jyoyo Kanji'* (daily usage Kanji; the Japanese language council, 1981), which included 'Kyoiku Kanji' and the other 949 commonly used Kanji characters, was selected as the standard Kanji characters (N=1945)[13]. Pupils aged between 13 and 15 in junior-high school mainly learn *'Jyoyo Kanji'*. Other Kanji characters, which are used in daily newspapers but do not belong to 'Jyoyo Kanji' (about 1000 Kanji characters) are learned during further education (high school and university) and through self-study. So, learning Kanji takes a long time and reading abilities vary depending on the individual's reading experience.

In short, the learning processes for Kana and Kanji are radically different. The 'age of acquisition' of Kana characters is very early (6-7 years old). In contrast, the 'age of acquisition' of Kanji characters varies depending on the type of character, ranging from 6 to 15 for compulsory education. Since 949 Kanji characters for *'Kyoiku Kanji'* are frequently used and consist of basic Kanji words in the Japanese vocabulary, frequency and familiarity for such Kanji words are co-related to the age of acquisition.

5) The number of strokes, and visual complexity

Obviously, Kanji characters are visually more complex than Kana characters. According to Kaiho and Nomura (1983), who investigated the number of strokes of each script, the average number of strokes for *'Kyoiku Kanji'* is 9.4 and the average number of strokes for the basic set for both Hiragana and Katakana characters is 2.3**.**

6) Summary of the psycholinguistic characteristics of written Japanese

The psycholinguistic characteristics of Japanese written words are inherently associated with the nature of the script type (Kanji and Kana). The following

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13 Before this Kanji list, *'Tokyo Kanji'* (N=1850) was published in 1946 and 1949 and many of them were transferred into *'Jyoyo Kanji'*.

psycholinguistic characteristics of written words in biscriptal Japanese are summarised as follows:

i) Near one-to-one correspondence between Kana characters and their pronunciation leads to a higher pronunciation predictability for Kana words, whereas multiple readings of Kanji characters, which came from a historical background, lead to the various degrees of print-sound consistency and lower pronunciation predictability for Kanji words;

ii) The phonographic nature of Kana characters, which allows transcription at any Japanese vocabulary, leads to higher acceptability of Kana transcriptions as lexical items, resulting in a range in lexicality of Kana written strings;

iii) Word-length of Kana words is longer than that of Kanji words, because a Kana character represents mora and a Kanji character represent bi-mora, and the number of mora for Kana words is also longer than that for Kanji words;

iv) While Kana characters are acquired early over a short period, Kanji characters are acquired over a long period of time through educational programmes and self-learning;

v) The way of learning Kanji directly affects the 'age of acquisition' of Kanji words and leads to an interrelationship between the 'age of acquisition', word familiarity and word frequency for Kanji words (i.e. early-acquired Kanji words have high familiarity and high frequency);

vi) Kanji characters are visually much more complex than Kana characters.

3.1.5. A comparison between Japanese and English orthography

Table 2 summarises the orthographic characteristics of both Japanese and English.

Table 2 A comparison of Japanese and English orthography

	Japanese		English
Number of script types	2		1
Script type	Kanji	Kana	Alphabet
Number of scripts	about 3,000 (for daily use)	75	26
	1945 (for compulsory education)	46 (for the basic set)	
Visual complexity of script (Mean Number of strokes)	9.4 (±3.6) (in 996 Educational Kanji for 6-12 years old children)	2.3 (±0.7) (in Hiragana basic set) 2.3 (±0.9) (in Katakana basic set)	2.0 (±0.9) (in Capital letters)
Linguistic level	morpheme (the vast majority) or word	mora	phoneme
Print-sound correspondence	quasi-regular	regular	quasi-regular

This clarification is necessary for comparing acquired dyslexia in Japanese and English. The most obvious difference is that Japanese is bi-scriptal, whereas English is mono-scriptal. As a phonographic script, Kana characters are more similar to the English alphabet. They represent a phonological minimum unit, a mora and a phoneme, respectively, and they are visually simple. In contrast, morphographic Kanji characters represent morphemes, occasionally represent words and are visually complex. With regard to the number of scripts, there is a huge difference between Kanji characters and Kana characters/English alphabets. This is related to the different representational level of each script.

However, Kanji words are similar to English words in terms of the relationship between orthography and phonology. As explained section 3.1.4. -1, print-sound consistency for Kanji words can be statistically defined[14] using the concept of

[14] This notion radically differs from the view presented by Sasanuma and Patterson (1995).

orthographic neighbours. In the case of English, how to evaluate the spelling-sound correspondence is still controversial, but the 'word-body' which, in monosyllabic words, consists of the vowel and terminal consonant (i.e. nucleus and coda) and which corresponds to the rhyme of the spoken syllable, is usually used for definition of this psycholinguistic variable. Based on the number of pronunciations for the word-body, and the typicality of the word-body's pronunciation, print-sound consistency for English words is categorised as follows:

i) Consistent words, in which the word-body is always pronounced the same way in different words (e.g. *tent*, *pent*, and *rent*);

ii) Inconsistent-typical words, in which the word-body is pronounced like most other orthographic neighbours (e.g. *hint*, *mint*, and *tint*); and

iii) Inconsistent-atypical words, in which the pronunciation of the word-body is unusual among orthographic neighbours (e.g. *pint*).

More precisely, Jared (1990, 1997) suggested that the degree of consistency (i.e. body-level neighbourhood consistency) is best measured by the sum of the frequency of its friends (i.e. word-body neighbours with the same pronunciation of the word-body) and its enemies (i.e. word-body neighbours with a different pronunciation of the word-body). Thus, it can be considered that the degree of consistency in English words varies, depending on these orthographic neighbourhood statistics. In this respect, English words and Kanji words are similar. In other words, statistical constraints on the pronunciation of the constituent characters in Kanji words would be comparable to the statistical constraints on

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They wrote "In kanji, by contrast, it appears that there is no dependable subword level over which the reader can learn to generalise. Although most kanji characters have only two or three common pronunciations (one *kun*-reading and one or two *on*-readings), none of these could be described as the most regular or typical pronunciation." (pp. 222-223).

pronunciation of English spelling. This point highlights the significance of cross-linguistic study for oral reading performance in Japanese and English.

3. 2. The neuropsychological approach to acquired reading disorder in Japan

3.2.1. A brief history of neuropsychological studies of acquired dyslexia and the double-dissociation between Kanji and Kana

The description of acquired reading/writing disorder in Japanese patients with aphasia was first seen in the early 20th century (Miura, 1901). Until the 1970s, acquired reading/writing disorders had been reported sporadically within the perspective of the Japanese-specific aphasic symptom (e.g. Asayama, 1912; Kimura, 1934; Kotani, 1935; Sakamoto, 1940; Hirose, 1949; Imura, 1943; Ohashi, 1965; Imura, Nogami, & Asakawa, 1971; Yamadori, 1975; Torii, Hiraguchi, Yoshimoto, Enokido, Yagishita, Ando, & Ainoda, 1976; Kurachi, 1979; Nagae, 1979). They had reported on whether their aphasic patients showed a discrepancy between Kanji and Kana in their reading/writing performance.

The paper by Imura, Nogami and Asakawa (1971) compiled descriptions of acquired reading/writing disorders observed in different types of Japanese aphasic patients. They considered that the Japanese writing system influences the manifestation of symptom features and wrote that ‘a special custom of language system in a particular culture can exhibit the very important knowledge of neuropsychological disorders which has been covered under the culture where the different language system is utilized’ (p.89). This perspective was based on the presumption that the reading/writing processes of Kanji and Kana are qualitatively different, and that disorder of the written language of Japanese aphasics should reflect this difference. Furthermore, some researchers supposed that different brain areas support Kanji or Kana processing, and this is closely related to semantic and phonological procedure, respectively (e.g. Kimura, 1934). This traditional view of reading/writing disorders of aphasic patients has been recognised as a ‘Kanji versus

Kana problem' in Japanese Aphasiology and has been in existence for a long period of time (e.g. Sakamoto, 1940; Special issue of 'Kanji vs. Kana problem' in Japanese journal of *Neurological Medicine*, vol.13, 1980).

With regard to the oral reading deficits of Japanese aphasics, the scattered case reports produced by medical doctors up until the 1960s suggested that a reading disorder in Kana was more prominent than a reading disorder in Kanji. In the 1970s this observation was accepted as the 'general rule' of acquired reading deficits for Japanese scripts (Imura et al., 1971; Yamadori, 1975). In this context, the oral reading performance by Gogi (word meaning) aphasic patients (Imura, 1943) was notable, because it showed selective impairment of Kanji word reading with preserved reading aloud of Kana. Imura described the nature of the oral reading errors by his Gogi aphasic patients, and he listed up to 4 categories of reading errors: ON/KUN confusion, semantic error, visual error, and others. ON/KUN confusion was only observed in this type of aphasia. It is worth noting that ON/KUN confusion is exactly a LARC error. For example, his patient read 相手/ai-te/ as /sou-ʃu/. Though both /sou/ and /ʃu/, which are ON-reading, are correct pronunciations for other words (e.g. 相談 /sou-daN/; 選手/seN-ʃu/), they are incorrect for 相手 (KUN-reading /ai/ for 相 and KUN-reading /te/ for 手 are the correct pronunciation for 相手[15]). Other studies of Gogi aphasia have also reported this type of reading error (Fujii & Morokuma, 1959; Koshika, Asano, Imam chi, & Miyazaki, 1969; Sasanuma & Monoi, 1975; Matsubara, Enokido, Torii, Hiraguchi, & Ainoda, 1983).

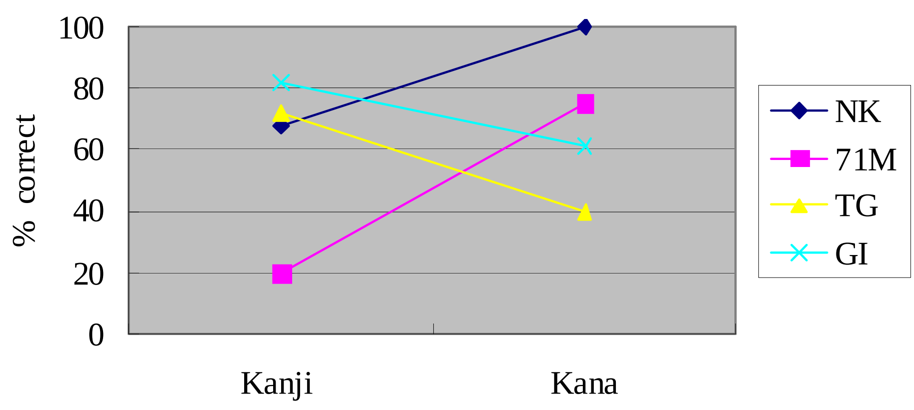
From the late 1970s, the neuropsychological perspective gradually became

[15] 相手 is a high familiarity word (i.e. written word familiarity is 6.5), but 2-character Kanji words with Kun-reading like 相手 are not typical (see Fig.8).

popular and the research about pure alexia, alexia with agraphia and alexia without agraphia has been dominant in Japan. Such neuropsychological investigations reached a general consensus that the Japanese patients with alexia with agraphia show a double dissociation between Kanji and Kana scripts on oral reading tasks, and this corresponds to different lesions in the brain. The patients with a left angular gyrus lesion showed superiority of reading aloud of Kanji over Kana (e.g. Iwata, Sugishita, Kawai, Yamashita, & Toyokura, 1979; Yamadori, 1975, 1979; Kawamura, 1990). On the other hand, the patients with a left posterior interior temporal lobe lesion demonstrated an advantage of oral reading of Kana over Kanji (e.g. Kawahata, Nagata, & Shishido, 1987; Kawahata, Tagawa, Hirata, Nagata, & Shisihdo, 1988; Kawamura, 1990).

Figure 10 shows the results of some reported cases.

Fig.10. Oral reading performance by four Japanese patients suffering from Alexia with Agraphia.



NK: Kawahata et al. (1987, 1988)

71N: Sakai et al. (1992)

TG & GI: Kawamura (1990)

The proportion of correct oral reading performances by TG and GI (Kawamura, 1990), who had a left angular gyrus lesion, were 72% and 82% for Kanji and 40% and 61% for Kana, respectively. In contrast, NK (Kawahata, et al., 1987, 1988), who had a left posterior inferior temporal lobe lesion, showed preserved reading aloud of Kana (100% correct) and selectively impaired Kanji word reading (68% correct). Sakai, Sakurai, Sakuta, and Iwata (1992) also reported the same dissociation between Kanji and Kana word reading in their patient, who was a 71 year old man with damage to the left temporal lobe to the temporo-occipital junction involving fusiform gyrus (75% correct for Kanji > 20% correct for Kana). In the case of pure alexia, many patients had damage to the left posterior cerebral artery or a sub-angular lesion and showed alexia in both Kanji and Kana (Kawamura, 1990). The patients with pure alexia sometimes showed a kinesthetic facilitation of oral reading of Kana, which is called ‘kinesthetic reading’ (e.g. Torii & Enokido, 1979).

In summary, classical studies of Japanese neurological patients with aphasia paid much attention to reading performance which could be dissociated between Kanji and Kana. Neuropsychological studies of acquired reading deficits after focal brain damage described how two different lesions are associated with the double dissociation between Kanji and Kana in oral reading (left posterior inferior temporal lobe lesion: Kanji < Kana; left angular gyrus lesion: Kanji > Kana). These researches reinforced the presumption that i) lexical processing for Kanji and Kana is different due to the different nature of the scripts in which Kanji and Kana characters were considered as ideographic and phonographic, respectively; and ii) Kanji is processed by semantic procedure and Kana is processed by phonological procedure.

3.2.2. The neurological reading model for Japanese orthography

Iwata (1984, 1985 & 1987) proposed the hypothetical neural mechanisms in the brain underlying oral reading of written Japanese (Fig.11), based on the results of the neuropsychological studies which demonstrated the double dissociation between Kanji and Kana in oral reading. In this model, visually presented character stirrings are recognised in the occipital lobe and this information is processed to Wernicke's area by the two distinct pathways.

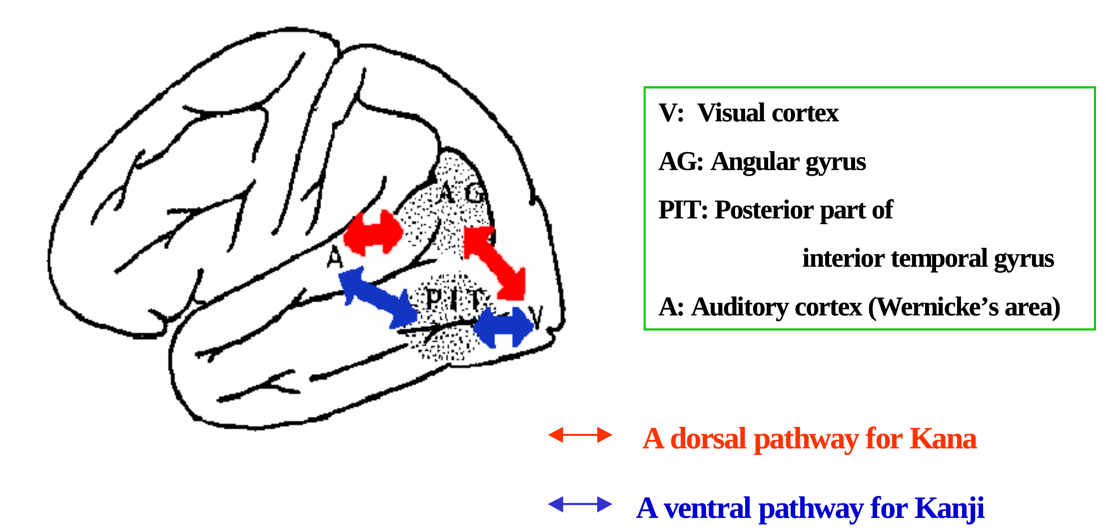


Fig. 11 The neurological reading model for Japanese orthography (Iwata, 1984)

One pathway is the dorsal route via the angular gyrus, which also receives somashetic information for kinesthetic reading. This pathway is used mainly for the phonological reading processes involved in Kana reading. The other is the ventral route via the posterior part of the inferior temporal gyrus. This pathway is used for semantic reading processes and is indispensable for Kanji word reading. That is, Iwata assumed that different neurological circuits correspond to the phonological and semantic pathways which are responsible for Kana and Kanji reading, respectively[16]

This neurological model is influential in neuropsychological reading research in Japan, partly because the double dissociation between Kanji and Kana in written word processing seemed to be explained by this model, and partly because the model fits the traditional and intuitive notion that the processes involved in reading Kanji and Kana are qualitatively different. Thus, this model is still used as a rationale for interpreting the reading deficits in Japanese neurological patients in recent studies (e.g. Sakurai, Momose, Iwata, Sudo, Ohtomo, Kanazawa, 2000). Though activation studies on normal reading by PET revealed that activation areas for both scripts overlapped (Sakurai, Momose, Iwata, Ishikawa, & Takeda, 1992; Sakurai & Momose, 1994), the view that reading of Kanji and Kana is processed using different brain networks is popular in neuropsychological research community in Japan.

3.2.3. Methodological problems in the neuropsychological studies of acquired dyslexia in Japanese

The neuropsychological studies of reading disorders had a serious methodological problem which arose from a lack of knowledge about lexicality. Both classical and neuropsychological studies did not control the lexicality of their reading stimuli. Kanji word stimuli were usually selected from *Kyoiku Kanji* (see 3.1.3). Kana stimuli usually consisted of single Kana characters and Kana transcriptions from Kanji words. For example, the study that demonstrated Kana superiority over Kanji

[16] Morton and Sasanuma (1984) showed similar view of reading model for Japanese. They wrote, "The general conclusion is that kana is read phonetically and kanji is read visually." (p. 40).

(Kawamura, 1990) used 416 single Kanji characters, which are Kyoiku Kanji for grade 1 to 3 in elementary school, and Kana transcriptions of these Kanji characters. Since single Kanji characters (e.g. 月, 正) are used in i) a single-character Kanji word (e.g. 月/tu-ki/ *moon*); ii) a Kanji-Kana compound (e.g. 正しい/tada-ʃi-i/ *correct*); and iii) a constituent character of multiple-character Kanji words (e.g. 正月 /ʃo-gatu/ *new year*), Kana transcriptions of a single Kanji character are pseudohomophones or nonhomophonic nonwords. The study that demonstrated Kanji superiority over Kana (Kawahata, et al., 1987, 1988) used 5 single Kana characters, 20 words written using 2, 3, 4 and 5 Kana characters and 25 Kanji words ranging from 1 to 5 mora words. In this case, single Kana stimuli are nonwords and it is unclear whether 2- to 5-character Kana strings were real Kana words or Kana transcriptions.

As shown in these examples, Kana stimuli in neuropsychological studies included Kana nonhomophonic nonwords and Kana pseudohomophones. In other words, the double dissociation between Kanji reading and Kana reading reported by neuropsychological research does not mean discrepancy of oral reading performance between Kanji words and Kana words. Thus, the following two possibilities are suggested:

i) Kana superiority over Kanji might result from a consistency effect, in which the print-sound predictability of Kanji words is much lower than that of Kana strings; and

ii) Kanji superiority over Kana might be attributable to a lexicality effect (Kanji words > Kana nonwords), because Kana reading stimuli included Kana pseudohomophones and single Kana characters.

In other words, the reported phenomenon of double dissociation between Kanji and

Kana was based on unreliable reading material, arising from the methodological problem of neuropsychological studies. Therefore, it is unclear whether acquired reading disorder in Japanese is really script-dependent.

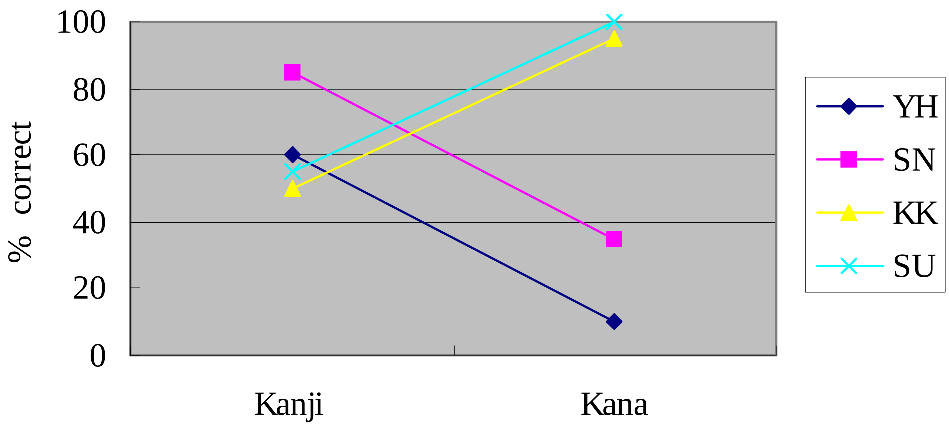
3.3. The cognitive neuropsychological studies of acquired dyslexia in Japanese

Cognitive neuropsychological research of reading disorders in Japanese patients with aphasia started in the late 1960s (Sasanuma, Ito, & Fujimura, 1969). Earlier works (Sasanuma & Fujimura, 1971; Sasanuma, 1974) shared the traditional view that reading processing for Kanji and Kana is qualitatively different (i.e. a semantic procedure for Kanji and a phonological procedure for Kana) and the reading disorders of Japanese neurological patients should reflect this difference. In the late 1970s and 1980s, the framework of the dual-route model and case studies of acquired dyslexia in English influenced the interpretation of Japanese acquired dyslexia, and the double dissociation between Kanji and Kana was related to the two distinctive dyslexic types (surface and deep dyslexia) and emphasised *script-specific* (or *script-dependent*) dyslexic patterns. Since the middle of the 1990s it has been reported that Japanese neurological patients showed similar characteristics of surface dyslexia and phonological dyslexia in alphabetic orthography, thus suggesting *script-nonspecific* (or *script-independent*) Japanese dyslexic patterns.

3.3.1. Classical cases and acquired dyslexia types in Japanese

Sasanuma (1979) studied oral reading performance in two Japanese patients with aphasia, YH and KK, and reported two distinctive dyslexic patterns. In the book *'Deep Dyslexia'* (Eds. Coltheart, Patterson and Marshall, 1980), she presented her interpretation that YH, who showed a marked deficit of Kana reading coupled with relatively preserved Kanji word reading, was a Japanese version of deep dyslexia, and that KK, who showed selective impaired Kanji word reading, was a Japanese version of surface dyslexia. Furthermore, Sasanuma added SU, who showed a similar dyslexic pattern to KK, in the book '*Surface Dyslexia*' (Eds. Patterson, Marshall & Coltheart, 1985) and presented SN, who demonstrated a similar reading pattern to YH (Sasanuma, 1986). Fig.12 depicts the double dissociation of oral reading of Kanji and Kana[17] in these four patients.

Fig.12. Oral reading performance by four classical cases of Japanese acquried dyselxia (Sasanuma, 1986).



Through this pioneering work, which was mainly published in English, the view that a Kanji-specific reading disorder is Japanese surface dyslexia and a Kana-specific reading disorder is Japanese deep dyslexia (i.e. a script-specific dyslexic pattern) was circulated in the cognitive neuropsychological communities in the English-speaking world. In addition to this work on the Japanese version of surface dyslexia and deep dyslexia, from early the 1990s reports were made of

[17] Fig.12 shows the results of oral reading of 20 single-character Kanji words and 20 Kana transcriptions of the identical Kanji words by four patients.

patients, who showed a lexicality effect on oral reading of Kana strings which was considered as phonological dyslexia in Japanese.

The rationale behind the Japanese version of surface, deep and phonological dyslexia was based on the following three assumptions: i) Kanji words can be treated as exception words (or inconsistent words) in English, because the Kanji character-sound relationship is opaque; ii) Kana words can be treated as regular words in English, because the Kana character-sound relationship is transparent (or regular); and iii) a Kana nonsense sequence can be treated as nonwords in English, because Kana is a phonogram like English.

Table 3 The basic information about classical cases of Japanese acquired dyslexia

	Age (years)	Sex	Education (years)	Etiology	Lesion in CT-scan	Aphasia type
KK	51	M	14	CVA	L.temporo-parietal	Wernicke
SU	46	M	14	CVA	L.temporo-parietal	Wernicke
Case 7	51	M	14	CVA	L.temporo-parietal	Wernicke
HS	77	M	6	CVA	R.MCA territory	Crossed aphasia
Case M	32	M	16	CVA	L.basal ganglia, subsortical parietal	Fluent aphasia
KT	57	M	16	CVA	L.MCA territory	Anomic aphasia
TY	65	F	-	CVA	The enterior horn of L.lateral ventricle	Anomic aphasia
HN	55	M	16	CVA	L.temporo-parietal	Conduction aphasia
AK	52	M	9	CVA	L.caudate nucleus, L. parietal	Fluent aphasia
HM	51	M	12	CVA	L. MCA territory	Fluent aphasia
YH	57	F	11	CVA	L.front-temporo-parietal	Broca
SN	49	M	11	CVA	L.temporo-parietal	Wernicke
TO	46	F	9	CVA	L.putamen, subcortical temporal, angular gyrus	Broca
Case A	47	M	16	CVA	L.front-temporo-parietal	Unclassified

Classical cases of Surface dyslexia

KK : Sasanuma (1979, 1980a, 1986)
SU : Sasanuma (1984, 1985, 1986)
Case 7 : Sasanuma (1980b)

Classical cases of phonological dyslexia

HS : Mizuta et al. (1992)
Case M : Matsuda et al. (1993)
KT : Patterson et al. (1996)
TY : Sasanuma et al. (1996)
HN : Maekawa et al. (1999)
AK : Sekino et al. (2003)
HM : Mori & Nakamura (2003)

Classical cases of deep dyslexia

YH : Sasanuma (1979, 1980a, 1986)
SN : Sasanuma (1980b, 1986)
TO : Hayashi et al. (1985)
Case A : Asano et al. (1987)

This section reviews classical cases of acquired dyslexia in the order of surface dyslexia, phonological dyslexia and deep dyslexia. Table 3 shows the basic information (Age, Sex, Education, Etiology, Lesion in CT-scan, and Type of aphasia) about the patients in the classical case studies.

1) Classical surface dyslexia in Japanese

There are three classical cases of surface dyslexia, KK (Sasanuma, 1980a), Case 7 (Sasanuma, 1980b) and SU (Sasanuma, 1984, 1985). The characteristics of oral reading performance in these patients can be summarised as follows:

i) Selectively impaired Kanji word reading coupled with preserved oral reading of 'Kana words' and Kana nonwords;

ii) Errors in Kanji word reading consist mainly of neologistic and irrelevant words, and few semantic errors occurred.

Characteristic i) is the opposite pattern to the Japanese version of deep dyslexia (see Fig.12) and this had been considered as a signature feature of Japanese surface dyslexia until recent studies appeared (e.g. Fushimi, Komori, Ikeda, Patterson, Ijuin, & Tanabe, 2003a). Sasanuma (1985) argued that a selective deficit in Kanji processing would be treated as a regularity effect in English surface dyslexia. Her rationale was based on the assumption that ‘kanji, which is a logographic code, not a phonological one, represents the “ultimate” form of orthographic irregularity’ (p.240). Although she did not explicitly explain her logic, it was assumed that preserved oral reading of transparent Kana and impaired oral reading of opaque Kanji is comparable to preserved oral reading of regular words and impaired irregular words in English surface dyslexia cases. She also argued that the regularisation error is ‘simply impossible in principle in reading kanji’ (p.240). This appears to be based on her presumption that ‘logographic’ Kanji is processed by semantic procedure, not by phonological procedure (i.e. sub-lexical procedure). So, she could ignore the fact that her cases did not make ‘regularisation errors’ (more precisely LARC errors) in Kanji word reading. As a result, a selective impairment of Kanji word reading was treated as a defining feature of the Japanese version of surface dyslexia. Below are detailed descriptions of the reported patients with this type of acquired dyslexia.

Selectively impaired Kanji word reading

SU was able to read all ‘Kana words’, which were Kana transcriptions of Kanji words, for both 20 concrete nouns and 20 abstract nouns. KK also could read the same ‘Kana words’ with a high proportion of accuracy (95% correct for both concrete and abstract nouns). Furthermore, the accuracy of oral reading of two-character Kana nonwords (N=20) was 100% in SU and 70% in KK. In contrast, the reading accuracy of 20 concrete Kanji words and 20 abstract Kanji words was 55% and 40% in SU and 50% and 15% in KK. In the modified Peabody Picture Vocabulary Test (PPVT: Sasanuma, 1980a, N=50), the discrepancy between Kana and Kanji was substantial. While SU was able to read 100% of the Kana transcriptions, he could read only 10% of Kanji words. Likewise, KK could read 82% of Kana transcriptions, but could read only 4% of Kanji words. In the same test, Case 7 was also able to read 94% of Kana transcriptions, but could read only 24% of Kanji words.

Error pattern in oral reading

The error pattern of these patients was not exactly identical. In oral reading task of the modified PPVT, SU produced no responses (45/88, 51%), irrelevant words to the target (21/88, 24%), circumlocutions (e.g. 裁判官 *judge* →'punishes a bad guy'; 退屈 *boredom*→'there is nothing to do'; 18/88, 20%), and semantic errors (4/88, 4%). Neologistic errors were KK's dominant error type (40/48, 83%). KK also made phonological errors (5/48,10%) and semantic errors (3/48, 6%). Case 7 mainly made neologistic errors and phonological errors, but also produced small semantic errors (only the description was seen and no data is available).

It is worth mentioning that SU made ON/KUN confusions in oral reading of 20 adjectives and 20 verbs. SU read 洗う/ara-u/ *wash* as /seN-u/ and read 重い/omo-i/ *heavy* as /choo-i/. SU assigned ON-reading /seN/ for 洗 and ON-reading /choo/ for 重. Though these KUN-readings are the correct pronunciation of each Kanji character, they are wrong for the target written words. That is, SU made LARC errors, but its proportion was very limited [18] (2/16, 13% in adjectives; 1/17, 6% in verbs).

Semantic function of classical surface dyslexia cases

SU demonstrated preserved spoken word comprehension (96% correct), and

18 Shinkai, Tanemura, Kaneko, & Maekawa (1995) reported that the six Japanese aphasic patients with the same oral reading pattern as classical cases of surface dyslexia did not produce LARC errors in Kanji word reading. Their accuracy of oral reading for 'Kana words' (Kana transcriptions of Kanji words) and Kanji words was as follows: Case 1: 100% > 55%; Case 2: 100% > 20%; Case 3: 100% > 75%; Case 4: 100% > 75%; Case 5: 100% > 48%; Case 6: 90% > 50%. Case 1 and Case 2, who showed severe semantic impairment, produced irrelevant words (e.g. 薬 /ku-su-ri/ *medicine* →車 /ku-ru-ma/ *car*) and semantic errors (e.g. 北風 /kita-kaze/ *north wind*→冬 /fu-yu/ *winter*). Case 3 and Case 4, who showed better comprehension of written sentences than spoken sentences and fairly good picture naming (over 70% correct), produced neologistic errors including one character correct responses (e.g. 紅茶 /kou-tʃa/ *tea*→/ku- tʃa /), irrelevant words, and visual errors (e.g. 果物 /kuda-mono/ *fruits*→古物/ko-butu/ *old thing*). Case 5 and Case 6, who showed superiority of written comprehension over spoken comprehension and better comprehension of written stimuli than Cases 3 and 4, made phonological errors (e.g. 湯呑 /yu-nomi/ *tea cup* →/ku-nomi/), and phonological searches, in which some of them reached the target response (e.g. 砂漠 /sa-baku/ *desert* →/sama/, /saba/, /satsu/, /sazu/, then /sa-baku/).

preserved reading comprehension for Kana transcriptions (98% correct), but showed deteriorated reading comprehension for Kanji words (78% correct). KK's accuracy of spoken word-picture matching was 86% and his accuracy of reading comprehension was 74% for Kanji words and 66% for Kana transcriptions. Meanwhile, their performance of lexical judgment was slightly different. While both could judge 100% of two-character Kanji nonwords, their accuracy for two-character Kanji words was 90% for SU and 75% for KK. In the lexical judgment of 3-character Kana words and nonwords, SU was able to respond to all items correctly, whereas KK's accuracy in this task was 90% for Kana words and 50 % for Kana nonwords.

SU was tested further using two different semantic tasks for Kanji words. One was identification of semantically related words, in which a list of three target Kanji words (e.g. 台風 *typhoon,* 雷 *thunder,* 風 *wind*) was presented. SU was asked to point to the Kanji word which was most semantically related to the target three stimuli words from another Kanji word list (e.g. 冬 *winter,* 雨 *rain,* 水 *water*). In this example, 雨 is the correct answer. Another task was a categorisation task, in which SU was asked to classify a set of 25 Kanji words into the five superordinate categories (e.g. food, animals, furniture, weather and plants). SU's accuracy was 60% (12/20) in the former test and 50% (50/100) in the latter test. Both results indicated that SU had semantic impairment.

2) Classical phonological dyslexia in Japanese

Mizuta, Matsuda, & Fujimoto (1992) firstly reported that an aphasic patient, HS, showed selectively impaired Kana nonword reading coupled with preserved Kana word reading. While HS's oral reading of Kana words, which consisted of 2, 3, 4 and

5 Kana characters, was preserved (40/40, 100%), he could not read 3-, 4- and 5-character Kana nonwords. HS could read only 2-character Kana nonwords with low accuracy (6/10, 60%). Matsuda, Suzuki, Kobayashi, & Mizuta (1993) also reported a similar case (hereinafter it refers to Case M), whose oral reading of words - including concrete nouns written in Kanji and Kana, adjectives, verbs and function words - was 99% correct (307/310), but who showed a deficit in Kana nonword reading. Case M's accuracy of reading aloud Kana nonwords was modulated by character-length (100%, 70%, 30% and 20% correct in 2-character, 3-character, 4-character and 5-character strings, respectively). Case M made lexicalisation errors (28% of his total reading errors). The substantial lexicality effect in these patients is comparable to phonological dyslexia in English and French.

After these reports, selective impairment of Kana nonword reading has been considered as a signature characteristic of phonological dyslexia in Japanese. This point must be emphasised, because many recent studies have used this definition. So, there are another 5 cases of classical phonological dyslexia in Japanese (KT: Patterson, Suzuki, & Wydell, 1996b; TY: Sasanuma, Ito, Patterson, Ito, 1996; HN: Maekawa, Kaneko, Shinkai, Nagami, & Tanemura, 1999; AK: Sekino, Furuki, Ishizaki, 2003; HM: Mori & Nakamura, 2003).

The characteristics of the published cases of classical phonological dyslexia in Japanese are summarised as follows:

i) remarkable superiority of oral reading of Kanji and Kana words over Kana nonhomophonic nonwords (i.e. lexicality effect);

ii) a marked advantage of oral reading of pseudohomophones over nonhomophonic nonwords (i.e. pseudohomophone effect);

iii) lexicalisation errors and a visual/phonological resemblance to the target are error responses for reading aloud of nonhomophonic nonwords;

iv) a fairly well preserved ability to read aloud single Kana characters.

Below are detailed descriptions of the reported patients with this type of acquired dyslexia.

Preserved word reading

The level of success in reading words aloud ranged from 87% to 100% in the reported cases of Japanese phonological dyslexia. KT (Patterson et al., 1996b) was able to read 90% of concrete Kanji words (N=30), 97% of abstract Kanji words (N=30), 98% of Hiragana words (N=40), and 91% of Katakana words (N=52). TY (Sasanuma et al., 1996) was also able to read 100% of concrete Kanji words (N=40), 97.5% of abstract Kanji words (N=40) and 100% of Kana words (Hiragana words, N=20; Katakana words, N=20). HN (Maekawa et al., 1999) could read 99% of Kana words (Hiragana words, N=99; Katakana words, N=36) and was also good at oral reading of both concrete and abstract Kanji words (82/88, 94%, and 40/40, 100%, respectively). AK (Sekino et al., 2003) could read 87% of Katakana words (N=30, 2-4 mora words) and 91% of 2-character Kanji words (N=30). HM (Mori & Nakamura, 2003) was able to read 100 % of high-familiarity Kana words and 95% of low-familiarity Kana words, in which the reading stimuli were 80 Hiragana words and 80 Katakana words, ranging from 2 to 6 characters.

KT and TY showed a good performance in reading aloud adjectives and verbs (KT: 30/30, 100%, 29/30, 97%, respectively; TY: 40/40, 100% in both). While TY was also read 98% of the function words (N=40), KT's performance in function words, which are always written in Hiragana, was poor (31/52, 60%).

<u>Impaired nonword reading</u>

With regard to nonsense written strings in Japanese, three types of stimuli were used in these studies. They were single Kana characters, nonhomophonic nonwords written in Kana characters, and Kana pseudohomophones.

Kana nonhomophonic nonwords were usually created through three procedures (Sasanuma et al., 1996): a) transposing the sequential order of Kana words (e.g. ピストル/pi-su-to-ru/ *pistol*→スピトル/su-pi-to-ru/); b) substituting one constituent character of Kana words (e.g. ひまわり /hi-ma-wa-ri/ *sunflower* → ふまわり /fu-ma-wa-ri/); and c) randomising the order of the constituent characters of Kana words (e.g. ねじまわし/ne-ji-ma-wa-shi/ *screwdriver* →まじねしわ /ma-ji-ne-shi-wa/).

Kana pseudohomophones were created by transcribing a) Kanji words into Kana strings (e.g. 石油/seki-yu/ *petroleum*→せきゆ /se-ki-yu/; 温泉/oN-seN/ *hot spring*→おんせん/o-N-se-N/), b) Hiragana/Katakana words into Katakana/Hiragana strings (e.g.ひまわり /hi-ma-wa-ri/ *sunflower* →ヒマワリ/hi-ma-wa-ri/；ナイフ /na-i-fu/ *knife*→ ないふ/na-i-fu/), respectively; or c) Hiragana or Katakana words into Hiragana and Katakana mixtures (e.g. ミルク/mi-ru-ku/ *milk* →みルく /mi-ru-ku/).

a) Single Kana characters

In oral reading of single Kana characters the majority of the classical phonological dyslexic patients performed relatively well. Some of them could read all or almost all of the Kana characters (100% correct in HN; 99% correct in Case M). AK was good at reading aloud the basic set of Kana characters, which correspond to V or CV (91% correct in 46 Hiragana characters; 90% correct in 46

Katakana characters), but his accuracy of a full set[19] of Kana characters had deteriorated (60% correct in 104 Hiragana characters; 63% correct in 104 Katakana characters). TY's accuracy in reading 71 Kana characters that consist of the basic set and the Kana characters with diacritical mark was 82%. HS's accuracy of single Kana characters was also 80% (the test numbers were not mentioned). In contrast, KT's accuracy of the basic set and full set of Hiragana characters was 36% (16/45)[20] and 26% (27/104), respectively.

b) Oral reading of nonhomophonic nonwords

Nonword reading performance varied across the patients. KT was not able to read any of the 3-character nonwords. Lexicalisation errors (e.g. からめ→カメラ *camera*) were KT's dominant error for Kana nonword reading (36/50, 72%). AK also could not read any of the 2- or 3-character Kana nonwords. AK made lexicalisation errors, and also produced substitution, deletions, and additions of single mora of the nonword stimuli. Like Case M, HN's nonword reading performance was modulated by character length (100%, 68%, 76% and 57% correct in 2-character, 3-character, 4-character and 5-character strings, respectively). HN's error responses in reading aloud nonwords, which were created by the same three procedures (transposing, substituting and randomising: Sasanuma et al., 1996), were lexicalisation errors (around 60%) and visual (therefore phonological) resemblance

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19 A full set of Kana characters consists of the basic set, the Kana characters that have a diacritical mark representing phonetic distinction such as a voicing consonant (e.g. ぎ/gi/), and two-character Kana compounds corresponding to CjV mora (e.g. きゃ/kja/). (see 3.2.3. -3. in this Chapter).

20 Patterson et al. (1996b) noted that KT's reading accuracy for the basic set was 60% (27/45), 'when he was instructed "Please try to think of the meaning of the kana character or think of a kanji character with the same pronunciation" (p.814) '. This score was significantly better than KT's performance without instruction (P=0.02). There are some words that have only one mora (e.g. 目/me/ *eye* –め/me/; 木/ki/ *tree* –き/ki/).

to the target (around 40%). HN's lexicalisation errors occurred most frequently in oral reading of transposed nonwords. Maekawa et al. (1999) observed that HN made lexicalisation error with/without struggling to pronounce the target nonword. When HN did not make lexicalisation errors immediately, he initially produced a partially correct pronunciation of the target, but finally reached the real word that is visually/phonologically similar to the nonword stimulus (e.g. がたす/ga-ta-su/ →/ga-ta ….ga, ra-su, ga-ra-su [ガラス *glass*]).

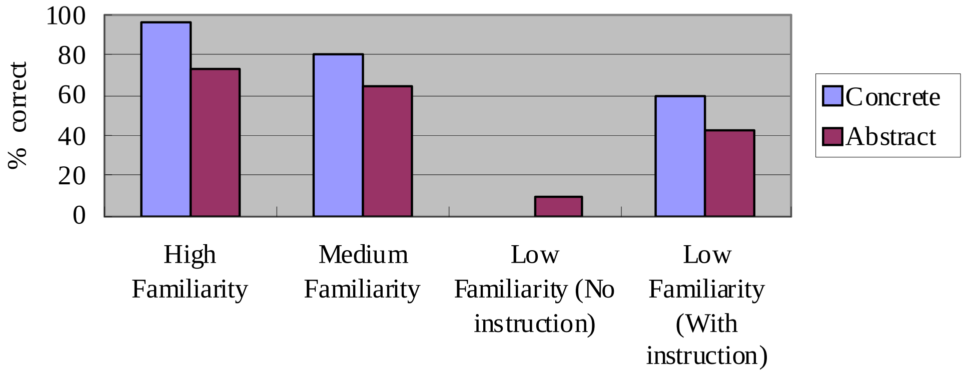
Sasanuma et al. (1996) reported that their patient's accuracy of nonword reading was modulated by the type of nonwords. Oral reading of substituted nonwords was most successful for TY (69/124, 56%), followed by transposed nonwords (40/125, 32%), and randomised nonwords (6/37, 16%). TY's overall accuracy was 40% and lexicalisation was observed to form 27% of her error responses. The occurrence of lexicalisation also differed in the three types of nonwords. In transposed nonwords, TY made a lot of lexicalisation errors in transposed nonwords (43%), but this type of error occurred less in substituted nonwords (16%) and were not observed in randomised nonwords (0%). The majority of her reading errors were substitutions, transpositions, deletions or additions of single mora of the nonword stimulus (i.e. a visual/phonological resemblance to the target). With regard to TY's lexicalisation errors, the researchers wrote that 'She was clearly aware that the stimulus strings were nonwords and that her responses were incorrect, as indicated by her constant utterance of the phrase "Ja-nai!" meaning "No, it isn't (correct)!" to herself immediately after she made part-word, and some times whole-word, lexicalisations' (p.833). For HM (Mori and Nakamura, 2003), his accuracy of nonword reading was 41% (66/160) and the majority of his reading errors were lexicalisation (59%) followed by phonological errors (25%).

c) Oral reading of pseudohomophones

All reported cases demonstrated a pseudohomophone advantage over nonhomophonic nonwords in their oral reading performance. TY was 90% correct on reading aloud of 187 pseudohomophones created by the three procedures explained above. HN was also able to read 94% of 36 pseudohomophones, which were Hiragana transcriptions of Katakana words. AK's performance was 82% and 71% correct in 30 Hiragana transcriptions of Katakana words and Kanji words, respectively. In the case of HM, he could read 89% of Hiragana transcriptions of Katakana words (142/160) and 93% of Katakana transcriptions of Hiragana character words (148/160), and the familiarity of the base word influenced his oral reading performance of Katakana pseudohomophones (high familiarity base words: 78/80, low familiarity base words: 70/80, $p < 0.05$).

Patterson et al. (1996b) also manipulated the properties (i.e. concreteness, familiarity) of the base Kanji words for creating Hiragana transcriptions. In KT's oral reading performance, a concreteness and familiarity affect of the base Kanji words was detected on the reading aloud of Hiragana pseudohomophones created by Kanji words. KT's oral reading accuracy for Hiragana transcriptions created from high familiarity, concrete Kanji words (e.g. 新聞 /shiN-buN/ *newspaper* →しんぶん /shi-N-bu-N/) was 97%. On the other hand, KT's reading accuracy for Hiragana transcriptions created from low familiarity, abstract Kanji words (e.g. 雲泥 /uN-dei/ *metaphor of big difference* →うんでい/u-N-de-i/) was 10%. The former rate is similar to KT's accuracy in oral reading of Kanji and Kana words, whereas the latter rate is similar to KT's accuracy for nonhomophonic nonwords (see Fig. 13 that was drawn using the data of Table 2 in Patterson et al., 1996b). That is, the pseudohomophone advantage had disappeared as a result of the use of lower familiarity Kanji words.

Fig.13. KT's reading performance for pseudohomophones which were transcribed from cocnrete or abstract Kanji words of varying familiarity (Adapted from Patterson et al., 1996b).



Interestingly, the instruction[21] that "these are all words" facilitated KT's oral reading performance of Hiragana transcriptions created from low familiarity Kanji words (18/30, 60% when the base Kanji words are concrete nouns; 13/30, 43% when the base Kanji words are abstract nouns).

Phonological function of classical phonological dyslexic cases

Out of seven cases with classical phonological dyslexia, six cases were tested using repetition. The majority of these cases showed a good performance in word repetition and preserved nonword repetition. TY and HN were 100% correct on 3- to 5-mora words, and HM was also 100% correct on 2- to 6-mora words. Case M also had no difficulty in repeating both words and nonwords (the length of test stimuli

[21] This effect of explicit instruction in reading of pseudohomophones is comparable to the instruction effect on oral reading of single Kana characters (see footnote 8, Patterson et al., 1996b).

was not known). KT was able to read 95% of 2- and 3-mora nonwords, either immediately (ordinal repetition) or even after a four-second delay (delayed repetition). TY was 100% correct on 3-mora nonwords, but 87% correct on 4- and 5-mora nonwords. HM and HN also showed a less accurate performance in nonword repetition compared to word repetition. HM's accuracy in 2- to 6-mora nonwords was 72% and HN's accuracy in 3- to 5-mora nonwords was 75%. HS showed severe impairment in both word and nonword repetition (40% correct and 35% correct, respectively).

With regard to phonological manipulation ability, four phonological dyslexic patients were evaluated. In the phonological segmentation test (Monoi & Sasanuma, 1975), HN was fairly good at the mora recognition task in which a subject was asked whether the target mora /ka/ was or was not included in the individually presented 3-mora spoken word or nonword. HN was also quite good at the mora segmentation task in which a subject was asked the position of the mora /ka/ in a 3-mora word by pointing out the appropriate position from the three horizontally placed circles representing the three mora positions. HN's accuracy was 90% (43/48) on mora recognition and 88% (21/24) on mora segmentation. In contrast, KT showed a poor performance in both tasks. KT's accuracy was 56% (27/48) on mora recognition and 46% (11/24) on mora segmentation. Moreover, KT demonstrated a significant lexicality effect in a mora concatenation task in which the subject was asked to concatenate three spoken morae, which were presented sequentially (but there was a pause between the first and the second mora), into an uttered chunk of speech (30/30, 100% correct for words vs. 17/30, 57% correct for nonwords). HN also showed a lexicality effect in phonological manipulation tasks. In a mora concatenation task, in which the subject was asked to blend 3- to 5-spoken morae - which were given at the rate of one per second - into an uttered chunk of speech, HN's accuracy was 100% correct for 80 words, but 63% correct for 40 nonwords. In a mora deletion task in which the subject was asked to delete the first mora from each of 3- to 5-mora spoken words/nonwords, HN's accuracy was 80% correct for words but 55% correct for nonwords. In the case of TY, the performance difference between word and nonword was only numerical in 3-mora concatenation (40/40, 100% for words > 38/40, 95% for nonwords), and in moral deletion from 3-mora words/nonwords (54/60, 90% > 50/60, 83%). Meanwhile, HM showed a similar accuracy in a deletion task for both words (26/30, 87%) and nonwords (25/30, 83%).

Thus, many classical phonological dyslexic patients showed deteriorated phonological manipulation with nonwords, and some of them also showed a lexicality effect in repetition and mora concatenation tasks, suggesting phonological impairment.

3) Classical deep dyslexia in Japanese

There are four published cases of classical deep dyslexia in Japanese, YH (Sasanuma, 1979, 1980a), TO (Hayashi, Ulatowaska, Sasanuma, 1985), SN (Sasanuma, 1980b, 1986), and a male case (Asano, Takizawa, Hadano, & Hamanaka, 1987; hereinafter this case is referred to as Case A).

The defining features of deep dyslexia in alphabetic orthography are i) inability of nonword reading; ii) a concreteness/imageability effect (superiority of concrete/high imageability words over abstract/low imageability words); iii) a part of speech effect (noun >adjective > verb > function words); and iv) semantic, visual and deviational errors. So, reading performance by the four patients with the Japanese version of deep dyslexia is reviewed in the light of these features. In addition, attention is paid to Kana word reading, because classical deep dyslexia in Japanese was reported as a Kana-specific reading disorder.

Nonword reading

YH and SN were tested with 20 two-character Hiragana nonwords (e.g. りふ, つそ). YH could not read Kana nonwords at all, and SN showed a poor performance (10% correct). Case A also showed difficulty in reading Kana nonwords (3/20, 15%), whereas he was able to read 58 out of 101 single Kana characters (57%). TO was not examined using nonword stimuli and single-character Kana.

The concreteness effect, and the discrepancy between Kanji and Kana word reading

YH and SN were tested using 20 concrete single-character Kanji words (e.g. 犬 *dog*, 森 *forest*) and 20 abstract single-character Kanji words (e.g. 公 *public*, 理 *rational*). YH demonstrated a considerable concreteness effect on single-character Kanji word reading. YH was able to read 12 out of 20 concrete nouns (60%), whereas she could not read any abstract nouns. SN showed superiority of concrete word reading over abstract word reading (85% > 65%). Case A also showed a marked concreteness effect on Kanji word reading (95% > 40%), though the properties of the stimulus Kanji words were not known. TO was not examined in reading abstract words. TO's accuracy of reading concrete nouns was 36.2% for single-character Kanji words and 24.3% for two-character Kanji words.

With regard to Kana word reading, Hayashi et al.'s (1985) study used only Kana words (N=29), of which TO could not read any Kana words. Since TO was suspected to be a right homonymous hemianopia it is plausible that TO's superiority of Kanji word reading over Kana words (about 24-36% for Kanji word reading > 0% for Kana word reading) reflects a word-length effect, because this study used 1- and 2-character Kanji words and 3-, 4-, 5-, and 6-character Kana words.

Other studies used Kana pseudohomophones transcribed from Kanji words as 'Kana words'. YH and SN showed a slightly better performance in relation to concrete ‘Kana words’ (i.e. Kana transcriptions of concrete Kanji words) compared to abstract ‘Kana words’ (i.e. Kana transcriptions of abstract Kanji words). SN could read 35% of concrete ‘Kana words’ (7/20), but he could only read 10% of abstract ‘Kana words’ (2/20). YH could not read abstract ‘Kana words’ but she read 10% of the concrete ‘Kana words’ (2/20). Asano et al. (1987) did not explain the property of Kana word stimuli, so it is unclear whether they used Kana words or Kana transcriptions of Kanji words, or both. Their patient demonstrated a marked concreteness effect. The accuracy of concrete Kana words and abstract Kana words in case A was 85% (17/20) and 20% (4/20), respectively.

<u>Part of speech effect</u>

As explained in section 3.1.4. -2, adjectives and verbs are written in a Kanji-Kana compound (e.g. 美しい *beautiful*, 書く *write*), in which a Kanji character represents the root or stem of the word and a Kana character (i.e. Hiragana) represents the inflectional ending, and function words are written in Hiragana (e.g. だから *so*). Because of the nature of the Japanese writing system, reading accuracy of nouns, adjective, verbs and function words in Japanese neurological patients inherently involves the differential effect of Kanji and Kana reading. That is, the results of a ‘part of speech’ effect in Japanese cannot be compared in a straightforward way to deep dyslexia in English.

In this context, the evaluation procedure of previous studies should first be explained. Sasanuma (1979, 1980a and 1986) simply compared reading accuracy of these grammatical categories, using 20 nouns (20 Kanji words), 20 adjectives, 20 verbs and 40 function words[22]. She also examined Kana transcriptions of adjectives and verbs. Hayashi et al. (1985) compared concrete nouns (both 103 Kanji words and 29 Kana words), 20 adjectives and 20 verbs, but they did not examine function word reading. Asano et al. (1987) followed the same procedure as Sasanuma and each grammatical category consisted of 20 words.

The following are the patients' results in oral reading of nouns, adjectives, verbs and function words. SN showed a part of speech effect (concrete nouns of Kanji words: 85% > adjectives: 50% > verbs: 35% > function words: 7.5%). YH's accuracy of oral reading of concrete nouns (single-character Kanji words) was worse than that of verbs (25% < 60%), and YH was not able to read any adjectives or function words. TO also showed the same pattern as YH. TO's accuracy of reading of concrete nouns of single-character Kanji words (36.2%) was better than that of verbs (25%), and TO could not read any adjectives. Case A showed superiority of oral reading of concrete nouns (the accuracy of both Kanji words and Kana words was 95% and 85%, respectively) over oral reading of adjectives (65% correct), verbs (65% correct), and function words (60% correct).

Error types in oral reading

Generally, different types of errors were observed in oral reading of Kanji words and of 'Kana words' (i.e. Kana transcriptions), but the proportion of error types

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22 Sasanuma (1979, 1980a) used the different numbers of test stimuli, which consisted of 40 concrete nouns of Kanji words, 21 adjectives, 19 verbs and 39 function words. Twenty words for nouns, adjectives, and verbs, and 40 function words were used in Sasanuma (1986).

varied between the four cases. YH produced a high proportion of semantic errors for concrete, single-character Kanji words (14/25, 56%; c.f. semantic error for abstract, single -character Kanji words was only one out of 40 errors) and of no responses (11/25, 44%). For example, YH read 弓 *bow* /yu-mi/ as 矢 /ya/ *arrow* and 山 /ya-ma/ *mountain* as 森 /mo-ri/ *forest*. Semantically related noun compounds, which are usually two-character Kanji words (e.g. 体 /ka-ra-da/ *body* →体操 /tai-sou/ *gymnastics*; 歯 /ha/ *teeth* →歯科/ʃi-ka/ *dentist*), were also produced. This type of error was called a 'compound formation' by Sasanuma (1980a), and it was considered that a 'compound formation' reflects the nature of Japanese orthography, though she did not explain what kind of nature this is. Semantic errors (17/24, 71%) and phonological errors (6/24, 25%) were SN's dominant error types in Kanji word reading. TO made a high proportion of semantic errors in single-character Kanji word reading (14/30, 47%) and in two-character Kanji word reading (18/48, 38%), and also produced no responses (11/30 and 16/48, respectively). Unlike YH and SN, TO made visual errors in single-character Kanji words (2/30, 7%) and in two-character Kanji words (1/47, 2%). With Case A, semantic errors were prominent (44/63, 70%) and a few visual errors were also observed (4/63, 4%). No responses were quite limited in Case A (4/63, 4%). Thus, all cases made a considerable number of semantic errors in Kanji word reading and some of them also made a small proportion of visual errors.

With regard to error types in Kana word reading, there is no reliable data. TO, who was tested using Kana words, could not read any Kana words. So, the following results were reading errors for Kana transcriptions. The majority of error types were no responses in YH (47/49, 96%) and neologistic errors in SN (35/46, 76%). Case A made partial responses (e.g. きめる→きめ; 24/72, 33%), visual/semantic errors (e.g. つらい *tough*→ くらい *dark*; 19/72, 26.5%), visual errors (11/71, 15%), and neologisms (10/71, 14%).

Taken over all, the characteristics of classical deep dyslexia in Japanese are summarised as follows:

i) great difficulty in Kana nonword reading;

ii) difficulty in oral reading of Kana transcriptions (i.e. pseudohomophone);

iii) a concreteness effect on Kanji word reading;

iv) an advantage of oral reading of concrete nouns (Kanji words) over adjectives (Kanji and Kana compounds), verbs (Kanji and Kana compounds), and function words (Kana words);

v) a marked occurrence of semantic errors in Kanji word reading;

vi) a diversity of oral reading errors and almost no semantic errors for Kana transcriptions.

Thus, these characteristics were approximately consonant with deep dyslexia in alphabetical orthography. Sasanuma (1980a) pointed out that Kanji/Kana discrepancy and script-dependent reading errors reflect the nature of Japanese orthography. She considered that profound impairment of Kana reading, coupled with relatively preserved Kanji reading might be a defining feature of the Japanese version of deep dyslexia. Coltheart (1980a) followed this notion and treated it as the hallmark of Japanese deep dyslexia in his review paper.

Semantic function of classical deep dyslexia cases

It is worth mentioning the results of a comprehension task (word-picture matching) and a lexical decision task in the classical deep dyslexic cases. YH and

SN were tested using the modified PPVT (N=50). They showed relatively preserved auditory comprehension (YH: 86%; SN: 92%) and Kanji written word comprehension (YH: 72%; SN: 92%). TO's written word comprehension was tested using 20 high-frequency concrete nouns and she made no errors in both Kanji word-picture matching and Kana word-picture matching. Meanwhile, their performances in lexical decision tasks were slightly different. YH's accuracy of judgment was 70 % for both two-character Kanji words and nonwords, but her accuracy of judgment of three-character Kana strings was 25% for words and 0% for nonwords. TO was tested using 10 two-character Kanji words, 10 two-character Kanji nonwords but homophones with the Kanji word stimuli (e.g. 調子/cho-ʃi/ *tempo*, 兆子/cho-ʃi/ no meaning), 10 Kana words and 10 Kana nonwords which consisted of between 3 and 6 Kana characters. TO's accuracy of judgment in these conditions was 70%, 40%, 80% and 10%, respectively. For TO, lexical judgment of nonwords was worse than that of words.

Thus, the patients with classical deep dyslexia showed relatively preserved word comprehension, but accuracy in lexical judgment varied.

4) Methodological problems in the classical case studies, and 'script-dependent' dyslexic patterns in Japanese

In the cognitive neuropsychological studies for the classical cases of Japanese acquired dyslexia, psycholinguistic variables of oral reading stimuli were not correctly manipulated for Kanji and Kana strings. Instead, the difference of print-sound consistency for Kanji and Kana was treated as a property of the consistency of words. Kana nonwords were considered to be similar to English nonwords. Thus, they used the formula that "Kana words = English regular words, and Kanji words = English exception words, and Kana nonwords = English nonwords" for categorising acquired dyslexia types in Japanese. Interestingly, this methodological problem in Japanese acquired dyslexia research has never been pointed out in published paper. There were only few criticisms. For instance, the double dissociation between Kanji and Kana was criticised by statistical unreliability because of the quite limited number of oral reading stimuli (Sugishita, Otomo, Kabe, & Yunoki, 1992), and by an insufficient description of the property of reading stimuli (Hadano, Hayashi, Takizawa, Hamanaka, & Hirakawa, 1985).

This section points out how the oral reading stimuli used for the classical case studies were inappropriate and insufficient in terms of manipulation of psycholinguistic variables, which turn led to the failure to detect 'real' acquired dyslexic patterns in Japanese.

There are seven methodological problems relating to the oral reading stimuli in the classical case studies for Japanese acquired dyslexia:

i) Consistency of Kanji words was not manipulated;

ii) Kanji nonwords were not created and used;

iii) Instead of Kana words, Kana pseudohomophones transcribed from Kanji words were mainly used as 'Kana words';

iv) Word-length was not controlled and manipulated;

v) In the vast majority of studies imageability was not manipulated;

vi) In many studies word frequency was not controlled and manipulated;

vii) In the majority of studies word familiarity was not controlled and manipulated.

Problem i) is partially attributed to the difficulty of evaluating the consistency of Kanji words, which has already been explained in 3.1.4.-1. Without manipulating the consistency of written words, the radical contrast of character-sound correspondences between Kanji and Kana was substituted for the variable of consistency (Sasanuma, 1980a; 1984; 1985; 1986) in which Kana words were treated like 'regular words' in English, and Kanji words like 'irregular or exception words' in the English writing system.

Problem ii) is associated with the intuitive notion that 'logographic' Kanji is processed by semantic procedure. This blocked the creation of nonwords using Kanji characters. Indeed, Coltheart et al. (2001) argued that “monosyllabic nonwords cannot even be written in the Chinese script or in Japanese kanji, so the distinction between a lexical and nonlexical route for reading aloud cannot even arisen.” (p. 236). As Fushimi et al. (2003a) mentioned, Coltheart et al.'s point could be applied to the Chinese language, in which one character consists of a word that always has one syllable and word meaning. However, their description is totally wrong for Japanese Kanji, because many Kanji characters appear as a constituent character of multiple-character Kanji words and only a limited number of Kanji characters appear as single-character Kanji words, and these are not always monosyllabic. So, it is possible to create multi-character Kanji nonwords that have no meaning, but are pronounceable on the basis of knowledge of the phonology of each constituent Kanji character. Wydell et al. (1995) and Fushimi et al. (1999) created two-character Kanji nonwords and found that normal subjects can read Kanji nonwords with a high level of accuracy (90% and 88%, respectively).

Problem iii), which had already been pointed out by Coltheart, Patterson, and Marshall (1987), is related to an insufficient perception about lexicality (or wordness). Kana transcriptions of Kanji words are pseudohomophones from the psycholinguistic point of view. For a layperson's perception Kana transcriptions are recognised as words, not as a type of nonword. This is because Kana transcriptions are acceptable in Japanese daily usage if a person cannot retrieve or does not know the Kanji character. This is one of the reasons that Kana transcriptions were treated as ‘Kana words’ in the previous research. Furthermore, within the experimental framework of traditional investigations of reading disorders, which forced forward the comparisons between Kanji and Kana, written stimuli consisted of both Kanji words and Hiragana transcriptions that share the same semantic representation.

Problem iv) appears to be associated with the nature of written Japanese, in which the vast majority of Kanji words consist of two-character words and Kana words consist mainly of three-, four-, five-character words (i.e. two-character Kana words are rare).

Problems v), vi) and vii) are mainly attributable to little or no availability of a database for imageability, word frequency and word familiarity at the time when these classical case studies were conducted.

Methodological problems vi) and vii) lead to less reliability of the dyslexic patterns in classical cases of any type, because word frequency and word familiarity affect word reading and modulate the effects of the psycholinguistic variables. The relationships between 5 methodological problems (i-v) and classical acquired dyslexia in Japanese are as follows:

a) Classical surface dyslexia was considered to be a Kanji word-specific reading disorder, because consistency of Kanji words was not manipulated and Kanji nonwords were not used as reading stimuli;

b) Classical phonological dyslexia was considered to be a Kana nonword-specific reading disorder, because Kanji nonwords were not used as reading stimuli;

c) Classical deep dyslexia (i.e. marked reading impairment of Kana strings coupled with relatively preserved Kanji word reading) is unreliable, because Hiragana transcriptions of Kanji words were used as reading stimuli of 'Kana words' excluding the case study for TO (Hayashi et al., 1985). A classical deep dyslexia pattern might reflect a lexicality effect (Kanji words > Kana pseudohomophones);

d) Profound impairment of Kana word reading compared to Kanji word reading might reflect a word-length effect, as pointed out in the case of TO who was a suspected right homonymous hemianopia;

e) Since imageability was not manipulated, an imageability effect has not been demonstrated in Japanese deep dyslexia.

Thus, the Japanese acquired dyslexia patterns described by the classical case studies are not totally reliable because of the methodological problems explained above. 'Script-dependent' dyslexic patterns might create a false picture for Japanese acquired dyslexia.

3.3.2. Recent cases and 'script-independent' dyslexia patterns

From the middle of the 1990s the cognitive neuropsychological studies, which used well-manipulated and well-controlled reading stimuli, were conducted and they suggest that the Japanese acquired dyslexic pattern is not 'script-dependent'. The patients with a degenerative disease (semantic dementia) demonstrated a consistency effect on Kanji word reading. It was reported that the patients showed a lexicality effect on both Kana and Kanji character strings. The research on Japanese dyslexic patients, using the framework of the triangle model (Patterson et al., 1995; 1996b), influenced the interpretation of the dyslexic pattern of recent cases. This section reviews recent case studies of Japanese acquired dyslexia. Table 4 shows the basic information (Age, Sex, Education, Etiology, Lesion in CT-scan, and Type of aphasia) about the patients in the recent case studies.

Table 4 The basic information about recent cases of Japanese acquired dyslexia

	Age (years)	Sex	Education (years)	Etiology	Lesion in CT-scan or MRI	Aphasia type
NK	71	F	14	Atrophy	L.temporal	Progressive aphasia
YK	60	M	12	Atrophy	L.temporal > R.temporal	Semantic dementia
KI	61	M	16	Atrophy	R.front-temporal > L.front-temporal	Semantic dementia
TI	57	M	16	Atrophy	L.temporal > R.temporal	Semantic dementia
MN	64	F	12	Atrophy	L. & R. temporal	Semantic dementia
KT	57	M	16	CVA	L.MCA territory	Anomic aphasia
Case K	64	F	9	CVA	L.temporal, insula	Non-fluent aphasia

Recent cases of Surface dyslexia
NK : Patterson et al. (1995)
YK : Nakamura et al. (2000)
KI : Nakamura et al. (2000)
TI : Fushimi et al. (2003a)
MN : Fushimi et al. (2003b)

Recent cases of Phonological dyslexia
KT : Fushimi et al. (2000)
Case K : Kato et al. (2004)

1) Surface dyslexia

Classical surface dyslexia in Japanese (i.e. the Japanese version of surface dyslexia: Sasanuma, 1979, 1980a, 1980b, 1984, 1985 and 1986) showed selective impairment of Kanji word reading with preserved transparent Kana word reading, and a limited number of LARC errors in oral reading of Kanji-Kana compound verbs and adjectives. Although some Japanese neurological patients frequently produced LARC errors[23], print-sound consistency was not examined in Kanji word reading.

Patterson et al. (1995) used the Kanji words that were manipulated by 'categorical consistency' (see 3.1.4. -1) and examined oral reading performance in a Japanese neurological patient with progressive aphasia. Their case, NK, demonstrated a consistency effect, a frequency[24] effect, and the interaction between frequency and consistency. NK was 75% correct (60/80) on high frequency words but 48% correct (38/80) on low frequency words. While NK's oral reading of consistent words and inconsistent-ON words was preserved (85% and 88%, respectively), her oral reading accuracy of inconsistent-KUN words and Jukuji-KUN words was severely impaired (40% and 33%, respectively). In low frequency words, a marked consistency effect was observed. NK was only 20% correct on low frequency, inconsistent-KUN words and 10% correct on low frequency Jukuji-KUN words[25]. NK made a substantial proportion of LARC errors (48/62, 77%), but NK produced a limited number of

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[23] LARC errors observed in Japanese neurological patients had been reported using the tern 'ON/KUN confusion' (Imura, 1943) and it has been anecdotally reported that this type of error occurred frequently in Gogi (word meaning) aphasia (see 3.1.1). A Japanese patient with Wernicke aphasia, MY, (Kashiwagi & Kashiwagi, 1987) produced many LARC errors. For instance, MY made visual errors (133/330, 40%) and LARC errors (89/330, 27%) for Kanji words in oral reading of newspaper articles (i.e. text-reading data). MY's proportion of ON/KUN confusion was 65% and MR also produced the pronunciation appropriate to other words containing the constituent Kanji characters of the target word (31%). So, Kashiwagi and Kashiwagi (1987) pointed out that the term 'mis-selection of Reading for Kanji character' is suitable for description of MY's errors of Kanji word reading instead of 'ON/KUN confusion'.

[24] This word frequency was not based on objective values; it was based on subjective ratings on a seven-point scale (Wydell, 1991).

[25] The 10 control subjects also misread 22 % of the low-frequency Jukuji-KUN words.

visual errors (2/62, 3%) and phonological errors (7/62, 11%). With regard to oral reading of Kana strings, NK was 100% correct on Kana words, Kana pseudohomophones (Kana transcriptions of Kanji words), and Kana nonwords. Hence, NK demonstrated a print-sound consistency effect on Kanji word reading, and prominent LARC errors. This dyslexic pattern is consonant with surface dyslexia in English.

Nakamura, Nakanishi, Hamanaka, Nakaaki, &Yoshida (2000) also reported that two patients with semantic dementia, YK and KI, showed a print-sound consistency effect on Kanji word reading, and made LARC errors. They were tested using 103 Kanji words, 103 Kana pseudohomophones transcribed from the 103 Kanji words, and 30 Kana nonwords ranging from 3 to 5 characters. They defined typicality of Kanji characters' reading by calculating how often the target pronunciation of the Kanji character occurred among orthographic neighbours (*pronunciation frequency* in their terminology)[26]. KI was 100% correct on 23 typical words, but only 17.5% correct on 80 atypical words. YK showed a similar pattern and his accuracy was 87% for typical words and 8.8 % for atypical words. Their reading performance of Kanji words was also modulated by familiarity. Both KI and YK were able to read 71.4% on high familiarity atypical words (N=7). LARC errors were predominant in KI (63.6%), but less prominent in YK (21.1%). YK frequently made no responses (62%), and this type of error also occurred in KI (25.8%). With regard to oral reading of Kana pseudohomophones and Kana nonhomophonic nonwords, KI's

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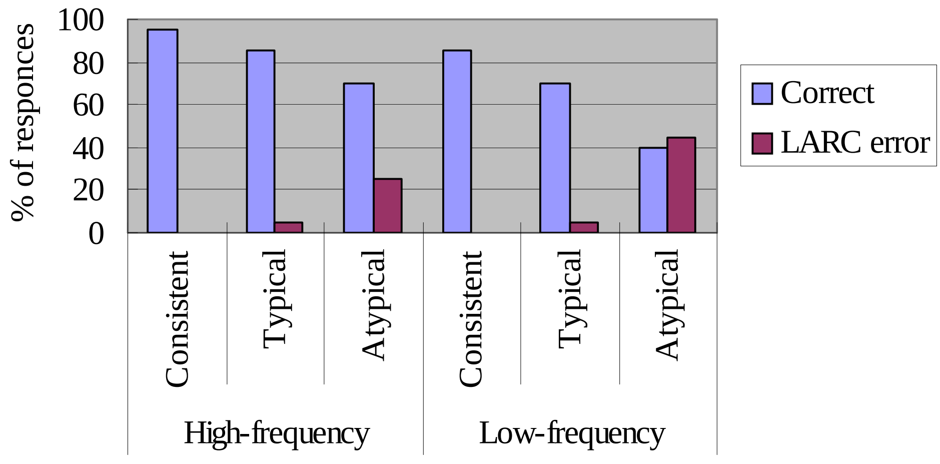
[26] For instance, 定 has two pronunciations - /tei/ and /jyo/. Among orthographic neighbours, 定 is pronounced as /tei/ in 56 two-character Kanji words, and as /jyo/ in 6 two-character Kanji words. The pronunciation frequency was 90% (56/62) for /tei/ and 10% (6/62) for /jyo/. In the researchers' definition, typical words are the two-character Kanji words in which the pronunciation frequency of both constituent characters is over 50%, and atypical words are the two-character Kanji words in which the pronunciation frequency of either constituent character is under 20%.

accuracy was between 83% and 100% and YK’s accuracy was between 91% and 100%. Although the number of word stimuli with a different consistency was not matched in this study, these 2 cases showed a character-sound typicality effect on two-character Kanji words and on the occurrence of LARC errors, together with preserved oral reading of Kana strings. So, KI's and YK's oral reading performance can be categorised as surface dyslexia.

Fushimi et al. (2003a) examined a patient with semantic dementia, TI, using 120 two-character Kanji words manipulated by 'statistical consistency' (see 3.1.4. -1) and word frequency, which were the stimuli for normal Japanese readers (Fushimi et al., 1999). The values of the consistency ratio for consistent, inconsistent-typical and inconsistent-atypical words were 1.00, 0.85, and 0.56, respectively, in the high-frequency band, and1.00, 0.86 and 0.44, respectively, in the low-frequency band. Fig. 14 shows TI’s oral reading performance.

Fig. 14. TI's reading performance in two-character Kanji words (Fushimi et al., 2003a).



TI’s overall accuracy was 74% and TI's accuracy for consistent, inconsistent-typical and inconsistent-atypical words was 95%, 85% and 70%, respectively, in the high-frequency band, and 85%, 70% and 40%, respectively, in the low frequency band[27]. That is, TI demonstrated a graded consistency effect in which his accuracy was best for consistent words, intermediate for inconsistent-typical words, and worst for inconsistent-atypical words. This gradient was more marked for low- rather than high-frequency words.

The occurrence of LARC errors was also modulated by consistency and frequency. TI frequently made LARC errors in inconsistent-atypical words for the low-frequency (45%) and the high-frequency bands (25%). However, a limited number of LARC errors occurred in inconsistent-typical words for both the high and low frequency bands (5%).

TI’s oral reading performance was also examined using two-character Kanji nonwords created by Fushimi et al. (1999). They created Kanji nonwords by re-combining the first constituent character of a two-character Kanji word and the second constituent character of another two-character Kanji word (e.g. 満員 /maN-iN/ *full*, 輸送 /yu-sou/ *transport* → 満送 /maN-sou/), which is explained in detail in the next section about phonological dyslexia. The researchers made three types of nonword, based on the ratio of typical/neighbours, and manipulated character frequency. TI’s accuracy of nonword reading was 74% overall: 90% for the high-character-frequency band and 50% for the low-character-frequency band. Since 20 Japanese adult readers had read aloud two-character Kanji nonwords with 89% accuracy, TI’s accuracy of Kanji nonword reading for the high-character

[27] In the low-frequency band, the error rate of twenty Japanese normal readers was 11.8%, 5.8% and 5.3% for inconsistent-atypical, inconsistent-typical, and consistent words, respectively. In the high-frequency band, the error rate of twenty control subjects was under 5% in all types of consistency words (Fushimi et al., 1999).

frequency band was within the normal range. TI’s main error responses were visual errors and incomplete responses. With regard to oral reading of Kana strings, TI was able to read 20 Kana pseudohomophones - which were Hiragana transcriptions of Kanji words and 20 Kana nonhomophonic nonwrods, which were Hiragana transcriptions of typical pronunciations for two-character Kanji nonwords - with 100% accuracy.

Thus, TI demonstrated i) a graded Kanji character-sound consistency effect; ii) LARC errors modulated by consistency and frequency; iii) preserved Kanji nonword reading for the high-character-frequency band; and iv) intact oral reading of Kana strings. These results suggest that TI’s dyslexic pattern is consonant with surface dyslexia in English.

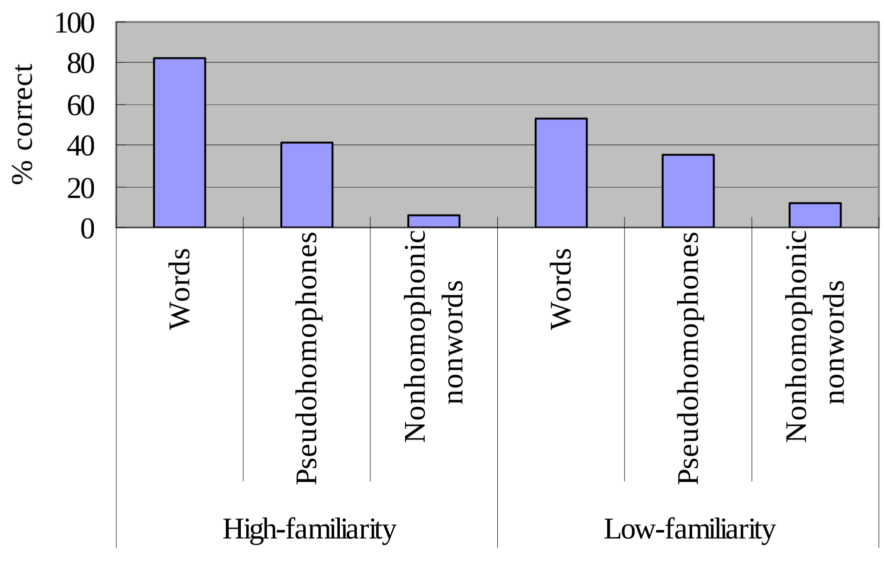
Fushimi, Komori, Ikeda, Ijuin, and Tanabe (2003b) also reported another patient, MN, with semantic dementia, who showed a similar reading pattern to TI. MN demonstrated a graded consistency effect on oral reading of the same 120 two-character Kanji words. MN's accuracy for consistent, inconsistent-typical and inconsistent-atypical words was 100%, 90% and 80% respectively, in the high frequency band , and 80%, 75% and 45% respectively in the low frequency band. MN's dominant error type was LARC. ME could read a high proportion (81%) of Kanji nonwords.

To summarise, Kanji character-sound consistency in reading aloud of two-character Kanji words was detected in the five Japanese patients, NK, KI, YK, TI and MN and this characteristic and the occurrence of LARC errors together are comparable to a surface dyslexia pattern in a quasi-regular orthography like English.

2) Phonological dyslexia

Fushimi, Ijuin and Tatsumi (2000a) and Fushimi, Ijuin, Tatsumi, Tanaka, Kondo, & Amano (2000b) first provided the oral reading data for Kanji nonwords in a relation to a Japanese neurological patient, KT (Patterson et al., 1996b), in their additional investigation. They made a list of consistent two-character Kanji words, in which the constituent Kanji character has only one pronunciation (e.g. 応援 /ou-eN/ *aid*, 婚約 /koN-yaku/ *engagement*), and varying word familiarity (high and low). Then, Kanji pseudohomophones were created by replacing a constituent Kanji character with different Kanji characters which had the same pronunciation with the original character (e.g. 応援 /ou-eN/ *aid*→応演 /ou-eN/, 婚約 /koN-yaku/ *engagement* →婚躍/koN-yaku/). Nonhomophonic Kanji nonwords were created by exchanging each constituent character of 2 different Kanji pseudohomophones (e.g. 応演 /ou-eN/, 婚躍 /koN-yaku/ →応躍 /ou-yaku/, 婚演 /koN-eN/).

Fig. 15. KT's readomg performance in two-character Kanji nonwords (Fushimi et al., 2000a).



As shown in Fig.15 (drawn based on Fig. 6 in Fushimi et al., 2000a, with their permission), KT demonstrated both a lexicality effect and a pseudohomophone effect for Kanji written strings. So, KT showed a lexicality effect on both Kana (Patterson et al., 1996b) and Kanji strings (Fushimi et al., 2000a, 2000b). That is, KT demonstrated a 'script-independent' phonological dyslexia pattern.

Kato, Shinkai, Fushimi, & Tatsumi (2004) reported a patient who showed a 'script-nonspecific' lexicality effect (referred to as Case K from here onwards). Case K was able to read single Kana characters (103/107, 96%), Kana words (90%) and two-character Kanji words (98%). In contrast, her reading accuracy of both Kana and Kanji nonhomophonic nonwords was deteriorated (57% and 45%, respectively). Lexicalisation errors were observed in both Kana and Kanji nonword reading (27% and 52%, respectively). Thus, this patient demonstrated a lexicality effect on both Kana and Kanji strings. Case K also showed an advantage of Kana pseudohomophones over Kana nonhomophonic nonwords (88% > 57%), but the oral reading data for Kanji pseudohomophone was not available.

With regard to phonological ability, which was impaired in classical phonological dyslexia in Japanese, Case K showed 100% accuracy on 3- to 8-mora word repetition and a less accurate performance in 3- to 8-mora nonword repetition (81%). Case K was fairly good at the mora recognition task (44/48, 92%) and on mora segmentation (23/24, 96%). However, Case K was performed poorly in a mora deletion task for both words (33% correct) and nonwords (20% correct). So, this case showed a deficit of phonological manipulation.

In short, these two patients' dyslexic pattern suggests that phonological dyslexia in Japanese is not a Kana nonword-specific reading disorder.

3) The weak points of recent case studies, and unresolved issues

The weakest point of recent case studies relates to a small number of cases. There were 5 cases with surface dyslexia and only 2 cases with phonological dyslexia. Therefore, the following unresolved issues remain.

With regard to surface dyslexia, a) it is not clear whether other neurological patients, who are not diagnosed as semantic dementia, show a consistency effect on Kanji word reading; b) the semantic impairment of the patient with surface dyslexia has not explored in detail; and c) it is not known whether there are patients with semantic impairment who demonstrated preserved oral reading of Kanji words or no consistency effect on Kanji word reading.

With regard to phonological dyslexia, a) it is unclear whether other patients showed a script-nonspecific lexicality effect; b) it is not known whether there are patients without phonological impairment who showed phonological dyslexia pattern; and c) it is not known whether there are patients with phonological impairment who showed a lexicality effect on Kanji strings only.

With regard to deep dyslexia, there are no case studies which used psycholinguistically well-manipulated and well-controlled reading stimuli. This is the greatest problem. Thus, it is unclear whether a classical deep dyslexia pattern represents a real picture of Japanese deep dyslexia.

In short, although recent case studies showed 'script-nonspecific' dyslexic patterns in Japanese, too many unanswered questions remain and block clarification of acquired dyslexia in Japanese.

3.4. Reading models for Japanese and their interpretations of acquired dyslexia

In 1971 Sasanuma and Fujimura proposed the Japanese reading model which assumed the Kanji/Kana discriminator and script-dependent reading procedures. In the 1980s the dual-route model developed in the English language influenced the way to explain Japanese acquired dyslexia patterns, and several reading models for Japanese were proposed with some variations (e.g. Sasanuma, 1986, 1987). In 1990 Patterson mentioned that the triangle model could apply to the Japanese language, and interpretations of Japanese acquired dyslexia patterns using the triangle model have been presented in some studies since the middle of the 1990s. Fushimi et al. (2000a) explicitly proposed the Japanese version of the triangle model. This section presents the proposed reading models for Japanese and its interpretations of Japanese acquired dyslexia patterns.

3.4.1. The classical reading model for Japanese and its interpretation of Japanese acquired dyslexia

1) The classical reading model for Japanese

The first attempt at modeling reading processes in Japanese was made by Sasanuma and Fujimura (1971). Hayashi et al. (1985) followed their idea and depicted it as the box and arrow model shown in Fig. 16. This model has a subsystem which discriminates Kanji and Kana characters – it is called the *Kanji/Kana discriminator*. The function of this subsystem is transcoding Kana stimuli into a phonological code or an orthographic code, which is depicted by blue and wine-red arrow respectively, and transcoding Kanji stimuli into an orthographic code. Kana strings are read aloud using the two procedures: i) a phonological code activates an input phonological lexicon, and this information is translated into an output phonological lexicon directly, or via a semantic lexicon; ii) an orthographic code for Kana activates an orthographic lexicon and this information is translated into an input phonological lexicon and then a phonological output lexicon. Meanwhile, an orthographic code for Kanji activates an orthographic lexicon, and this information is translated into an output phonological lexicon via a semantic lexicon. This model assumed that Kana strings are processed by both phonological and semantic procedure and Kanji strings are processed by only semantic procedure.

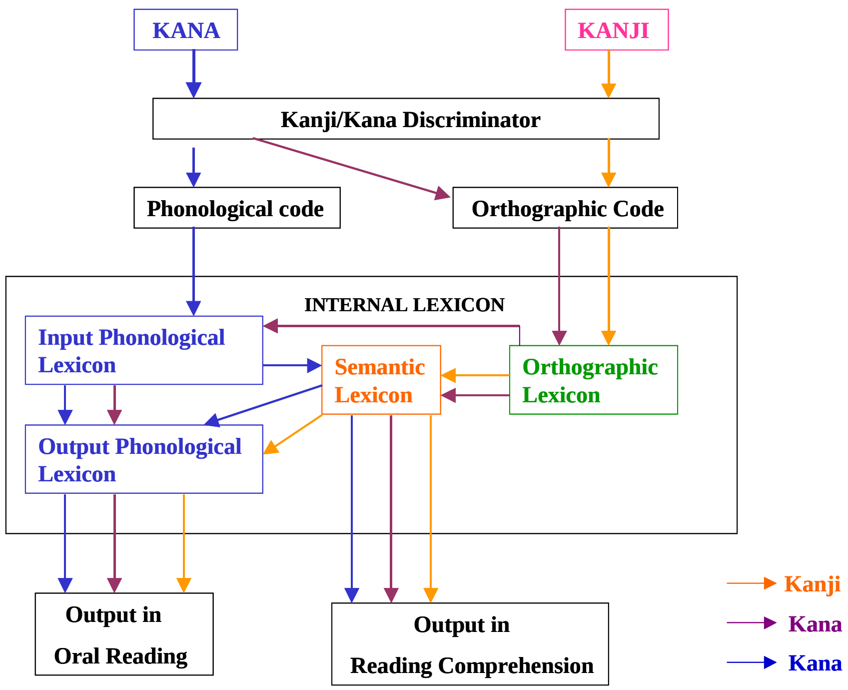


Fig. 16. The classical reading model for Japanese (Sasanuma & Fujimura, 1971).

2) Interpretations of Japanese acquired dyslexia patterns using the classical reading model for Japanese

This model can interpret classical surface dyslexia as impairment of the semantic procedure, classical phonological dyslexia as impairment of the phonological procedure, and classical deep dyslexia as severe impairment of the phonological procedure and mild impairment of the semantic procedure. However, because this model only assumes a semantic procedure for Kanji word processing the following cannot be explained: i) a consistency effect on Kanji word reading, which was observed in recent surface dyslexia cases; and ii) a lexicality effect on Kanji nonword reading in phonological dyslexia in recent studies. Thus, the classical model is not good enough to explain acquired dyslexia patterns in Japanese.

3.4.2. The semi-dual route model for Japanese reading and its interpretation of Japanese acquired dyslexia

1) The semi-dual route model for Japanese reading

Sasanuma (1986, 1987) proposed the Japanese reading model using the framework of the dual-route model. As shown in Fig.17, there are 3 procedures for reading (the lexical semantic route, the lexical non-semantic route and the non-lexical route), but she hypothesised different processing for Kanji and Kana. The lexical routes process Kanji words and high-frequency Kana words, whereas the non-lexical route processes low frequency Kana words and Kana nonwords. That is, Sasanuma did not assume the non-lexical route for Kanji. In this respect, this model can be called as the semi-dual route model for Japanese. Though Sasanuma did not give any reason why the non-lexical route did not involve Kanji processing, it appears that her model was influenced by the traditional view that ‘ideographic’ Kanji is only processed using semantic procedure. This model differs from the classical model in three respects: i) this model assumes that Kana nonwords are processed through the non-lexical route; ii) the lexical routes process high-frequency Kana words; and iii) there is no Kanji/Kana discriminator.

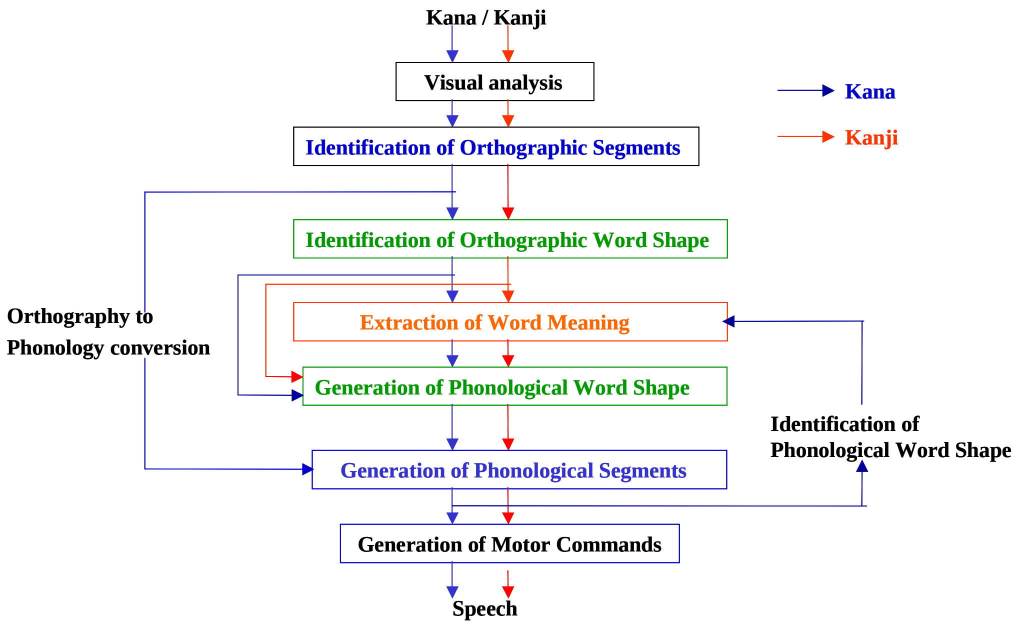


Fig. 17. The semi-dual route model for Japanese reading (Sasanuma, 1986).

2) Interpretations of Japanese dyslexic patterns using the semi-dual route model for Japanese reading

This model can explain classical surface dyslexia as impairment of the lexical routes, but cannot explain a consistency effect on Kanji word reading demonstrated by recent cases of surface dyslexia. This is because this model assumes that Kanji words are processed only in the lexical route. Classical deep dyslexia can be interpreted as severe impairment of the non-lexical route and mild impairment of the lexical route. With regard to phonological dyslexia, classical cases can be explained as the damage of the non-lexical route. However, this model cannot explain recent cases of phonological dyslexia which showed preserved Kana word reading at low frequency band, because this model assumes that both low frequency Kana words and nonwords are processed in the non-lexical route. Hence, this model is not sufficiently appropriate for interpreting acquired dyslexia in Japanese.

3.4.3. Japanese versions of the dual-route model and their interpretations of Japanese acquired dyslexia

1) The non-interactive version of the dual-route model for Japanese

Howard, Franklin and Whitworth (2004) presented a lexical information-processing model, modified for Japanese script (Fig.2, p.5), for the Japanese version of PALPA (i.e. SALA: the Sophia Analysis of Language in Aphasia). Fig.18 is their model.

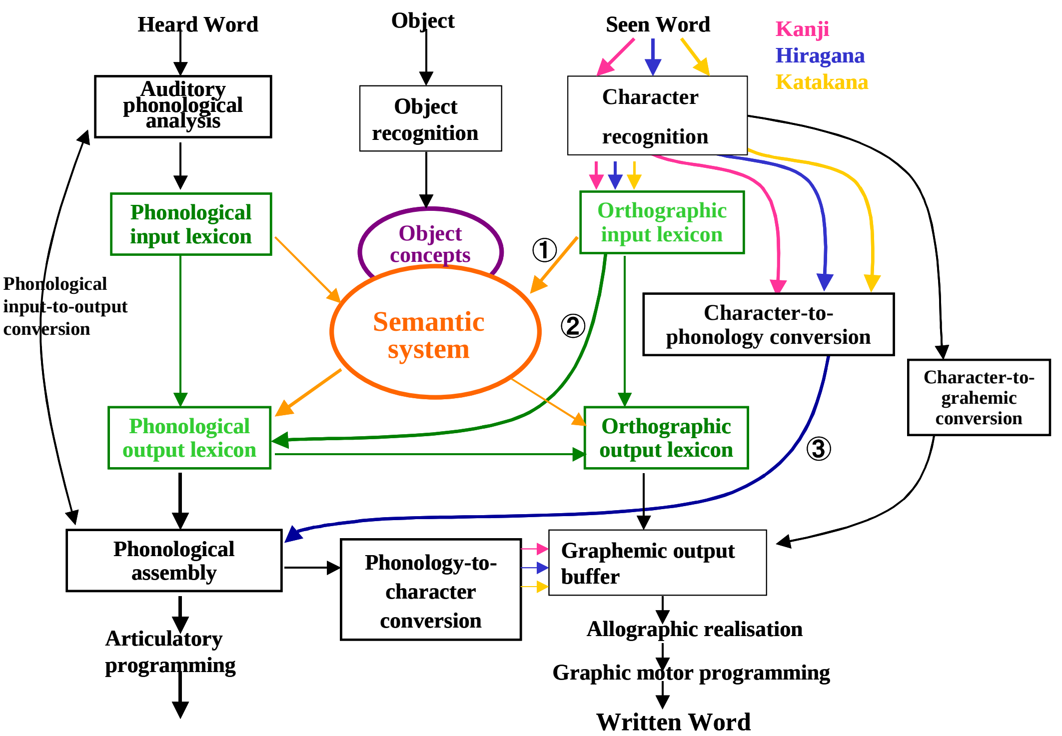


Fig. 18. An information processing model of lexical processing modified for Japanese scripts (Howard et al., 2004).

The hypothesised reading processing in their model has exactly the same reading routes as the dual-route model in English. That is, there are the lexical-semantic route (①), the lexical-nonsemantic route (②), and the non-lexical route (③), as shown in Fig. 18. They assumed that the non-lexical route could apply to 3 different types of script (Kanji, Hiragana and Katakana), though they did not explain in any detail about character-to-phonology conversion for the 3 scripts. This model is a serial-processing model as the dual-route model was originally assumed to be.

2) The interactive version of the dual-route model for Japanese

Paradis, Hagiwara, & Hildebrandt (1985) presented the Japanese reading model, adopting the information-processing model proposed by Marshall (1982)[28] as shown in Fig.19.

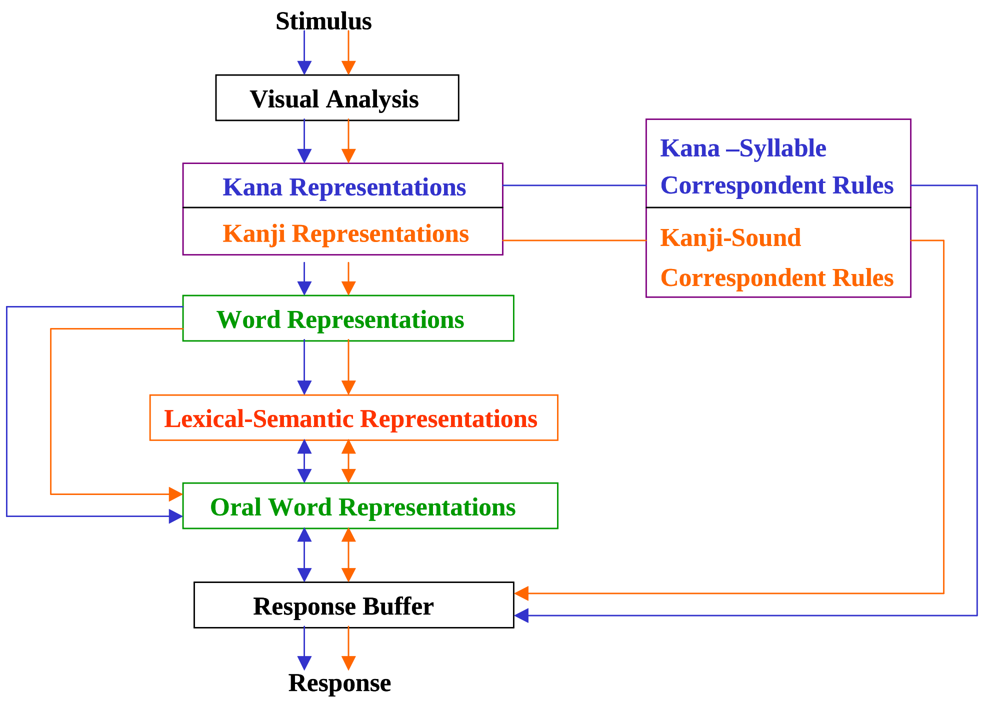


Fig. 19. The interactive version of the dual-route model for Japanese (Paradis, et al., 1985).

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[28] Marshall, J. C. (1982, March). Taxonomies of dyslexia. Lecture presented at Montreal Neurological Institute, McGill University.

This consists of the same components as the dual-route model but assumes the two feed backward routes: one is from the phonological output lexicon (‘oral word representations’ in this model) to the semantic system (‘lexical-semantic representations’ in this model); the other is from the response buffer to the phonological output lexicon. So, in this model there are interactions in the lexical-semantic routes (i.e. semantics ⇔ the phonological output lexicon, and the phonological output lexicon ⇔ the response buffer).

Paradis et al. assumed that the non-lexical route operated for both Kana and Kanji strings by Kana-syllable correspondence rules and Kanji-sound correspondence rules, respectively. However, they did not explain the ‘Kanji-sound correspondence rule’ at all. Since Kana is a transparent relationship between orthography and phonology their 'Kana-syllable correspondence rule’ is understandable from the one-to-one correspondence between a Kana character and a mora. In the case of Kanji, without an explanation it is unclear how Kanji strings are processed under the Kanji-sound correspondence rule.

3) Interpretations of Japanese acquired dyslexia using the Japanese versions of the dual-route model

Both the non-interactive and interactive versions of the dual-route model for Japanese can explain i) a consistency effect on two-character Kanji word reading, and ii) a lexicality effect on both Kanji and Kana strings, because it includes the non-lexical processing for Kanji that was not assumed by the classical model and the semi-dual route model for Japanese reading.

<u>Surface dyslexia</u>

Both models interpret the surface dyslexia pattern in classical and recent cases as a selective impairment of the lexical routes. In the non-lexical route the pronunciation for each constituent character of a Kanji string is activated with the consistency of Kanji character-sound correspondence. The non-lexical route can read Kanji words that have a typical relationship between a character and its pronunciation, but cannot always produce the correct pronunciation for Kanji words that have an atypical relationship between a character and its pronunciation. Processing of the lexical routes is necessary for correct pronunciation of atypical words. Thus, the damage to the lexical route leads to a marked impairment of atypical word reading, as was observed in surface dyslexia in the recent cases.

With regard to a graded consistency effect (consistent > inconsistent-typical > inconsistent-atypical) demonstrated in TI and MN, both models have difficulty explaining the less accurate performance in relation to inconsistent-typical words than consistent words. This is because the non-lexical route can read inconsistent-typical words, which have an inconsistent but highly typical correspondence between a Kanji character and its pronunciation. In order to explain the superiority of consistent words over inconsistent-typical words, as demonstrated by TI and MN, these two models need an additional assumption. If a Kanji character word (e.g. 会得/e-toku/) activates representations of orthographic neighbours (e.g. 会計/kai-kei/, 会社/kai-ʃa/, 会話/kai-wa/, 会釈/e-ʃaku/) at the orthographic input lexicon, there is a greater possibility of selecting the wrong pronunciation due to the malfunction of the lexical routes with a graded consistency of character-sound correspondence.

Phonological dyslexia

Both models can explain phonological dyslexia as an impairment of the non-lexical route, because this reading route is indispensable for processing Kana and Kanji nonwords. The non-interactive version of the dual-route model for Japanese reading, however, cannot interpret superiority of pseudohomophones over nonhomophonic nonwords, because this model does not assume the interaction between the lexical route and the non-lexical route. In contrast, the interactive version of the dual-route model for Japanese reading postulates an interaction between the response buffer and the phonological lexicon and between the phonological lexicon and the semantic representation, so communication occurs between the non-lexical route and the lexical routes at the response buffer. This can explain the advantage of pseudohomophones that have phonological representations over to nonhomophonic nonwords that have no lexical representations.

Classical deep dyslexia

As pointed out in the previous section, the reliability of classical deep dyslexia pattern itself is low and the phenomenon of severely impaired Kana word reading with preserved Kanji word reading might reflect i) a lexicality effect (Kana pseudohomophones < Kanji words), and ii) a word-length effect (long-length 'Kana words' < short-length Kanji words). However, as the current research progresses it cannot deny the possibility that the classical deep dyslexia pattern may become a typical reading pattern in Japanese deep dyslexia; so classical deep dyslexia is interpreted in terms of clarifying the two models' ability to explain Japanese acquired dyslexia.

Both models need an additional assumption in order to explain classical deep dyslexia. If one assumes that the processing efficacy of the lexical-semantic route is higher for Kanji words than for Kana words, superiority of Kanji word reading over

'Kana word' reading can be explained as severe damage to the non-lexical route and mild damage to the lexical-routes. The additional assumption that the lexical-semantic route is more efficient for Kanji words than Kana words can explain the notable occurrence of semantic errors in Kanji word reading. Meanwhile, the dominant occurrence of visual errors in Kana words and Kana pseudohomophones was explained by highly efficient processing of the non-lexical route for Kana due to a transparent Kana character-sound consistency.

However, the non-interactive versions of the dual-route model for Japanese cannot explain the co-occurrence of semantic and visual errors. As explained in Chapter 2, this is because the dual-route model assumes that the non-lexical route and the lexical routes are independent. The exaggerated reliance on the lexical route, due to severe or complete impairment of the non-lexical route, can explain the marked semantic errors but cannot explain why visual errors are also occurred. Using the interactive version of the dual-route model for Japanese, this phenomenon is interpretable as the damage to the phonological output lexicon and the response buffer that receives information from both the lexical route and the non-lexical route.

To summarise, the non-interactive version of the dual-route model for Japanese reading is less reliable for explaining reported dyslexic patterns in Japanese, because this model cannot offer the explanation of a graded consistency effect in surface dyslexia, a pseudohomophone effect in phonological dyslexia, and the co-occurrence of semantic and visual errors in classical deep dyslexia. In contrast, the interactive version of the dual-route model for Japanese reading has the potential to explain these three phenomena. The both models, however, needed an additional assumption about differential efficacy of processing for the lexical-semantic route depending on the script type in order to explain classical deep dyslexia.

4) A possible Japanese version of the DRC model

This thesis proposes a possible Japanese version of the DRC model, in which the following assumptions are made: i) Kanji/Kana words are processed by both the lexical and the non-lexical routes; ii) correct oral reading of Kanji/Kana nonwords are processed by the non-lexical route; and iii) both Kanji/Kana words and Kanji/Kana nonwords can activate orthographic neighbours in the lexical routes. Figure 20 depicts this model. This will be referred as the Japanese version of the DRC model, hereinafter.

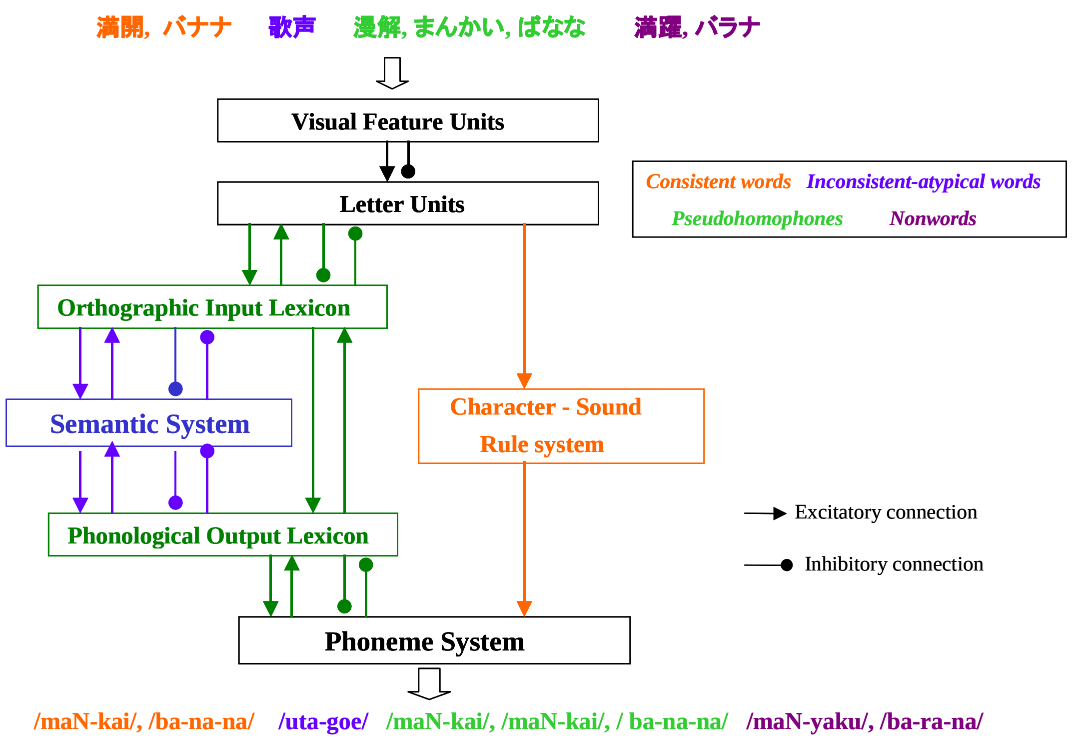

Fig. 20. A Japanese version of the DRC model.

It is legitimate that the Japanese version of the DRC model includes the interactive version of the dual-route model for Japanese reading. This is because the systems of the two models have the same components, and the latter model assumes the interaction between the phoneme system and the phonological output lexicon, and between the phonological output lexicon and the semantic system, as with the DRC model. The difference if that the DRC model includes additional interaction between the letter unit and the orthographic input lexicon, between the orthographic input lexicon and the semantic system, and between the orthographic input lexicon and the phonological output lexicon. Since the interactive version of the dual-route model for Japanese reading had the potential to explain the reported acquired dyslexic patterns in Japanese, it is reasonable to consider that the Japanese version of the DRC model has the potential to explain Japanese acquired dyslexia.

3.4.4. The Japanese version of the triangle model and its interpretations of Japanese acquired dyslexia

1) The Japanese version of the triangle model

Patterson (1990) first suggested that the triangle model could apply to Japanese reading processing. She wrote that ‘the present proposal is that the same parallel and independent transcoding procedures exist for these three[29] (indeed, probably for all) orthographies, and that differences in processing are to be found only in the detailed aspects and the relative speed of these basic computations’ (p.7).

Fushimi et al. (2000a) and Fushimi, Ijuin, Sakuma, Tanaka, Kondo, amino, Patterson, & Tatsumi (2000c) followed Patterson’s perspective, and proposed the Japanese version of the full triangle model, as shown in Fig. 21.

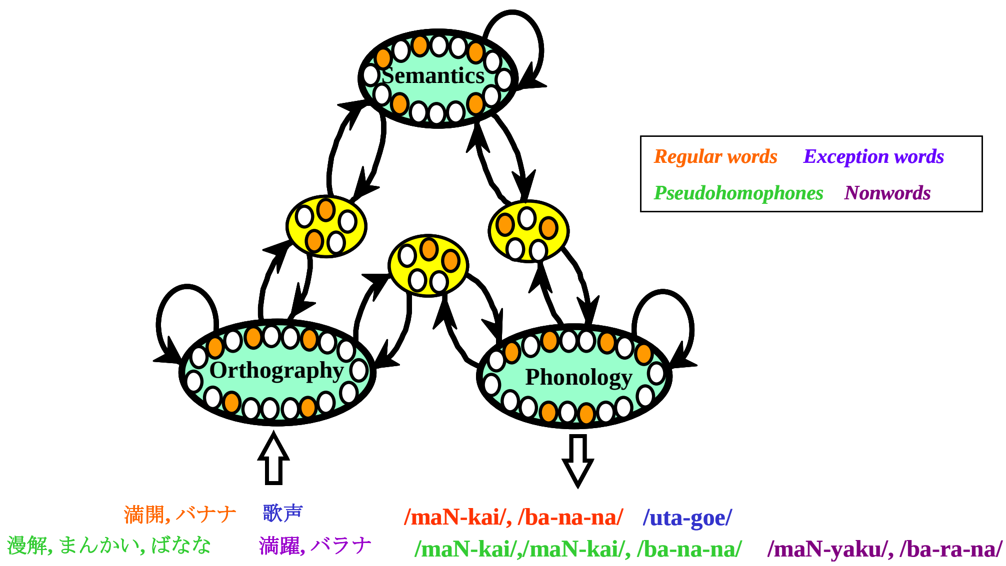

Fig. 21. The Japanese version of the triangle model (Fushimi et al., 2000)

They hypothesised that “any orthographic string, whether it comprises kanji or kana or both and whether it represents a word or nonword, is processed by the same

[29] This refers to English, Kanji and Kana orthographies.

mechanisms" (Fushimi et al. 2000c, p.27). In this hypothesis, both Kanji and Kana words are basically computed by direct translation from Orthography to Phonology (O→P computation) with supplementary support from Semantics when the O→P computation is inefficient. Correct pronunciation for Kanji/Kana nonword reading relies on only the O→P computation. Since this model makes the same basic assumptions as the triangle model (i) distributed representation, ii) attractor network, iii) weighted connections, iv) division of labour, v) a connectionist learning algorithm), this model can explain the differential efficacy of processing depending on the property of written strings without postulating different processing depending on the type of written strings. For instance, the Japanese version of the triangle model can explain the frequency-consistency interaction on Kanji word reading as below.

The amount of connection strength is strong for high frequency words that had a lot of learning opportunities, so the computation of high frequency words is more efficient compared to that of low frequency words. In Kanji words, orthographic neighbours which share the same constituent character at the same position support learning the translation from Orthography to Phonology, when the shared Kanji character has an identical pronunciation to the target word (i.e. *friends*). But, orthographic neighbours disturb learning the translation from Orthography to Phonology when the shared Kanji character has a different pronunciation (i.e. *enemies*). So, the amount of connection weight adjustment for a Kanji character word is determined by the consistency of character-sound correspondence. Consistent words, in which each constituent Kanji character has an identical pronunciation across the neighbours, have a strong connection strength, whereas inconsistent-atypical words, in which each constituent Kanji character has more than one legitimate pronunciation, and where one or both character pronunciations appropriate for the target Kanji character word are statistically atypical, have a weak connection strength. In the case of inconsistent-typical words, in which each constituent Kanji character has more than one legitimate pronunciation but the appropriate pronunciations of both characters are statistically typical, their connection strength is intermediate between consistent words and inconsistent-atypical words. That is, the rank order of connection strength is consistent words > inconsistent-typical words > inconsistent-atypical words and efficiency of the O→P computation is also in the same rank order. High frequency words are too efficient to be influenced by consistency. Thus, a graded consistency effect would be observed in low frequency words, in particular. Since the efficacy of the O→P computation for inconsistent-atypical words with a low frequency band is the lowest, these types of Kanji words need semantic support (O→S→P computation, or O→P⇔S computation) for correct pronunciation. This suggests that a semantic variable would affect oral reading of inconsistent-atypical words at a low frequency band.

There are supporting data for this explanation and prediction. As already mentioned, skilled adult readers demonstrated a frequency by consistency interaction in two-character Kanji word reading, and a significant consistency effect on two-character Kanji nonword reading (Fushimi et al., 1999). Kayamoto, Yamada and Takashima (1998) also reported a frequency by consistency interaction in single-character Kanji word reading. Furthermore, two studies observed the imageability effect on Kanji word reading. Fushimi, Ijuin, Sakuma, Tanaka, Tatsumi, Amano, & Kondo (1998) found that an imageability effect only emerged for low-familiarity inconsistent-atypical words. Shibahara, Zorzi, Hill, Wydell, &

Butterworth (2003) reported that imageability only has a reliable effect on both naming latencies and naming accuracy for low-frequency inconsistent-KUN reading words[30] (i.e. two-character Kanji words, in which each constituent Kanji character has more than one legitimate pronunciation, and the appropriate pronunciations are KUN reading). Fushimi et al. (2000c) detected a semantic contribution to oral reading of Kana strings. They manipulated orthographic familiarity, lexicality and imageability, and created both pseudohomophones - by transcribing Kanji words into Katakana, and nonhomophonic nonwords - by re-combining different Katakana pseudohomophones. In the high-imageability condition, pseudohomophones were read faster than nonhomophonic nonwords. This result suggests a semantic contribution (O→P⇔S) to reading aloud of Kana strings, because the efficacy of the O→P computation is equal between pseudohomophones and nonhomophonic nonwords. Not surprisingly, they found an orthographic lexicality effect in the low imageability condition, in which Katakana words were read more rapidly than both types of nonwords. In the triangle model, this effect emerges from the O→P computation, because nonwords are computed on the basis of the connection strength for orthographically similar words.

All these results as observed in Japanese skilled readers can be explained by the Japanese version of the triangle model.

It is worth noting that Ijuin and his colleagues developed a connectionist network, which was not implemented semantics. Their early computer network (1999, 2000) could simulate a frequency-by-consistency interaction in computing the phonology

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30 They considered KUN reading words as analogous to English exception words following the rationale of Wydell et al. (1995, 1998). Regarding the different manipulation of Kanji character-sound consistency, it was explained in section 3.1.4. -1.

of two-character Kanji words, which is comparable to that of skilled Japanese readers (Fushimi et al., 1999), but their network demonstrated a poor performance for nonword reading. Then, Ijuin, Fushimi and Tatsumi (2002) built an alternative network which has successfully simulated the oral reading performance skilled readers for both words and nonwords. More importantly, their model could reproduce surface dyslexic pattern by withdrawal of additional input from putative word meaning. These results indicate that the triangle model, which is a connectionist model, can apply to Japanese orthography.

2) Interpretations of Japanese acquired dyslexia using the Japanese version of the triangle model

Within the framework of the triangle model any output is calculated through interactive communication among the three principal components (i.e. Phonology, Semantics, and Orthography). Thus, the damage of the principal components affects the processing as a whole and the contribution or reliability of a particular procedure would be exaggerated.

<u>Surface dyslexia</u>

This model explains surface dyslexia patterns in classical and recent cases as a result of semantic impairment or the disrupted communication between Semantics and Phonology, which forces the reliance on the O→P computation to be greater. Since the efficacy of the O→P computation depends on character-sound consistency, a consistency effect or a graded consistency effect on oral reading appears. So, semantic impairment (damage to Semantics itself, or abnormally reduced communication between Semantics and Phonology) leads to the surface dyslexia pattern observed in recent cases. A classical surface dyslexia pattern (i.e. impaired

Kanji word reading coupled with preserved Kana word reading) can also be explained by semantic impairment. Because the efficacy of the O→P computation of Kana strings is very high, due to consistent character-sound correspondence, semantic impairment does not affect the oral reading of Kana strings.

Semantic impairment can also explain LARC errors which were the dominant error type in recent cases. LARC errors, in which patients produce inappropriate pronunciations for the target Kanji words but legitimate pronunciations for each constituent character in other Kanji words, emerged because the patients with semantic impairment cannot inhibit an alternative pronunciation or cannot chose the correct pronunciation due to insufficient semantic activation.

Phonological dyslexia

This model explains the recent cases of Japanese phonological dyslexia as resulting from phonological impairment which leads to an exaggerated reliance on semantic procedure (O→S→P or O→P⇔S). This explanation can also apply to the classical cases of phonological dyslexia, which only demonstrated a lexicality effect on oral reading of Kana strings. This is because these cases were not examined in Kanji nonword reading, which means they did not preclude a lexicality effect on Kanji strings.

Since the processing efficacies of semantic procedures are modulated by semantic variables (i.e. lexicality, concreteness/imageability) the following apply: i) semantically rich words (i.e. concrete words/high imageability words), which have stronger connection weights within Semantics or between Semantics and Phonology, fare better than abstract/low imageability words in oral reading accuracy; and ii) nonhomophonic nonwords, which have no semantic representation and phonological representation, are most prone to error; and iii) oral reading accuracy for pseudohomophones, which are orthographically nonwords but are phonologically words receiving semantic support, is better than that for non-homophonic nonwords. In this rationale, the degree of phonological impairment affects the manifestation of symptoms. When phonological impairment is mild, only a lexicality effect and a pseudohomophone effect would be observed. This dyslexia pattern is common in the phonological dyslexia observed in Japanese neurological patients.

Phonological impairment can also explain lexicalisation errors, in which patients with phonological dyslexia produce inappropriate pronunciation for the target Kana/Kanji nonwords but instead produce pronunciation of orthographically similar Kana/Kanji words to the target. This is because the patients with phonological impairment cannot inhibit these orthographic neighbours because of an exaggerated reliance on semantic procedure for oral reading.

Classical deep dyslexia

As pointed out in section 3.3.1. -4, the reliability of a classical deep dyslexia pattern itself is low, but it cannot deny the possibility that the reported dyslexic pattern is a typical reading performance in Japanese deep dyslexia at the current stage of research. For this, classical deep dyslexia is interpreted in terms of clarifying this model's ability to explain acquired dyslexic patterns in Japanese.

This model can interpret the classical deep dyslexia pattern (i.e. severe impairment of 'Kana word' reading coupled with preserved Kanji word reading) as i) an impairment of the O→P computation or ii) a very severe impairment of Phonology itself. In the case of i), the efficacy of the O→S→P computation affects oral reading performance, and Kanji word reading is more accurate than oral reading of Kana words and Kana pseudohomophones. In the case of ii), additional support from Semantics (O→S→P) becomes important for correct oral reading and Kanji words can receive benefit from this.

This interpretation is based on the presumption that the O→S→P computation is more efficient for Kanji than Kana. Within the framework of the Japanese version of the triangle model, the different nature of the two scripts can be encoded as different connection weight during learning. While the direct computation (O→P) for transparent Kana script is learned more easily, oral reading of opaque Kanji script has more pressure to learn the semantic procedure (O→S→P). So, the connection weights between Orthography and Phonology, and Orthography and Semantics would become different depending on the script-type. Although the Japanese version of the triangle model can predict that the different nature of the two scripts leads to a different efficacy of processing during learning, the explicit assumption that the semantic procedure is more efficient for Kanji than Kana seems to offer a clear explanation about classical deep dyslexia in Japanese.

The differential efficacies of processing for Kanji and Kana can also explain the different error pattern in Kanji/Kana word reading. Semantic errors are dominant in Kanji word reading, because a damaged direct procedure (O→P) and/or impairment of Phonology itself lead to a greatly increased reliance on semantic procedure, which is more efficient for Kanji than Kana. Meanwhile, visual (i.e. phonological) errors are dominant in Kana word reading due to a highly efficient direct procedure for Kana.

Furthermore, the interactive processing of this model can explain the co-occurrence of semantic and visual errors as observed in classical deep dyslexia. Phonological impairment (damage to Phonology itself or abnormally reduced communication between Orthography and Phonology) leads to degraded communication between Phonology and Semantics (P⇔S) and between Phonology and Orthography (P⇔O). Thus, neurological patients with phonological impairment always made both types of reading error.

To summarise, the Japanese version of the triangle model can explain the published cases of surface and phonological dyslexia, but this model needed an explicit assumption about more efficient computation of the semantic procedure (O→S→P) for Kanji compared to Kana in order to explain classical deep dyslexia easily.

3.5. Different interpretations of Japanese acquired dyslexia in the DRC model and the triangle model, and unresolved issues

The classical reading model for Japanese (Sasanuma & Fujimura, 1971) and the semi-dual route model for Japanese reading (Sasanuma, 1986, 1987) assumed different reading processing for Kanji and Kana. It is likely that the former model was influenced by the traditional view of reading disorder in Japanese. Sasanuma (1974) wrote that ‘two types of orthographic symbols in Japanese kana (“syllabic” symbols) and kanji (“ideographic” symbols) were impaired in different manners’ (p.96). The latter model arose from Japanese acquired dyslexia research which was influenced by English dyslexia research, and which treated Japanese written words with the analogical reasoning of English written words (Kana words = English regular words, Kanji words = English exception words, and Kana nonwords = English nonwords). This formula was used for categorising classical surface dyslexia (Kana words > Kanji words), classical phonological dyslexia (Kana words > Kana nonwords), and the classical deep dyslexia pattern ('Kana words' < Kanji words). However, the findings relating to surface dyslexia and phonological dyslexia in recent cases - which demonstrated script-independent dyslexic patterns - revealed that these reading models are not reliable.

The models, which have the potential to interpret recent acquired dyslexic cases, were the interactive version of the dual-route model for Japanese reading and the Japanese version of the triangle model. As pointed out in section 3.4.3.-4, a possible Japanese version of the DRC model includes the interactive version of the dual-route model for Japanese reading. Thus, this section compares the Japanese version of the DRC model (Fig. 20) and the Japanese version of the triangle model (Fig. 21) in their interpretations of surface dyslexia and phonological dyslexia in recent cases, and of classical deep dyslexia. Furthermore, unresolved issues in Japanese acquired dyslexia research are summarised. For convenience, in these discussions the two reading models are just called the DRC model and the triangle model.

The DRC model interprets surface dyslexia and phonological dyslexia as a selective impairment of the lexical route and the non-lexical route, respectively, whereas the triangle model explains the two types of acquired dyslexia as resulting from semantic impairment and phonological impairment, respectively. The marked difference is that the triangle model assumes the causal relationship between semantic impairment and surface dyslexia, and between phonological impairment and phonological dyslexia. These associations are, however, accidental and can be attributed to anatomical proximity for the DRC model.

With regard to classical deep dyslexia, the DRC model needs additional assumptions about the different efficacies of processing for Kanji and Kana. If the

DRC model adds the assumption that the processing of the lexical routes is more efficient for Kanji than Kana, this model can explain classical deep dyslexia as severe impairment of the non-lexical route and mild impairment of the lexical route.

Meanwhile, the triangle model can predict the different efficacies of processing for Kanji and Kana from different learning process, but adding an explicit assumption that the semantic procedure is more efficient for Kanji than Kana offers a clear explanation about classical deep dyslexia. The triangle model interprets classical deep dyslexia as resulting from phonological impairment (i.e. the damage of Phonology itself, or abnormally reduced communication between Orthography and Phonology). Hence, the triangle model assumes that the patient with deep dyslexia preserve Semantics themselves (i.e. the semantic system), but the DRC model does not predict this characteristic.

Taking the above into account, both the Japanese version of the DRC model and the Japanese version of the triangle model can explain the published cases of surface and phonological dyslexia in Japanese, but the way of interpreting them is radically different. Classical deep dyslexia in Japanese is interpretable by the both models if assumption about the differential efficacies of semantic procedure for Kanji and Kana is added. In this respect, neither model is adequate; however, this is not conclusive because case studies for classical deep dyslexia have not used suitably controlled reading stimuli.

Finally, the problems faced by the two models are pointed out and unresolved issues in Japanese acquired dyslexia research are mentioned.

The DRC model has five problems. First, this model does not predict the co-occurrence of semantic impairment and surface dyslexia. Second, this model does not predict the co-occurrence of phonological impairment and phonological dyslexia. Third, this model does not offer enough explanation for classical deep dyslexia. Fourth, the non-lexical route for Kanji is unclear. Although some researchers suggested that the non-lexical route operates Kanji characters (Tamaoka & Hatsuzuka, 1998; Saito, Masuda, & Kawakami, 1999), their suggestion did not comply with the detailed description about the Kanji character-sound rule system. Fifth, there are no simulation studies of a possible Japanese version of the DRC model.

Meanwhile, the triangle model also has four problems. First, it is difficult for this model to explain that neurological patients with semantic impairment do not show surface dyslexia pattern. Second, it is difficult for this model to explain the existence of phonological dyslexics without phonological impairment. Third, it has not yet verified that phonological impairment in deep dyslexia is more severe than that in phonological dyslexia by using either clinical case studies or simulation studies. Fourth, there are no simulation studies of the Japanese version of the full-triangle model.

More importantly, it is not known whether the two reading models can explain Japanese deep dyslexia pattern that will be demonstrated using psycholinguistically well-manipulated and well-controlled reading stimuli.

Therefore, in order to solve these problems, both cognitive neuropsychological studies of Japanese acquired dyslexia, and simulation studies of a possible Japanese version of the DRC model and the Japanese version of the triangle model should be conducted. In particular, a most important empirical issue is how bi-scriptal Japanese manifests deep dyslexia. Theoretically, whether the cognitive models can explain Japanese deep dyslexia, which appears to reflect the bi-scriptal nature of

Japanese, is meaningful issue.

To summarise this chapter, because of methodological problems in the majority of case studies Japanese acquired dyslexia research has not reached the stage of being able to establish acquired dyslexic patterns in Japanese. Although the Japanese versions of the DRC model and the triangle model have the potential to explain Japanese acquired dyslexia, there is not enough data for discussion of the explanatory power of the distinctive cognitive models.

Chapter 4

The Purpose of this Thesis and the Theoretical Framework of the Investigation

4.1. Empirical and theoretical issues in Japanese acquired dyslexia research

4.1.1. An unresolved conflict of acquired dyslexia patterns in Japanese

The striking demonstration of double dissociation between Kanji and Kana reading (e.g. Sasanuma, 1980a, 1985, 1986; see Fig.12**) s**upports the view that Japanese acquired dyslexia patterns are dependent on the script type (morphographic Kanji and phonographic Kana) - a fact which has been known in the cognitive neuropsychology research community for some time. According to classical case studies, three types of acquired dyslexia in Japanese are proposed as follows:

i) Surface dyslexia in Japanese is a Kanji-specific reading disorder, in which oral reading of Kanji words is in a severely deteriorated condition but oral reading of Kana strings is preserved (e.g. Sasanuma, 1979, 1980a, 1980b and 1985).

ii) Phonological dyslexia in Japanese is a Kana nonword-specific reading disorder, in which there is a prominent impairment of Kana nonword reading coupled with preserved oral reading of words written with both Kanji and Kana characters (e.g. Mizuta, et al., 1992; Matsuda et al., 1993).

iii) Deep dyslexia in Japanese is a Kana-specific reading disorder, in which there is a disproportionate deficit in reading aloud of Kana strings coupled with relatively well preserved oral reading of Kanji words (e.g. Sasanuma, 1979, 1980a, 1980b; Hayashi et al., 1985).

The rationale of these categorisations was based on the analogy that Kana words, Kanji words and Kana nonwords could parallel regular words, exception words and nonwords in English, respectively. With regard to classical surface dyslexia and classical phonological dyslexia, Japanese dyslexia patterns are consonant with English dyslexia patterns based on this analogy (Kana words > Kanji words = regular words > exception words in surface dyslexia; Kanji/Kana words > Kana nonwords = words > nonwords in phonological dyslexia). However, if this analogy is used, a classical deep dyslexia pattern (Kanji words > Kana words) is problematic because its English counterpart should show better oral reading of exception words than of regular words, but this has never been reported in acquired dyslexia research. Moreover, the fact that classical deep dyslexic patients, excluding TO (Hayashi et al., 1985), were tested using Kana pseudohomophones transcribed from Kanji words, could mean that a superiority of Kanji word reading over Kana word reading might be an orthographic familiarity effect (words > pseudohomophones).

On the other hand, recent case studies have indicated that Japanese acquired dyslexia patterns are not dependent on script type. In some surface dyslexics a consistency effect has been demonstrated in Kanji word reading, coupled with preserved oral reading of Kana strings and Kanji nonwords (e.g. Fushimi et al., 2003a). Several phonological dyslexics showed a lexicality effect on oral reading in both Kana nonwords and Kanji nonwords (Fushimi et al., 2000a, 2000b; Kato et al., 2004).

Hence, there is disagreement between classical and more recent case studies in relation to Japanese dyslexia patterns. Classical case studies experienced methodological problems, in that consistency was not manipulated and lexicality was not properly controlled. Instead the script type (Kanji or Kana) was treated as a psycholinguistic variable. Meanwhile, recent case studies, which use psycholinguistically well-manipulated and well-controlled reading stimuli, have been carried out on a limited number of patients and there is no information available on deep dyslexia. So, it is still not known whether Japanese acquired dyslexia patterns are dependent on, or independent of script type and, whatever the answer, why this should be so.

4.1.2. An unresolved conflict in models of reading

There are two distinctive interpretations concerning reading disorders following brain damage. Using the DRC model, the three types of acquired dyslexia can be interpreted as follows: i) selective impairment of the lexical routes leads to surface dyslexia; ii) selective impairment of the non-lexical route leads to phonological dyslexia; and iii) severe impairment of the non-lexical route and mild impairment of the lexical routes lead to deep dyslexia. In the meantime, the triangle model hypothesises that semantic impairment leads to surface dyslexia, and phonological impairment leads to phonological dyslexia and deep dyslexia. As shown in Chapter 2, both the DRC model and the triangle model can interpret acquired dyslexia patterns in alphabetic orthography. As explained in Chapter 3, the Japanese versions of the DRC model and the triangle model have the potential to explain reported Japanese dyslexia patterns.

The greatest difference between the two models is that the triangle model predicts a functional association between semantic impairment and surface dyslexia, and between phonological impairment and phonological/deep dyslexia, whereas the DRC model does not predict these causal relationships. For the DRC model, the association between semantic/phonological impairment and acquired dyslexia patterns is accidental and only reflects neuro-anatomical proximity.

However, the literature review of both English and Japanese acquired dyslexia research, in Chapters 2 and 3, revealed the problems of both models. The proponents of the DRC model (Coltheart, et al., 2001) avoided explanations about deep dyslexia patterns in English, and there is no simulation study based on the DRC model available for English deep dyslexia or any acquired dyslexia patterns in Japanese. Likewise, the hypothesis that the source of deep dyslexia is phonological impairment (Patterson and Lambon Ralph, 1999) has not been verified by either English or Japanese neurological cases. There is no simulation study based on the phonological impairment hypothesis available for deep dyslexia.

Since a Japanese deep dyslexia pattern has not yet been clarified because of the methodological problems in classical case studies (Sasanuma, 1979, 1980a, 1980b, 1986; Hayashi et al., 1985), it is open to question whether the Japanese versions of the DRC model and the triangle model can explain Japanese deep dyslexia.

Hence, in the interpretation of acquired dyslexia in Japanese and English there is a conflict between the DRC model and the triangle model, and this conflict has not yet been resolved.

4.2. The three research questions and frameworks of this thesis

In view of the unresolved conflicts in Japanese acquired dyslexia patterns, and the interpretations of Japanese dyslexia using the two different models of reading, three research questions are posed in this thesis.

4.2.1. Research Question 1 and the research framework

<u>Research Question 1</u>

"Do Japanese dyslexia patients show the same effects of psycholinguistic variables as observed in English dyslexia patients?"

Research Question 1 aims to examine whether Japanese acquired dyslexia patients show the same effects of psycholinguistic variables as observed in English surface dyslexia, phonological dyslexia and deep dyslexia. In order to capture Japanese acquired dyslexia patterns precisely it is very important to distinguish between psycholinguistic variables effects and the script-type effect of Kanji and Kana. This is the rationale behind Research Question 1.

The research framework of this question is to detect the psycholinguistic variables effects which have been used for diagnosing the three types of English acquired dyslexia, (i.e. consistency effect in surface dyslexia, lexicality effect in phonological dyslexia, and lexicality and concreteness/imageability effect in deep dyslexia), in Japanese patients' reading performance for both Kana and Kanji strings. Kanji strings and Kana strings were equally manipulated by these critical psycholinguistic variables – with the exception of print-sound consistency, because the Kana character-sound relationship is always consistent and one cannot manipulate print-sound consistency for Kana strings. In addition, word frequency, word familiarity, and word-length of the oral reading stimuli were manipulated or controlled, because these psycholinguistic variables were not included in classical case studies of Japanese acquired dyslexia.

4.2.2. Research Question 2 and the research framework

<u>Research Question 2</u>

" Do Japanese acquired dyslexia patients show any script-dependent effects?"

Research Question 2 aims to examine whether the script type affects oral reading performance by Japanese dyslexia patients. In order to resolve the empirical issue of whether Japanese dyslexia patterns are script-dependent or script-independent, it is crucial to examine whether there is a 'real' script-type effect, which cannot be explained by psycholinguistic variables effects. This is the rationale behind Research Question 2.

The research framework of this question is to compare the accuracy of reading aloud of both Kanji and Kana strings (i.e. words, pseudohomophones and nonhomophonic nonwords). The point of investigation is to re-analyse the reading performance in the experiments for Research Question 1 in terms of a Kanji vs. Kana framework. This comparison is necessary to detect a script-specific influence on reading performance, because the classical case studies (and also the neuropsychological case studies) in Japanese dyslexia research investigated the dyslexia pattern by comparing the accuracy of Kanji and Kana strings, and reported the double dissociation between Kanji and Kana.

4.2.3. Research Question 3 and the research framework

Research Question 3

"Can the Japanese versions of the DRC model and the triangle model explain Japanese acquired dyslexia patterns?

Research Question 3 aims to examine whether the Japanese version of the DRC model and the Japanese version of the triangle model can explain Japanese acquired dyslexia patterns as observed in the subjects of this thesis, and whether any modifications are needed so as to provide explanations of their dyslexia patterns. Examining the explanatory power of the two models is necessary in order to propose a suitable reading model that can explain Japanese acquired dyslexia patterns. This is because the DRC model and the triangle model have been developed using English as the language medium and the models have mainly been used to explain acquired dyslexia in alphabetic script. But, it is possible that any language could share the same reading mechanisms despite the different nature of scripts. This is the rationale behind Research Question 3. This question is theoretically important, because very few studies for non-alphabetic scripts examined the applicability of these models (e.g. Karanth, 2003).

The research framework of this question is intended to test the semantic impairment hypothesis (Patterson & Hodges, 1992; Graham et al., 1994; Patterson & Lambon Ralph, 1999) and the phonological impairment hypothesis (Patterson & Lambon Ralph, 1999), both of which are based on the triangle model. Thus, prior to carrying out oral reading experiments, semantic function and phonological function are evaluated. If Japanese-speaking neurological patients demonstrate the co-occurrence of semantic impairment and surface dyslexia, and the co-occurrence of phonological impairment and deep/phonological dyslexia, that would suggest that the Japanese version of the triangle model has more reliability than the Japanese version of the DRC model, because the DRC model does not predict these co-occurrences.

4.3. The predictions arising from the three research questions

4.3.1. The prediction of acquired dyslexia patterns in Japanese

With regard to Research Question 1, one can predict that Japanese patients with acquired dyslexia would demonstrate the same effects of psycholinguistic variables as reported in English cases, because it is likely that acquired dyslexia in any language will share the same mechanisms in the brain. Oral reading for both Kanji and Kana strings would be influenced by the same psycholinguistic variables, except for 'consistency' which cannot be manipulated in Kana strings due to the transparent character-sound correspondence. Thus, the three types of acquired dyslexia patterns in Japanese - which correspond with the English dyslexia type - can be predicted. Surface dyslexia in Japanese would show a consistency effect in Kanji word reading together with preserved oral reading of Kana strings. Japanese phonological dyslexia would show a lexicality effect (words > nonhomophonic nonwords) on both Kana and Kanji strings. Japanese deep dyslexia would show superiority of word reading over nonword reading, and also would show a imageability/concreteness effect on oral reading of both Kanji and Kana words.

4.3.2. The prediction of the bi-scriptal influence on Japanese dyslexia patterns

The double dissociation of reading accuracy between Kanji words and Kana words in classical case studies, which led to the view that Japanese dyslexia patterns are script-specific (or dependent), would be attributable to the different psycholinguistic properties of Kanji and Kana strings, which were explained in Chapter 3. Based on this point, one can predict the following three conditions which would lead to the difference in reading accuracy between Kanji and Kana strings.

Firstly, superiority of reading aloud of Kana strings over Kanji word reading in surface dyslexia patients would be observed as part of a consistency effect, because Kanji and Kana are different in terms of character-sound consistency.

Secondly, better oral reading accuracy for Kana pseudohomophones than for Kanji pseudohomophones would be observed in deep/phonological dyslexia patients as a reflection of a lexicality effect. This is because orthographic acceptability of Kana pseudohomophones is higher than that of Kanji pseudohomophones (see. 3.1.4.-2).

Thirdly, better oral reading accuracy for Kanji words than for Kana words would be observed in dyslexia patients with a deficit of visual recognition, as a reflection of a word-length effect. Since Kanji words usually consist of two characters and Kana words usually consist of between three and six characters, superiority of Kanji word reading over Kana word reading can be considered as a word-length effect if the reading stimuli are not controlled by this variable.

Hence, these predictions suggest that the double dissociation between Kana word reading and Kanji word reading, demonstrated by classical surface dyslexia and deep dyslexia in Japanese, would manifest a 'false' script-type effect, rather than psycholinguistic effects based on the different characteristics of Kanji and Kana words.

4.3.3. The prediction about explanatory power of the Japanese versions of the DRC model and the triangle model for Japanese acquired dyslexia

On the basis of the predictions about the results of Research Questions 1 and 2 above, Japanese dyslexia patients should show script-independent dyslexia patterns. In Chapter 3 the two models’ interpretation of script-independent surface dyslexia and phonological dyslexia, which were demonstrated by recent cases, had already been presented. If deep dyslexia in Japanese were a script-independent reading disorder, one would also be able to apply the explanation to English deep dyslexia.

So, the Japanese version of the DRC model would explain Japanese deep dyslexia as the severe damage to the non-lexical route and the mild damage to the lexical route, whereas the Japanese version of the triangle model would interpret it as the result of phonological impairment.

The difference in explanatory power of the two models would arise from the interpretation of the co-occurrence of phonological impairment and deep/phonological dyslexia, and of semantic impairment and surface dyslexia. This is because the Japanese version of the DRC model does not predict these associations, but the Japanese version of the triangle model predicts them as causal relationships.

4.4. The research strategy and the organisation of the three individual studies

4.4.1. The research strategy of this thesis

Cognitive neuropsychological research for reading depends on observed oral reading performances by subjects with neurological damage. This is a limitation of acquired dyslexia research, because the opportunity to examine dyslexia cases is, in a sense, accidental. Therefore, this thesis was constructed on the basis of fortuitous opportunities to investigate the four neurological patients - YT, HW, SO and ME - who showed distinctive, acquired dyslexia patterns in Japanese. The research strategy of this thesis is neither based on case series (which investigate multiple cases with similar linguistic performance), nor on group study. The thesis consists of three individual studies, all of which have been used in the discussion of the three research questions. Each study has its own focus and points of discussion, as explained in the next section.

Study 1 is a comparative study between YT and HW who showed deep dyslexia and surface dyslexia, respectively. Study 1 was carried out because classical case studies showed the double dissociation between Kanji and Kana word reading in deep and surface dyslexia, and verifying this dissociation and clarifying the two dyslexic patterns is very important in addressing Research Questions 1 and 2. Since there is no report for deep dyslexia using reading stimuli - which are psycholinguistically well manipulated/controlled - the description of YT is presented prior to that of HW in the result section of Study 1.

Study 2 and Study 3 are a case studies for SO and ME, whose dyslexia patterns were segregated by the script-type. Since SO had severe semantic impairment and ME had phonological impairment with a visuo-spatial deficit, an individual case study was constructed for each case.

Although Studies 1, 2 and 3 are independent case studies they share the same experimental tasks, except for additional oral reading experiments which were used for exploring SO's and ME's dyslexia pattern.

4.4.2. The organisation of the three independent studies for addressing the three research questions

This section presents each study's own research questions, which correspond with the three research questions of this thesis and the points of discussion.

1) Study 1

Study 1 (Chapter 6) is a comparative study of YT and HW who showed phonological impairment and semantic impairment, respectively. The data of each case was used as a control for the other case.

<u>Research question 1 of Study 1</u>

"Do Japanese dyslexia patients show the same psycholinguistic variables effects observed in English patients with deep dyslexia and surface dyslexia?"

The characteristics of the English deep dyslexia pattern are i) prominent impairment of nonword reading; ii) impairment of word reading manifested by a concreteness/imageability effect; iii) a part of speech effect (nouns > adjectives > verbs > function words); and iv) co-occurrence of semantic and visual errors. So, in order to discuss this research question these characteristics must be evaluated in Japanese cases. However, adjectives and verbs are written with both Kanji and Kana, and function words are always written with Kana characters. Furthermore, the imageability for the four types of words is different (nouns > adjectives > verbs > function words: Jones, 1985; Harm, 1998). Thus, detecting a part of speech effect is outside the framework of this thesis which is aiming to distinguish between the psycholinguistic variables effect and the script-type effect. Therefore, the results in the oral reading experiments for a) single Kana characters, Kana/Kanji nonwords, b) Kana/Kanji pseudohomophones, and c) Kana/Kanji words manipulated by concreteness/imageability are important for discussion of the Japanese deep dyslexia pattern.

Meanwhile, the typical surface dyslexia pattern in English (Type I) shows i) impairment of oral reading of exception words, coupled with preserved oral reading of consistent words; ii) regularisation errors for word reading; and iii) preserved nonword reading. As the recent case study (Fushimi et al., 2003a) revealed, Japanese surface dyslexia would show i) impairment of reading aloud of inconsistent-atypical words at a low frequency band; ii) LARC errors, which correspond with regularisation errors; and iii) preserved Kanji nonword reading. Thus, the results in the oral reading experiments for a) Kanji words manipulated by consistency, which were taken from the two word lists by Patterson et al. (1995) and Fushimi et al. (1999); and b) Kanji nonwords, which were also taken from Fushimi et al. (1999), are important for discussing the Japanese surface dyslexia pattern.

Research question 2 of Study 1

"Are Japanese deep dyslexia and surface dyslexia Kana and Kanji script-specific reading disorders, respectively?"

As the literature review in Chapter 3 pointed out, classical case studies, which reported script-dependent dyslexia patterns in Japanese, had methodological problems. Superiority of Kanji word reading over Kana word reading in classical deep dyslexia was reported, based on the results of reading aloud of Kanji words and Kana pseudohomophones. In classical surface dyslexia cases, in which impairment of Kanji word reading was contrasted with preserved Kana word reading, Kanji words were not manipulated by consistency.

Thus, the analysis of whether oral reading accuracy for Kana words and Kana pseudohomophones is lower than that for Kanji words is crucial for verifying a classical deep dyslexia pattern. The comparison between Kana and Kanji pseudohomophones is necessary for examining the influence of script-type on the Japanese deep dyslexia pattern. In order to verify classical surface dyslexia an examination of the consistency effect on Kanji word reading is essential, and the analysis of whether oral reading accuracy for consistent Kanji words is similar to that for Kana words is also necessary.

Research question 3 of Study 1

Research question 3 of Study 1 consists of two sub-questions which are essential to the discussion of Research question 3 of this thesis.

Research question 3-1 of Study 1

"Can one observe the co-occurrence of phonological impairment and deep/phonological dyslexia, and of semantic impairment and surface dyslexia?"

Examining whether Japanese patients with acquired dyslexia show these co-occurrences is theoretically important because the co-occurrence between phonological impairment and deep dyslexia has not yet been reported. The results of the evaluation tasks for semantic and phonological function, and the results of the oral reading experiments, are both necessary for addressing this question. If the results support both the phonological and semantic impairment hypotheses, the triangle model would be more reliable than the DRC model which does not predict causal relationships between phonological/semantic impairment and manifestation of the dyslexia type.

Research question 3-2 of Study 1

"Can the Japanese versions of the DRC model and the triangle model explain Japanese dyslexia patterns?"

The main focus is whether the two models can interpret Japanese deep dyslexia, because this has not yet been examined. Another focus is whether the two models can explain Japanese acquired dyslexia patterns with/without additional assumptions. If either model needs additional assumptions this would mean that the model needs to be modified. If either model does not need modification this suggests that that model would be more reliable.

2) Study 2

Study 2 (Chapter 7) is a case study of SO, who showed severe semantic impairment in comparison to HW and whose results were used as control data.

Research question 1 of Study 2

" What is a severe form of Japanese surface dyslexia like?"

The main concern of this question is whether severe semantic impairment would emerge as a distinguishable dyslexia pattern in comparison to typical surface dyslexia, but at the same time sharing the same defining characteristics. Thus, the points of this discussion are i) whether a consistency effect can be detected in oral reading of two-character Kanji words; b) whether oral reading accuracy of constituent Kanji characters in two-character Kanji words shows a consistency effect; and iii) whether Kanji nonword reading is preserved.

Another concern is whether oral reading performance by a patient with severe semantic impairment is influenced by semantic variables and orthographic familiarity.

Research question 2 of Study 2

"Is a severe form of Japanese surface dyslexia a Kanji script-specific reading disorder?"

Although classical surface dyslexia cases demonstrated superiority of Kanji word reading over Kana word reading, their oral reading performance for Kanji/Kana nonhomophonic nonwords was not known. If a dyslexia patient with severe semantic impairment shows impairment of Kanji word/nonword reading, coupled with preserved reading aloud of Kana strings, this suggests that oral reading performance in a severe form of Japanese surface dyslexia is segregated by the script-type. So, the results of the oral reading experiment for detecting a consistency effect, and for making a comparison between Kanji/Kana words, Kanji/Kana pseudohomophones and Kanji/Kana nonwords, are necessary for discussion of this research question.

Research question 3 of Study 2

"Can the Japanese versions of the DRC model and the triangle model explain the co-occurrence of severe semantic impairment and a severe form of surface dyslexia in Japanese?"

The point of this research question is to establish whether a severe form of surface dyslexia can be explained within the semantic impairment hypothesis, or whether an alternative explanation is required.

3) Study 3

Study 3 (Chapter 8) is a case study of ME, who showed not only phonological impairment but also visuo-spatial deficits (right visuospatial neglect and constrictive apraxia). ME's results are presented together with YT's profile and YT's results were used as control data.

Research question 1 of Study 3

"What is Japanese phonological dyslexia with a visuo-spatial deficit like?"

This research question focuses on how the dyslexia pattern of a patient who has phonological impairment coupled with a visuo-spatial cognitive deficit is different from deep/phonological dyslexia. The results of the oral reading experiment for detecting deep/phonological dyslexia and for examining word-length effect are important for this discussion.

Research question 2 of Study 3

"Is Japanese phonological dyslexia with a visuo-spatial deficit a Kana script-specific reading disorder?"

The classical deep dyslexia case, TO (Hayashi et al., 1985), who showed superiority of Kanji word reading over Kana word reading, was suffering from a suspected right homonymous hemianopia. Since the oral reading stimuli used for

TO's investigation consisted of single- or two-character Kanji words and three- to six-character Kana words, there is a strong possibility that TO's dyslexia pattern reflected a word-length effect, due to a visuo-spatial deficit. Therefore, this research question is crucial for verifying TO's dyslexia pattern which supported the view that Japanese deep dyslexia is a Kana-specific reading disorder (Sasanuma, 1980a).

So, the results of the oral reading experiments, manipulated by word-length and script-type, are essential for addressing this research question.

Research question 3 of Study 3

"Can the Japanese versions of the DRC model and the triangle model explain a variation of phonological dyslexia with a visuo-spatial deficit?"

The key to this research question is whether the two models can explain how both visual cognitive deficit and phonological impairment affect oral reading performance. So, grasping the difference between dyslexia patterns in the patient with phonological impairment with/without a visuo-spatial deficit is important for this discussion.

4.5. Empirical and theoretical importance of this thesis

In the final section of this Chapter the research in this thesis is justified on the basis of possible benefits for other researchers in acquired dyslexia research, and for therapists who are working with Japanese acquired dyslexics.

4.5.1. Carrying out empirical work that has not been conducted before

The significant value of this thesis is the clarification of patterns of acquired dyslexia in Japanese. This research area has empirical weaknesses. This is because the classical case studies had methodological problems, and there are only a limited number of recent case studies which used well-manipulated and well-controlled reading stimuli. Thus, there is an unresolved conflict in Japanese acquired dyslexia patterns: script-dependent vs. script-independent. This thesis tackles this problem and, investigates i) the deep dyslexia pattern using well-manipulated and well-controlled reading stimuli; ii) the typical Japanese surface dyslexia pattern; iii) a severe form of the Japanese surface dyslexia pattern; and iv) a variation of the Japanese phonological dyslexia pattern with visual recognition impairment; and then verifies the findings.

Therefore, empirical findings from this thesis may lead to a better understanding of Japanese acquired dyslexia and this may be helpful in understanding acquired dyslexia patterns in non-alphabetic orthography.

4.5.2. Adding theoretical knowledge about Japanese reading processing

The theoretical importance of this thesis is to examine the double association between semantic impairment and surface dyslexia, and between phonological impairment and deep/phonological dyslexia using non-alphabetical orthography. Whether this association is causal or accidental is an unresolved conflict between the DRC model and the triangle model (e.g. Blazely, Coltheart, & Casey, 2005). Although single associations have been reported in the literature, a double association has not previously been reported in a single study. Therefore, this thesis may add useful information to the discussion of this theoretically controversial issue.

Moreover, this thesis compares the interpretation of Japanese acquired dyslexia using the Japanese versions of the DRC model and the triangle model. This would be helpful for proposing a suitable reading model which could explain acquired dyslexia patterns in Japanese. Thus, this thesis may advance the state of knowledge about reading processing in Japanese.

Chapter 5

The Method of the Investigation

This chapter presents the case reports for the four subjects (YT, HW, SO and ME) and explains the experimental design and the contents and procedures of the tasks, which were used for Study 1, Study 2 and Study 3. The evaluation of the semantic and phonological functions for YT, HW and SO were carried out in 2000. The investigation of oral reading for these three patients was conducted in 2001 and 2002. The investigation for ME was carried out in 2003. The subjects gave permission for these investigations in advance of the research.

5.1. The subjects

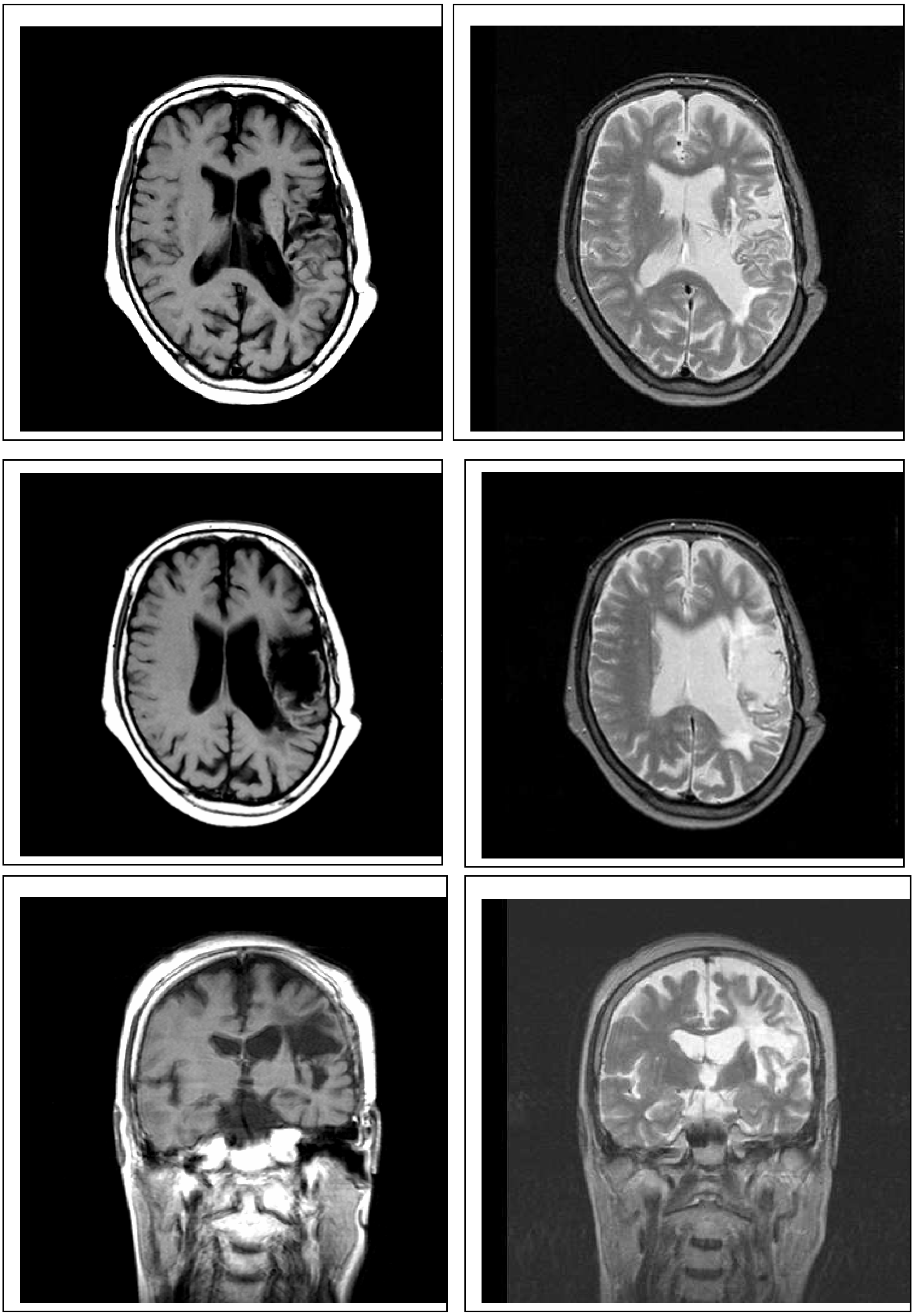
The subjects of this thesis were 4 aphasic patients who were native Japanese adults and were patients of Yokufukai Hospital, Tokyo. The patient profiles (age, gender, education, etiology and lesion site) and the main neuropsychological findings in the standardised tests are shown in Table 5. All cases were right-handed and 3 cases (not including ME) had a job before the onset of the illness. YT was a restaurant owner; HW was a licensed tax accountant; and SO was working at a patent office where his main work was to translate from English to Japanese. ME was a retired public official. YT had a high-school education and the other 3 cases were educated to university level. The pre-morbid literacy of all four subjects was good. While the etiology of HW and SO was herpes simplex virus encephalitis, both YT and ME had suffered from a haemorrhage. All subjects' mental state was good and they showed no sign of dementia. Only ME showed a visuospatial deficit. With regard to the lesion site and the neuropsychological assessment, the subjects are explained individually in the sections below.

Tabale 5 Case details and Basic Neuropsychological Data on YT, HW, SO, and ME

Subject	**YT**	**HW**	**SO**	**ME**
Age at Onset	55	53	65	84
Onset time	January 1996	June 1997	September 1997	April 2003
Gender	Female	Male	Male	Male
Education (years)	12	16	16	16
Etiology	Hemorrhage	Herpes encephalitis	Herpes encephalitis	Hemorrhage
Lesion site	Lt. putamen Lt..temporo-parietal	Lt.inferior-temporal	Lt.temporal (inferior～superior)	Lt.pariet-occipital
Aphasia type	Non-flunet	Fluent	Fluent	Fluent
WAB profile				
Assessment point	May-June 2001	March-April 2001	November 2001	July 2003
Spontaneous speech	14	17	15	18
Content (10)	8	8	7	9
Fluency (10)	6	9	8	9
Comprehension (10)	8.4	9.5	7.9	7.6
Repetition (10)	7.0	9.8	8.4	8.8
Naming (10)	7.5	6.5	3	8.4
Reading (10)	7.3	9.5	7.9	7.8
Writing (10)	5.1	8.9	7.7	3.6
Action (Left hand) (10)	9.5	10	8.8	9.2
Construction (10)	7.7	9.4	9.3	5.9
Aphasia Quotient (100)	73.8	85.6	68.5	85.6
Cognitive Quontient (100)	74.9	90.1	75.8	76.9
Object naming (% correct)	75	55	10	95
Picture naming (%correct)	61	43	14	68
Letter Fluency /ka/	1	7	8	7
Category Fluency 'animal'	7	7	6	12
Digit span				
Forward	2	4	4	4
Backward	0	3	3	2
WAIS-R				
Information	7	5	6	8
Digit Span	1	10	9	6
Vocabulary	5	6	5	12
Arithmetric	5	10	6	7
Comprehension	2	6	7	9
Similarities	1	9	6	10
Picture Compretion	9	11	10	6
Picture Arrangement	12	10	14	0
Block Design	10	14	10	4
Object Assembly	10	13	12	4
Digit symbol	5	8	8	3
Verbal IQ	58	84	78	93
Performance IQ	95	108	105	72
Full Scale IQ	74	95	90	81
Raven's Color. Prog. Matrices(36)	30	34	30	12
Rey figure copy (36)	35	34	33	28
Caliculation (SLTA)				
Addition (5)	3	5	5	4
Subtraction (5)	2	5	5	1
Multiplication (5)	1	4	5	2
Division (5)	0	5	5	1

5.1.1. Case report of YT

Fig. 22. Horizontal and coronal sections of an MRI for YT in June 2002 (left: T1 weighted imaging, right: T2 weighted imaging).



YT (year of birth 1941), a 55-year-old female restaurant owner with 12 years of education, had suffered a haemorrhage of the left putamen in January 1996. A CT scan, after the operation for removing hematoma, revealed a left hemisphere lesion in the sub-cortex and the cortex of the superior-temporal area, and the sub-cortex of the parietal area. Fig.22 is a Magnetic Resonance Imaging (MRI) scan for YT in June 2002. Before YT requested speech and language therapy as an outpatient at Yokufukai Hospital in June 1998, she had been an inpatient in three hospitals and had received speech and language therapy in each hospital.

(a) YT's spoken language

YT’s spontaneous speech was non-fluent but well articulated. When she faced a word-finding difficulty in picture description, she produced mainly semantic errors, often accompanied by the statement that the produced word was not the target (e.g. coffee → ’cider, it wasn’t’) or by onomatopoetic expression, which referred to the target (e.g. dog → /wa-N-wa-N/ which indicates dog’s bark). Phonological errors (e.g. / jo-Q-to/ *yacht* → /hi-Q-to/) were observed infrequently, sometimes accompanied by her self-correction. Her auditory comprehension was fairly good and her understanding in daily conversation was preserved. In a picture-naming test using objects in daily-use (e.g. pencil, spoon), YT scored only 11/30 (37%). The vast majority of her errors were no responses or 'don’t know' responses (11/19, 58%), and semantically related responses (7/19, 37%), including shared-feature errors and semantic associative errors, circumlocutions, onomatopoetic expressions, and gestures. Phonological cueing of the first mora of the target word had an effect on her naming performance (10/19, 53%).

YT’s Aphasia Quantity of the Japanese version of the Western Aphasia Battery (The Japanese version of WAB, 1986; hereinafter the WAB) at the first assessment in June 1998 was 58.1(information = 6, fluency = 4 in spontaneous speech; auditory comprehension = 6.75; repetition = 7; naming = 5.3). Her auditory comprehension of single words in the WAB was 49/60 (82%), in which she showed difficulty in distinguishing a finger's name and between right and left. Her accuracy of object naming was 50% (10/20). Her verbal fluency within a 1-minute time limit was 4 for a semantic category (animal) and zero for a letter (/ka/). After 4 months of intensive therapy (twice a week), YT showed improvement in spontaneous speech, auditory comprehension, and naming, and in October 1998 her Aphasia Quantity of the WAB became 68 (information = 8, fluency = 6 in spontaneous speech; auditory comprehension = 7.5; repetition = 7; naming = 5.5). Language therapy (once a week) was continued and YT's Aphasia Quantity became 73.8 (her profile of the WAB is shown in Table 5) in May 2001. Her verbal fluency for a semantic category (animal) had also improved (4→7).

(b) YT's written language

In the first assessment of the WAB in June 1998 YT showed good comprehension of written words (18/18), but her comprehension of written sentences was poor (22/40). In reading aloud single-Kanji-character concrete nouns YT's performance had deteriorated (29/60, 48%), despite her good comprehension of these targets as examined by the picture-Kanji character word matching task (59/60, 98%) in which one picture was presented with 4 single-character Kanji words (the target, semantic, visual, and unrelated distracter). In oral reading of single-character abstract Kanji words, she showed severe deterioration (11/60,18%). Semantic errors (e.g. 狸 *raccoon dog* →兎 *rabbit*; 肩 *shoulder* →頭 *head*; 緑 *green* →若葉 *young leaves*) occurred more frequently for oral reading of concrete words (17/31, 55%) than for abstract words (7/49, 14%). In the 50 Kanji Word Test (Sasanuma, et al., 1992), which was examined longitudinally, YT's score was 25/50 (50%) in July 1998, 37/50 (74%) in June 2000, and 41/50 (82%) in July 2001. While YT's oral reading errors in 1998 were mainly semantic errors (11/25, 44%) or no response errors (9/25, 36%), the majority of her incorrect responses in 2000 and 2001 were semantic errors (8/13, 62%; 6/9, 67%, respectively).

With regard to YT's spontaneous writing, she could write single words and Arabic numbers, but her writing of Kana characters in a Japanese syllabary list (‘*Gojyu-On-Hyou*', see p.139) was very poor (she wrote only 3 Kana characters).

After 4 months of intensive therapy, and homework of writing a diary, with some help from her husband who was asked to talk about daily activity with YT and make short written sentences, YT's reading and writing scores of the WAB improved from 5.55→6.85, 3.95→4.35, respectively. Her comprehension of written sentences in particular had improved (22/40 → 34/40). YT's reading and writing score of the WAB had further improved (7.3 and 5.1, respectively) in June 2001.

(c) YT's non-linguistic cognitive abilities

YT's score of Raven's Coloured Progressive Matrices (Raven, 1965) was 30/36 (mean score of age matched control is 29.2, SD5.4), indicating that her nonlinguistic reasoning ability was preserved. YT's score for copying the Rey's complex figure (Rey, 1941) was 35/36 (Fig.23) and her score of the Japanese version of the Behavioural inattention test (the Japanese BIT, 1999) was 142 (the cut-off score is 131/146), indicating that her visuospatial skills were intact. YT's performance IQ of the Japanese version of the Wechsler Adult Intelligence Scale-Revised (the Japanese version of WAIS-R, 1990), which was administered in January 2002, was 95, despite the fact that she used her left-hand instead of her paralysed right-hand.

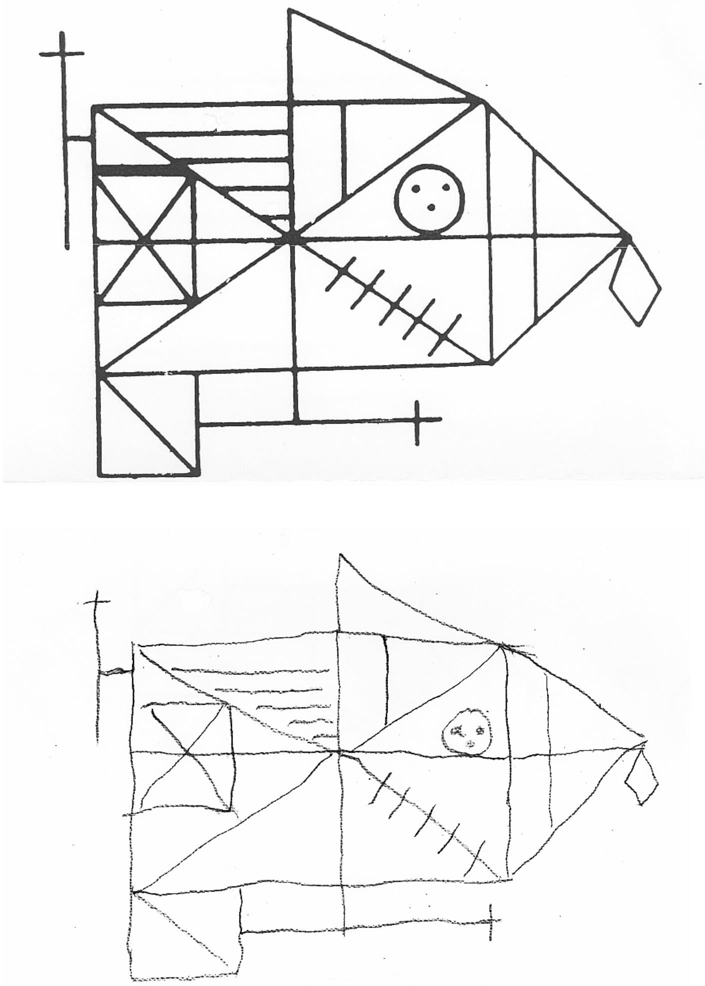
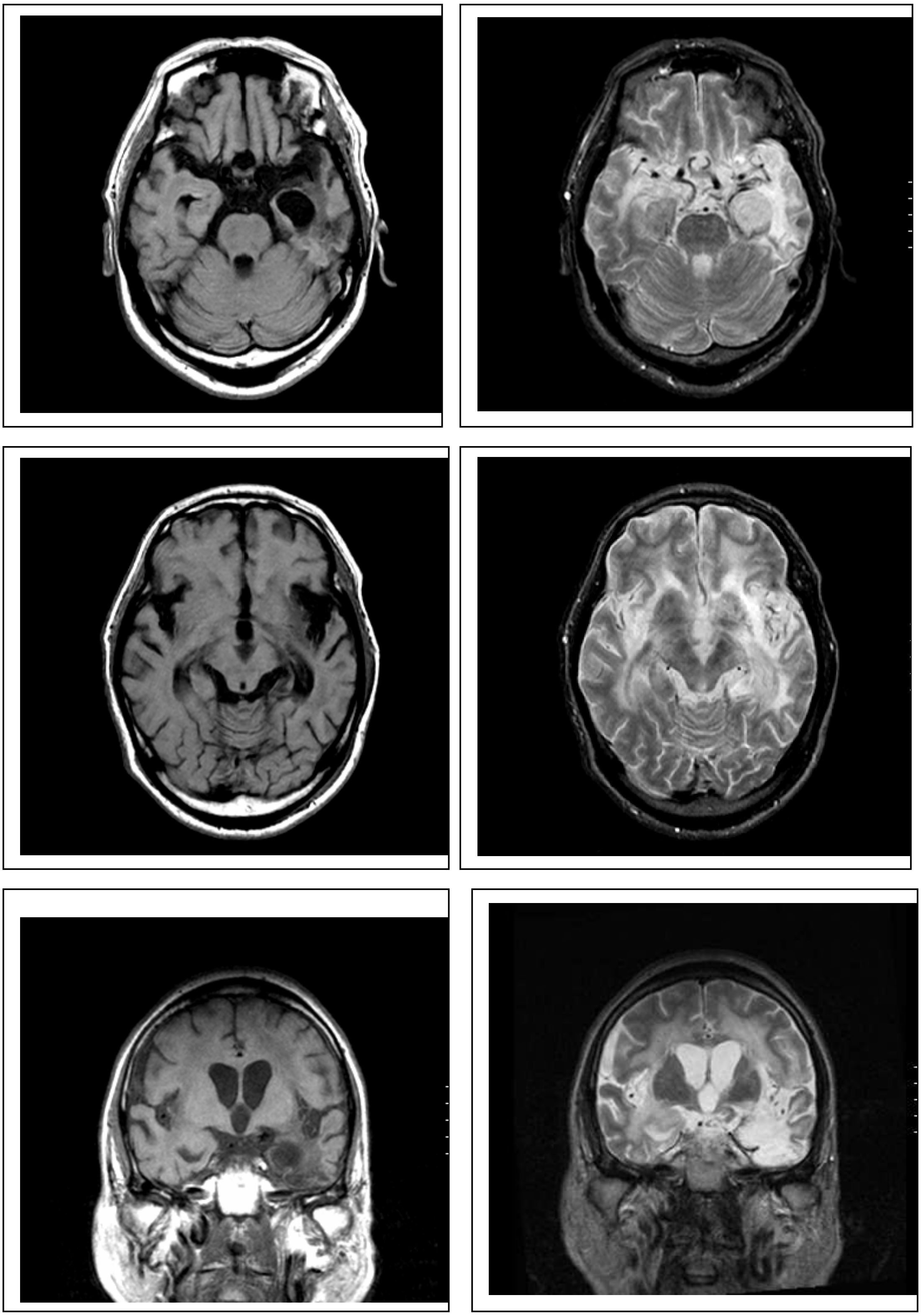


Fig. 23. YT's copying of the Rey's complex figure.

With respect to her calculation ability, (which was evaluated by the sub-test of the Japanese Standard Language Test for Aphasia: SLTA, 1975), YT's ability in addition and subtraction was relatively preserved, whereas she showed great difficulty with multiplication and division (see Table 5). YT's digit span (forward) was only 2 and she could not perform backwards correctly.

5.1.2. Case report of HW

Fig. 24. Horizontal and coronal sections of an MRI for HW in March 1999 (left: T1 weighted imaging, right: T2 weighted imaging).



HW (year of birth 1944), a 53-year-old male licensed tax accountant with 16 years of education, had suffered herpes simplex virus encephalitis in June 1997. After onset of the virus a CT scan revealed the damage to the left-inferior-temporal lobe. Fig.24 is an MRI scan for HW in March 1999. Before HW began to receive speech and language therapy as an outpatient at Yokufukai Hospital in January 1999 he had been hospitalised in two hospitals and had received speech and language therapy between November 1997 and April 1998.

(a) HW's spoken language

In the first assessment in January 1999 HW's spontaneous speech was fluent and well articulated but he showed severe word-finding difficulty. In picture description, he produced phonological errors (e.g. /ha-ta/ *flag*→/ha-to/ *pigeon*), and he often made more than one attempt in object naming. For instance, a toy pistol (the pronunciation is /pi-su-to-ru/) was named as /kja-be-tu/ *cabbage*, /ki-N-ko/ *safe*, /e-N-pi-tu/ *pencil* and /pe-N/ *pen*, which were all words unrelated to the target. In a picture-naming task, which is the sub-test of SLTA, HW scored only 5/20 (25%). He produced words and sentences which were not related to the target words, and circumlocution. He often produced multiple-responses (e.g. pencil →use, dog, cat, write; book→boiled rice, eat, studying hard; goldfish→cousin of a fish, it may be eatable). HW did not show a phonological cueing effect on his picture naming at all. HW’s Aphasia Quantity of the WAB was 75.9 (information = 8 and fluency = 8 in spontaneous speech; auditory comprehension = 8.95; repetition =9.2; naming = 3.8). Single word comprehension in the WAB was 56/60 (93%), in which he showed difficulty in distinguishing the names of body parts and between right and left. His accuracy of real object naming was 5/20 (25%). The number of words produced in a verbal fluency task within a 1-minute time limit was 3 for a semantic category (animal) and 1 for a letter (/ka/).

After about one-year of therapy (once a week), HW showed improvement in auditory comprehension and naming, and his Aphasia Quantity of the WAB became 81.1 (information = 8, fluency = 8 in spontaneous speech; auditory comprehension = 9.45; repetition = 9.4; naming = 5.7) in April 2000. His improvement in object naming was remarkable (5/20→10/20) and a phonological cueing effect was occasionally observed (2/10, 20%). At that time, the '*conduite d'approche*', which is sequences of phonological approximations (Joanette, et al., 1980), was frequently observed in his object naming responses. Indeed, half of his correct responses in the WAB object naming consisted of self-correction (e.g. *wool*/ke-i-to/→/ke-N/, /ki-gu/, /ke-i/, then the target name; *knife* /na-i-fu/ → /ho-u-cjo-u/ *kitchen knife*, /ta-i-fu/, /to-u-fu/*soybean curd*, /ha-i-fu/, then the correct name; *eraser* /ke-shi-go-mu/ → /ke-su-mo-no/ *something to erase*, /ke-mu-ri/ *smoke*, then he reached the target name). Language therapy was continued (once a week) and HW's Aphasia Quantity became 85.6 in March 2001 (his profile of the WAB is shown in Table 5). The volume of verbal fluency for both category and letter increased and HW produced 7 words for each condition.

(b) HW's written language

In the first assessment of the WAB in January 1999, HW showed good comprehension of written words (18/18) and written sentences (40/40). But oral reading errors in Kanji words were observed when HW spontaneously read aloud the written sentence for the comprehension task in the WAB. They were partially-correct responses, in which the pronunciation of a constituent Kanji character was produced, and they might be categorised as visual errors (不足

/fu-soku/ *shortage*→不安/fu-aN/*anxiety*; 関東/kaN-tou/ the name of region in Japan→ /kaN-oku/ nonword). In oral reading of single-character concrete/abstract Kanji words, HW's reading accuracy was 22/30 (73%) and 24/30 (80%), respectively. In the 50 Kanji Word Test (Sasanuma, et al., 1992), which was examined longitudinally, his score was 17/50 (34%) in July 1999, 40/50 (80%) in April 2000, and 47/50 (94%) in May 2001. In 1999 HW's oral reading errors were unrelated responses (25/33,76%) (e.g 舌/shi-ta/*tongue*→/ha-chi/; 観測/kaN-soku/ *observation*→ /koN-shitu/) and partially-correct responses (8/33, 24%), (e.g. 建設 /keN-setu/ *building* →/keN-shitu/). In 2000, unrelated responses had reduced (4/10, 40%) and partially-correct responses had increased (5/10, 50%). In April 2001 his three reading errors were of the same type, plus a sort of semantic error in which he read 下降/ka-kou/ *fall* as 'shita e oriru' *going down*.

With regard to HW's spontaneous writing, in the first assessment in January 1999 he could write sentences but Kanji words were very often written using Hiragana characters and he sometimes made errors in Hiragana writing (e.g. 行きました /yu-ki-a-shi-ta/ *went*→ひきました/hi-ki-ma-shi-ta/). HW could write Arabic numbers and many of the Kana characters in a Japanese syllabary list (23/46). In 2000, after one year of therapy, HW began to write Kanji words in dictation (4.5/6) and his writing scores of the WAB improved from 5.9→6.5. In 2001 HW's reading and writing score had further improved (9.5 and 8.9, respectively) and his spontaneous writing of the Kana characters in a Japanese syllabary list had increased (42/46) in April 2001.

(c) HW's non-linguistic cognitive abilities

HW's score for Raven's Coloured Progressive Matrices was 34/36 (the mean of an age-matched control is 34.2, SD2.1), showing that his nonlinguistic reasoning ability was preserved. HW's score for copying the Rey's complex figure was 34/36 (Fig.25) and his score in the Japanese version of the BIT was 144/146, indicating that his visuospatial skills were intact. HW's performance IQ of he Japanese version of WAIS-R, which was administered in February 2002, was 108. His calculation ability, evaluated by the subtest of SLTA, was good (see Table 5). His digit span was 4 for forward and 3 for backward.

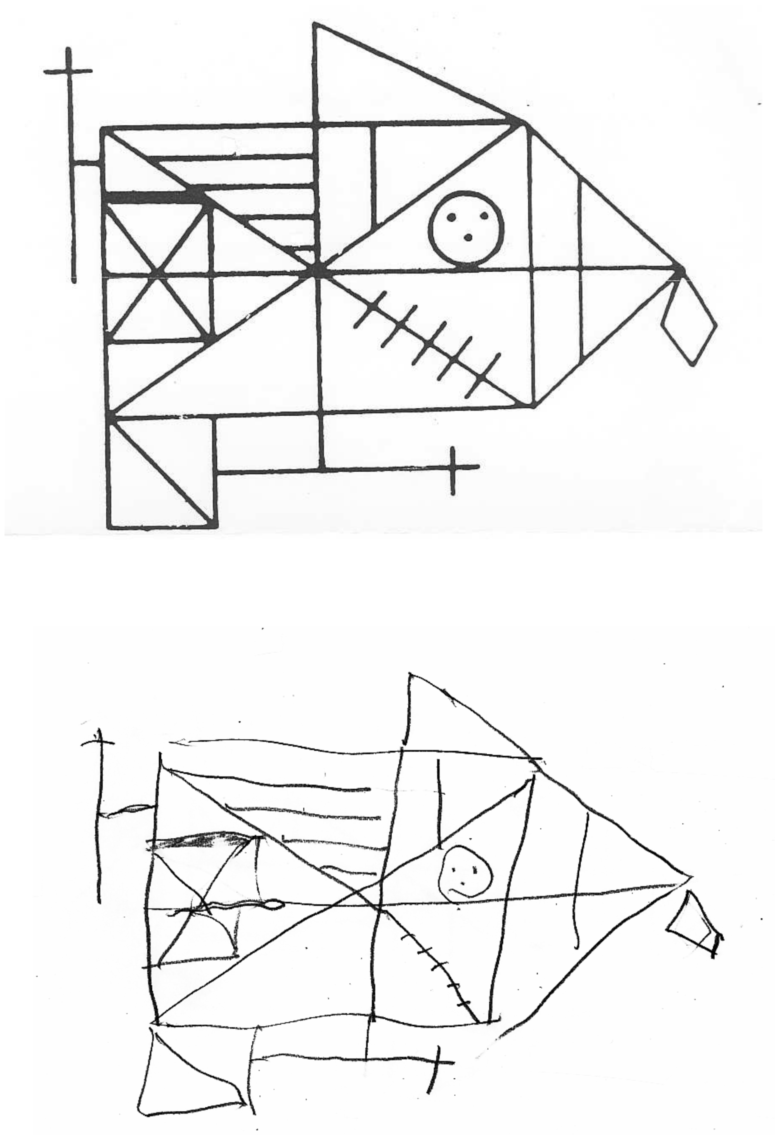
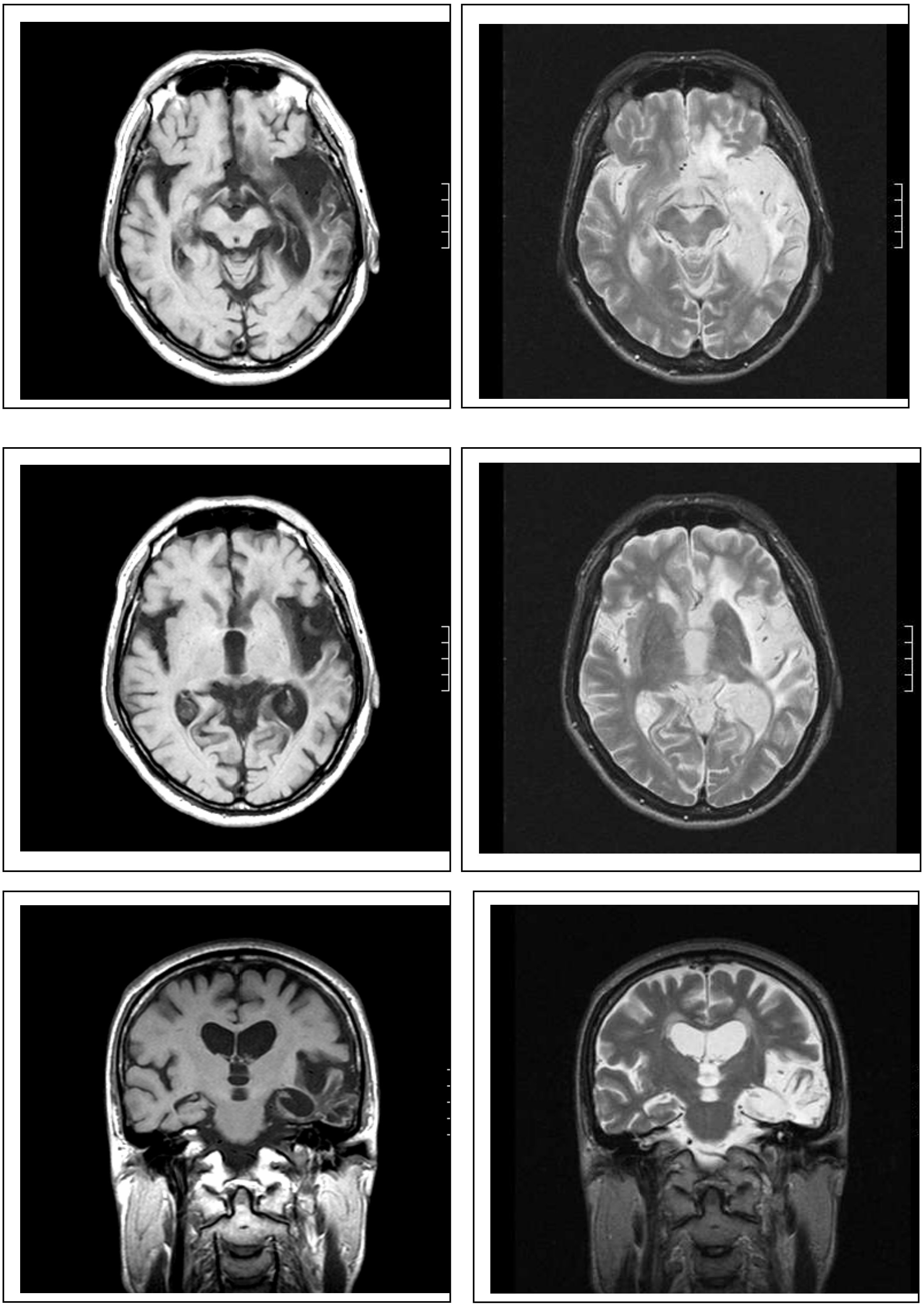


Fig. 25. HW's copying of the Rey's complex figure.

5.1.3. Case report of SO

Fig. 26. Horizontal and coronal sections of an MRI for SO in December 2001 (left: T1 weighted imaging, right: T2 weighted imaging).



SO (year of birth 1932), a 65-year-old male patent office worker with 16 years of education, had suffered herpes simplex virus encephalitis in September 1997. After the onset of the virus, a CT scan revealed the damage to the left-temporal lobe. Fig.26 is an MRI scan for SO in December 2001. SO had been hospitalised in Yokufukai Hospital from September 1997 to November 1997. From October 1997, he had received language therapy as an inpatient (5 times a week) and an outpatient (once a week), in the same hospital.

(a) SO's spoken language

In the first assessment in October 1997, just one month after onset of the illness, SO's spontaneous speech was fluent and well articulated, but showed a marked word-finding difficulty. In picture description he produced a limited number of content words and unrelated words in the form of sentences. In real object naming of the WAB, SO could not name one object. His responses were unrelated words (e.g. pencil →ball; tooth brush →knife), nonwords (e.g. *ash trey* /hai-zara/→/shin-guushi/, /shi-game/), and empty words (e.g. glass → ordinary thing). After this task SO asked the target names and they were presented to him, but he could not accept the orally presented target words as the names of stimulus objects. SO's auditory comprehension of single words was very poor (19/60, 32%). SO’s Aphasia Quantity of the WAB was 37.4 (information = 2 and fluency = 8 in spontaneous speech; auditory comprehension = 3.1; repetition =5.6; naming = 0). SO was given language therapy (once a week) and showed improvement. In January 1999, his Aphasia Quantity of the WAB became 64.8 (information =6, fluency = 8 in spontaneous speech; auditory comprehension = 7.2; repetition = 8.2; naming = 3.0). In November 2001 SO's Aphasia Quantity was 68.5 (his profile of the WAB is shown in Table 5) and his verbal fluency had also improved (7→8 for animal and 4→6 for /ka/).

However, SO's ability in real object naming remained severely impaired (0/20 in October 1997; 3/20 in January 1999 and November 2001). SO's naming errors were mainly in unrelated words and nonwords which were neologistic jargon, and their phonology was a combination of limited mora (e.g. /ha-gu/ /shi-gu/ /na-gu/ /ha-gu-re/ /na-gu-shi/) in 1997, or a synthesis of limited words (e.g. /fude-piN/ *brash-line*, /piN-seN/ *pin-line*, /kasa-piN/ *umbrella-pin*, /sara-piN/ *plate-pin*) in 1999. In November 2001, SO made three nonword responses (/deN-bushi/, /saN-piru-bera/, and /kasa-bu/), a phonological error (/pi-su-to-ru/ → /pi-su/to/), and unrelated word responses, which consisted of only three words (pencil, letter, and pen). In a picture-naming task, which is the subtest of SLTA, an improvement in SO's picture naming was detected (4/20 (20%) in December 1997, 8/20 (40%) in October 1998, and 9/20 (45%) in June 1999), and his semantic errors (e.g. boiled rice →meal, lunchbox; crocodile →it is in the sea or river) gradually increased (2→4→5). Like HW, SO did not show a phonological cueing effect on his object/picture naming at all.

(b) SO's written language

SO's score of comprehension of written words and sentences in the WAB, as examined in October 1997, December 1997, January 1999and November 2001 was 6/18, 10.5/18, 14.5/18 and 18/18 respectively for written words, and 14/40, 26/40, 38/40 and 40/40 respectively for written sentences. In the four assessment points his reading scores of the WAB were 2.9, 5.15, 7.65 and 7.95. In oral reading of single -character concrete Kanji words, evaluated in November 1997, his reading accuracy was 5/60 (8%). His reading errors were unrelated words (18/55, 33%), no responses (18/55, 33%), nonwords (15/55, 27%), and semantic errors (4/55, 7%). In the 50

Kanji Word Test (Sasanuma, et al., 1992), which was examined longitudinally, his score was 8/50 (16%) in December 1997, 17/50 (34%) in October 1998, 27/50 (54%) in December 1999, and 29/50 (58%) in June 2001. The vast majority of SO's oral reading errors were unrelated responses, including words and nonwords (e.g 都市 /to-shi/ *city*→/teN-jyo/ *ceiling*; 朝 /asa/ *morning*→/hana/ *flower;* 公園 /kou-eN/ *park* →/eN-shi/).

With regard to SO's spontaneous writing, in October and December 1997 he could write several content words using Hiragana characters in picture description, as well as Arabic numbers and many of the Kana characters in a Japanese syllabary list (15/46 in October 1997→ 39/46 in December 1997). SO's dictation of Kana transcriptions from Kanji words (e.g. /e-N-pi-tu/ 鉛筆 *pencil*→えんぴつ) was perfect even one month after the onset of the illness. This was in contrast with his difficulty in dictation of Kanji words, in which he produced a combination of unrelated Kanji characters (e.g. /to-kei/時計 *clock*→ 職章). In the assessments carried out in January 1999 and November 2001, SO's writing of content words was still poor and he wrote unrelated words, but he was able to write all Kana characters in a Japanese syllabary list spontaneously. Thus, SO's writing scores of the WAB had improved (4/10→6.2/10→6.85/10→7.5/10 in the four assessment points).

(c) SO's non-linguistic cognitive abilities

SO's score for Raven's Coloured Progressive Matrices was 30/36 (the mean of an age matched control is 29.2, SD5.4), showing that his nonlinguistic reasoning ability was within the normal range. SO's score for copying the Rey's complex figure was 33/36 (Fig.27) and his score in the Japanese version of the BIT was 140/146, thus indicating that his visuospatial skills were preserved.

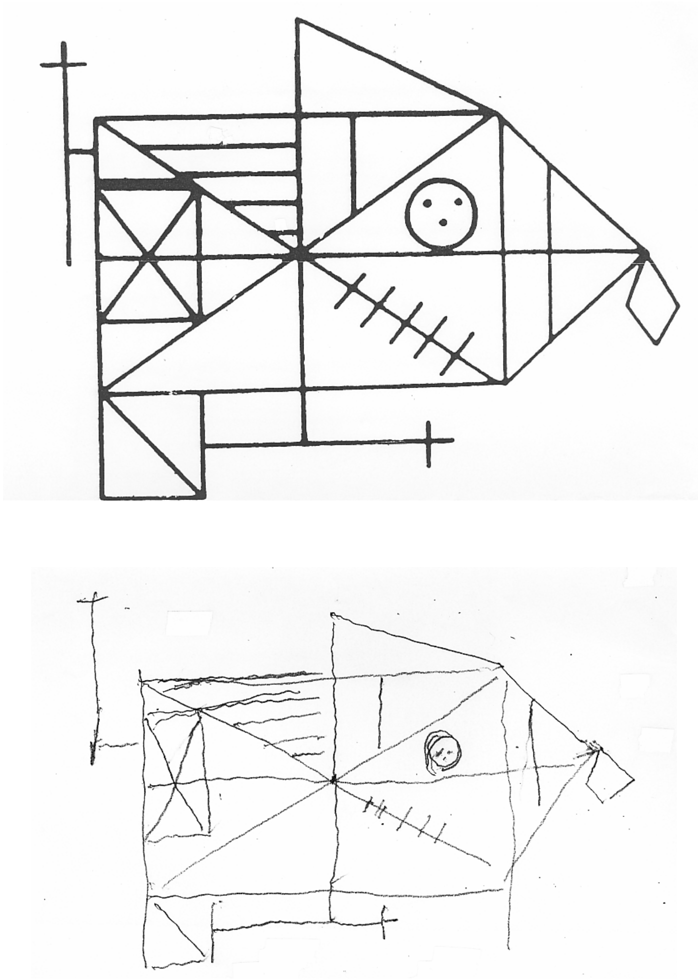


Fig. 27. SO's copying of the Rey's complex figure.

SO's performance IQ in the Japanese version of WAIS-R, administered in March 2002, was 105. SO's calculation ability, evaluated by the sub-test of SLTA, was perfect (see Table 5). His digit span was 4 for forward and 3 for backward.

5.1.4. Case report of ME

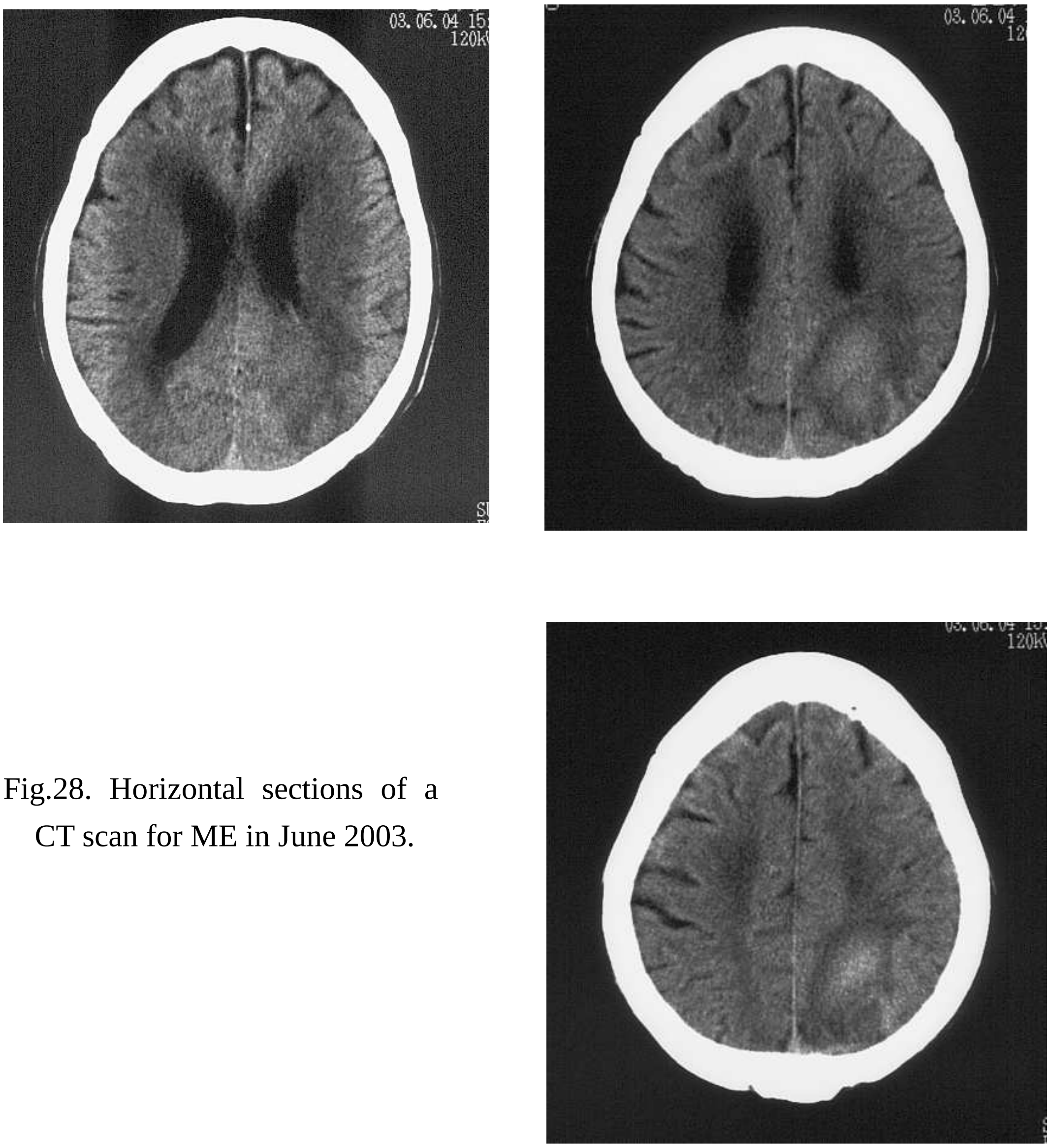


Fig.28. Horizontal sections of a CT scan for ME in June 2003.

ME (year of birth 1918), an 84-year-old male retired public officer with 16 years of education, had suffered a haemorrhage in April 2003. A CT scan in June 2003 (Fig.28) had revealed the lesion in the left parieto-occipital lobe (an MRI scan was not carried out for ME for medical reasons). ME was an inpatient in a hospital in

Tokyo for about 2 months from April 2003, and in June 2003 he was transferred into Yokufukai Hospital where he had been hospitalised until the end of July 2003. ME had received language therapy between June and August 1997 as an inpatient (5 times a week) and as an outpatient (once a week). Since ME had been hospitalised in another institution in September 2003, due to pulmonary emphysema, language therapy for ME had been terminated.

(a) ME's spoken language

In the first assessment of the WAB in June 2003 ME's spontaneous speech was fluent and well articulated, but showed mild word-finding difficulty with moderate impairment of auditory comprehension. In picture description ME could explain a scene fairly well and his accuracy of object naming was good (19/20, 95%).

However, he showed difficulty in following oral instructions of simple and complex sentences (22/80, 28%) due to his misunderstanding of prepositional particles. Thus, ME's Aphasia Quantity of the WAB was 78.7 (information = 8 and fluency = 8 in spontaneous speech; auditory comprehension = 6.15; repetition =9.0; naming = 8.2). After one month of intensive therapy, ME showed improvement in auditory comprehension, spontaneous speech, and naming, and his Aphasia Quantity rose to 85.6 (information = 9 and fluency = 9 in spontaneous speech; auditory comprehension = 7.6; repetition =8.8; naming = 8.4). The number of words produced in a verbal fluency task within a 1-minute time limit had also increased from 10 to 12 for a semantic category (animal) and from 6 to 7 for a letter (/ka/).

It is worth highlighting the influence of ME's visual deficit on his naming performance. White-and-black line drawings of 28 nouns, whose familiarity matched the 20 real objects of the WAB's naming task, were used in a picture-naming task (the mean familiarity and range for 28 picture stimuli and 20 real object stimuli of the WAB were 6.0 (4.4-6.4) and 6.0 (4.3-6.5) respectively). As shown in Table 5, ME's accuracy of picture naming was 68% (19/28) and he showed a clear discrepancy between picture naming and object naming (95% correct, 19/20). Furthermore, he made not only semantic (4/9, 44%), circumlocution (2/9, 22%) and no response errors (1/9, 11%), but also 2 visual errors (toaster →radio; refrigerator→chest). Other subjects (YT, HW, and SO), whose visuospatial abilities were preserved, did not show such a discrepancy and did not make visual errors.

(b) ME's written language

In the assessment of the WAB in June 2003, ME showed good comprehension of written words (17.5/18) and a relatively preserved comprehension of written sentences (34/40). However, ME made errors in oral reading of content words (e.g. もと/mo-to/→/so-to/) and prepositional particles (e.g. で/de/ →/o/), written in Hiragana characters. On the other hand, ME showed preserved oral reading of Kanji words. In the 50 Kanji Word Test (Sasanuma et al., 1992) ME produced only one visual error (幹 /miki/ *trunk* →幹部 /kaN-bu/ *executive*), but he self-corrected this error and his accuracy in this test was 100%. His reading score of the WAB had slightly improved after one month of therapy (7.3/10 → 7.8/10).

With regard to ME's spontaneous writing, examined in July 2003, he almost always used Kana characters in the task of picture description, and made writing errors, including many nonwords and empty phrases. As shown in Fig.29, ME could write Arabic numbers and many of the Kana characters in a Japanese syllabary list (24/46).

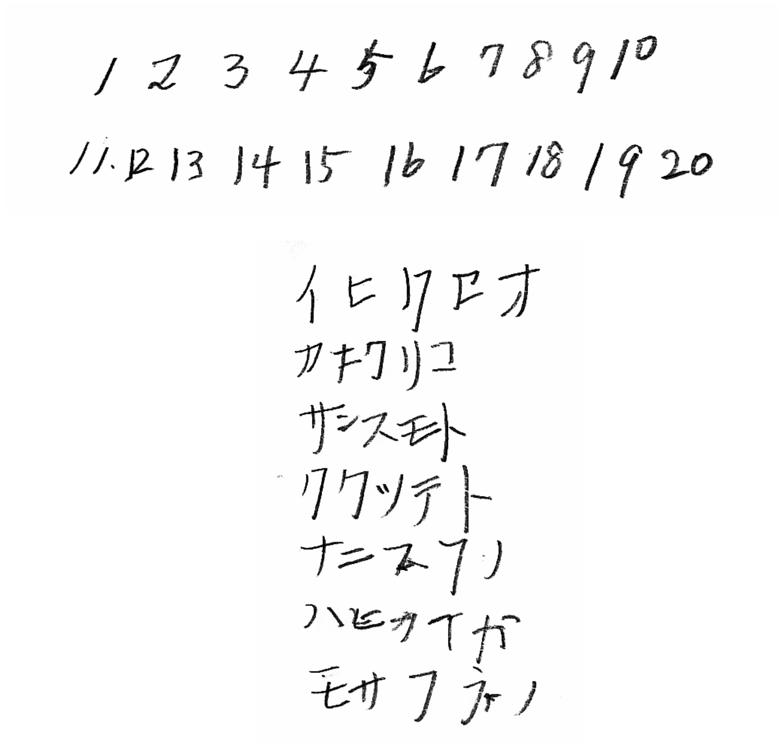
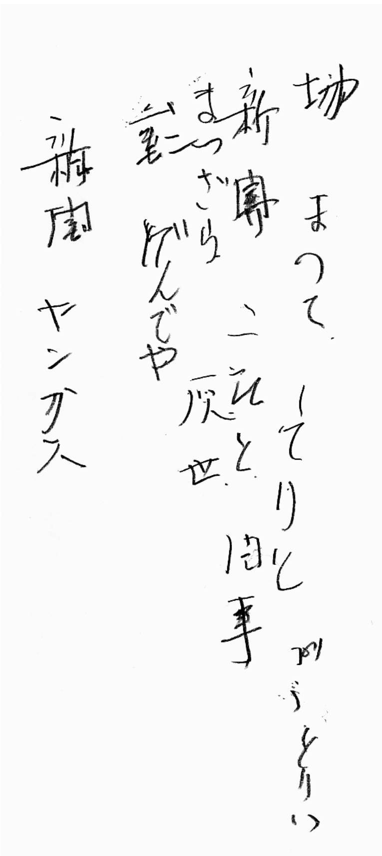


Fig.29. ME's spontaneous writing of Arabic numbers and Katakana characters.



切手　きって　とけい　時計
新聞　けいと　毛糸
はいざら　灰皿
鉛筆　えんぴつ
新聞　シンブン

Fig. 30. ME's writing in dictation of spoken words and correct written words.

ME, however, showed great difficulty with writing Kana and Kanji characters in spoken word dictation (Fig.30). In addition, a sort of *constructional agraphia* (Yamadori, 1985) was observed in his Kanji character writing in which ill-managed construction or incomplete Kanji characters were seen. Thus, ME's writing scores of the WAB were very poor (3.6/10).

(c) ME's non-linguistic cognitive abilities

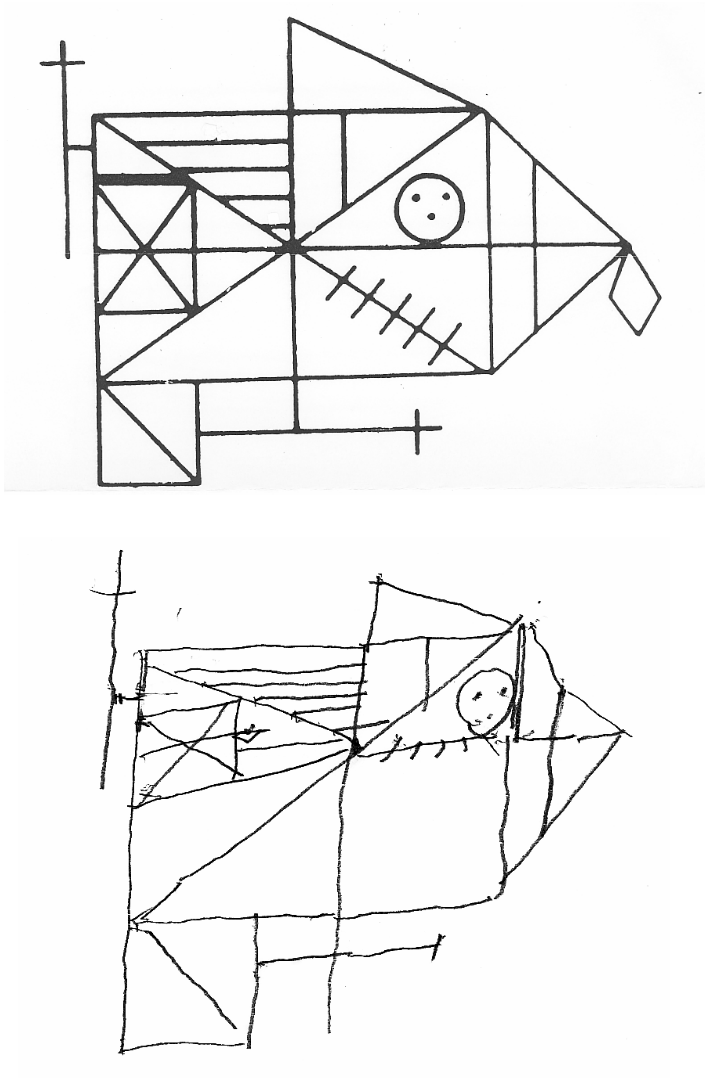
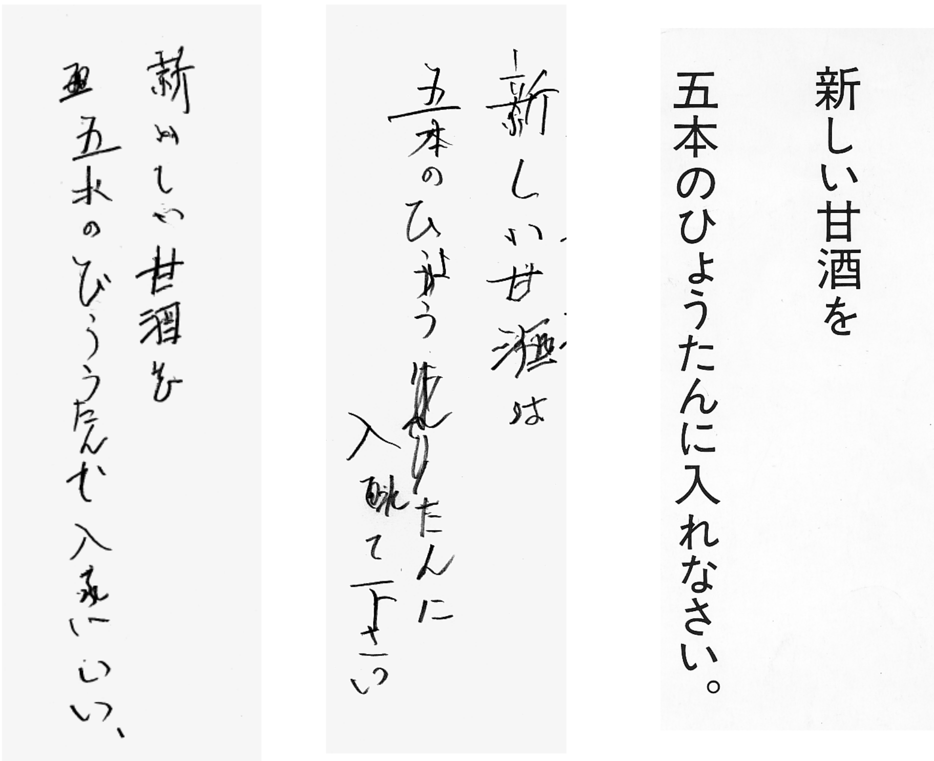


Fig. 31. ME's copying of the Rey's complex figure.

ME's score of Raven's Coloured Progressive Matrices, and the copying of the Rey's complex figure (Fig.31) was 12/36 (the mean of an age matched control is 24.9, SD5.3) and 28/36, respectively. The copying of a written sentence was relatively preserved, but he showed self-correction and instability of response (Fig.32).



22nd July 2003 18th July 2003 The model

Fig. 32. ME's copying of a written sentence at different times.

The Visual Perception Test for Agnogia (Japanese Society of Aphasiology, 1997), administered in July 2003, revealed a) right spatial neglect, b) reduced visuo-constructive ability, and c) impaired recognition of an unknown face. Fig.33 is ME's copying of a cube in this test. ME's right spatial neglect affected his daily activities. His physiotherapist and his occupational therapist pointed out that ME often knocked into a pillar or person located on his right hand side, and he did not wash the right part of body when having a bath. His performance IQ of the Japanese version of WAIS-R was 72, which reflected his visuo-constructive disorder, and this contrasted with his relatively preserved verbal performance (his VIQ was 93).

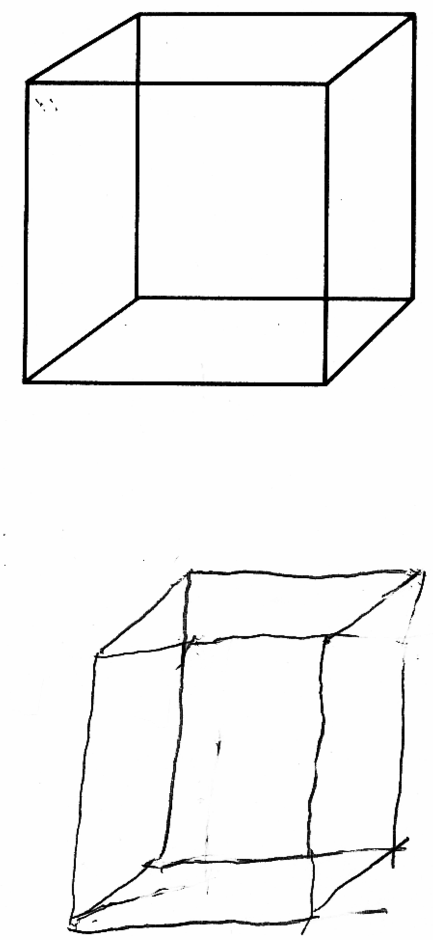


Fig. 33. ME's copying of a cube.

ME's calculation ability, evaluated by SLTA, was also impaired in subtraction, multiplication and division (see Table 5). Taking the above together, it was clear that ME's visuospatial abilities had deteriorated. In order to evaluate character recognition a same/different judgment task was used for both Kanji and Kana script

(Sato, 1998)[1]. ME's performance in this task is shown in Table 6. Although ME's performance of Kanji discrimination had deteriorated slightly under visually similar conditions, his ability to recognise complex Kanji characters, horizontally, was fairly good. Not surprisingly, his recognition of visually simple Kana characters was good. With respect to ME's digit span, forward was 4 and backward was 2.

Table 6 ME's performance in same/different judgments of Kanji and Kana script (One-second presentation)

Script type	Visual complexity	Condition of presentation	No.of correct
Kanji	High complex	visually similar	74/80
	High complex	visually dissimilar	79/80
Kanji	Low complex	visually similar	75/80
	Low complex	visually dissimilar	79/80
Kana		visually similar	90/92
		visually dissimilar	92/92

5.1.5. Summary of the neuropsychological profiles for the four subjects

The neuropsychological profiles of the four subjects were quite different. The spontaneous speech of YT was non-fluent, whereas the other subjects kept their fluent speech. With respect to naming disorders, which are the central symptom of aphasia, ME's level of deficit was mild and YT's was moderate, but HW and SO showed severe deficit. In particular, SO's naming impairment was prominent and he did not show significant improvement. For all four subjects their naming errors were also distinctive. YT made semantic paraphasia, semantically associated errors (gesture and onomatopoeia related to the target), and circumlocution errors. HW

[1] This task was devised for a patient, YM, with visual agnosia and letter-by-letter reading, and who showed profound impairment in Kanji character discrimination even in a 2-second presentation. Kanji character stimuli were manipulated by visual complexity and similarity, and they were tested in 4 conditions: High complex/similar (e.g. 殼-穀), Low complex/ similar (e.g.北-比), High complex/ un-similar (e.g.積-属), Low complex/un-similar (e.g.己-欠). Since Kana characters, visually simple script and visual complexity cannot be manipulated only visual similarity for Kana characters was manipulated (e.g. similar:あ-お; dissimilar:ふ-こ).

made multiple errors, including unrelated words/nonwords and broad explanations of the target. HW often tried to correct his own responses, which might be described using the term ‘conduite d’approche’ (Joanette, et al., 1980). SO made many unrelated words/nonword responses, in which empty words and a limited number of unrelated words were often produced. ME made mainly semantic errors, which shared the same semantic category with the target word, and also made visual errors. Phonological cueing facilitated the naming performance by YT and ME, but HW and SO did not show a phonological cueing effect on their naming. These different performances of spoken language tasks indicate that the underlying nature of aphasic symptoms is different in the four subjects.

With respect to non-linguistic cognitive abilities, YT, HW and SO all showed preserved visuo-contractive abilities, whereas ME had a visuo-constructive disorder and right spatial neglect.

5.2. Design of the experimental tasks

The experimental tasks in this thesis were designed on the basis of the research framework presented in Chapter 4 in order to address the research questions.

Based on the framework of Research Question 1, the oral reading experiments were designed using the psycholinguistically well-manipulated reading stimuli, whose variables were used for diagnosis of English acquired dyslexia (i.e. lexicality: words, consistency and concreteness/imageability). Except for consistency, which cannot be manipulated in Kana strings, all the variables were manipulated in both Kanji and Kana strings. Thus, the oral reading stimuli consisted of: 1) Kanji/Kana nonhomophonic nonwords, 2) Kanji/Kana pseudohomophones, 3) Kanji words manipulated by consistency, and 4) Kanji/Kana words manipulated by concreteness/imageability. Furthermore, Kanji/Kana words manipulated or controlled by word length were also used, because the word-length of Kanji words is shorter than that of Kana words (see Chapter 3).

As the literature review in Chapter 3 revealed, classical case studies of Japanese acquired dyslexia did not use a) Kanji nonhomophonic nonwords, b) Kanji pseudohomophones, c) Kanji words manipulated by consistency, and d) Kanji/Kana words manipulated by imageability. Even in recent case studies, Fushimi (2005) only used the reading stimuli manipulated by the critical three variables (lexicality, consistency and imageability) in his follow-up study for KT (Patterson et al., 1996b), a phonological dyslexic patient,. Thus, this thesis is the first attempt to examine the oral reading performance of multiple cases using systematically manipulated reading stimuli.

Based on the framework of Research Question 2, the bi-scriptal influence was examined by comparing the subjects' reading accuracy of Kanji and Kana strings which were equally manipulated by psycholinguistic variables except consistency as explained above. That is, the reading accuracy in the oral reading experiments for Research Question 1 was re-analysed in term of Kanji vs. Kana framework. This design allows us to distinguish a script-type effect and psycholinguistic variables effects.

Based on the framework of Research Question 3, the experimental tasks were designed to verify the semantic impairment hypothesis and phonological impairment hypothesis. Thus, the tasks, which require semantic and phonological functions, were tested. Moreover, because the triangle model can predict that performance in all language tasks reflects the nature of principal impairment (i.e. semantic or phonological impairment), tasks, which can examine i) the cross-domain effect, and ii) the phonological cueing effect, were designed.

5.3. Description of the experimental tasks

The experimental tasks consisted of i) the original tests which were created by the author, ii) the tests which were devised by other researchers; and iii) the modified tests, which developed or adapted the original tests created by other researchers. In each section, the source of the experimental tasks is mentioned.

5.3.1. Assessment of semantic function

1) Overview

Since both words and pictures/real objects can activate semantics, assessments of the semantic function were constructed using 6 tests with both lexical and non-lexical stimuli. The objectives of each assessment test are as follows:

a) The Pyramid & Palm Tree Test (Howard & Patterson, 1992) permits assessment of semantic associative knowledge via three types of stimuli for identical items (i.e.

non-verbal, spoken and written word stimuli).

b) The Tiger & Lion Test (Sato, 1996) permits i) assessment of spoken word comprehension in both the between-category condition and the within-category condition, informing the ability to distinguish semantically similar items via the spoken word; and ii) the naming ability for the identical items of spoken word comprehension.

c) The Written Concrete Word Comprehension Test (Sato, devised for this thesis) evaluates written word comprehension in the within-category condition, informing the ability to distinguish semantically similar items via the written word.

d) The Abstract Word Comprehension Test (Uno ed., 2003) evaluates abstract knowledge through the spoken/written word.

e) The Single-Character Kanji Word Synonym Judgment Test (Sato, devised for this thesis) permits the evaluation of concrete and abstract knowledge through the spoken/written word.

f) The 70 Picture Naming Test (Sato, devised for this thesis) evaluates whether familiarity and/or imageability affect(s) picture-naming ability.

2) Materials and Procedure

a) The Pyramid & Palm Tree Test (modified version for Japanese subjects):

Patterson et al. (1995) modified several test items in the original test (Howard & Patterson, 1992) in order to investigate a Japanese neurological patient, and they created 49 test items. The author of this thesis created and added 3 test items to Patterson et al. 's version of the Pyramid and Palm Tree Test. The number of test items was matched to the original test. Three versions of the test (3 pictures, 1 spoken word to 2 pictures, 1 written word to 2 pictures) were used. Patients were asked to match 52 test stimuli - presented in the forms of pictures, spoken words, and written words in each version - to a semantically associated item among 2 picture stimuli.

b) The Tiger & Lion Test (Sato, 1996)

This test comprised a spoken word comprehension task and a picture-naming task. In the comprehension task 60 test stimuli, formulated using 6 exemplars from 10 categories (human body parts, fruit, vegetables, animals, birds, vehicles, musical instruments, kitchen utensils, carpenter's tools and clothing), were tested by a spoken word-picture matching procedure under 2 different sets of conditions. The target picture (e.g. banana) was presented along with 5 within-category distracters (e.g. apple, grape, strawberry, watermelon, and pineapple) in the same category condition, and with 5 between-category distracters (e.g. elephant, truck, fork, trousers, and foot) in a different category condition. In the picture-naming task the patients were asked to name 60 pictures, which were identical to the test items of the comprehension task. Stimulus pictures were taken from 'A standardised set of 260 pictures' created by Snodgrass and Vanderwart (1980) and the black-and-white pictures were copied and enlarged to 120%. The auditory comprehension task in within-category condition was carried out first, and 3 days later the auditory comprehension task in between-category condition was administered. After 3 days, the picture-naming task was carried out.

c) The Written Concrete Word Comprehension Test (Sato, devised for this thesis) Using a written word-picture matching procedure 42 Kanji written words, made up of between 1 and 3 characters, and 42 Katakana written words comprising between 2 and 6 characters were tested. Both the 42 Kanji words (e.g. 熊 *bear*) and the 42 Katakana words (e.g. ハーモニカ *harmonica*) came from the same 7 semantic categories (stationery, musical instruments, kitchen utensils, vehicles, animals, food, and house related objects). Fig. 34 shows two example tasks of this test. The target picture was presented with 5 within-category distracters whose names were written in the same script as the target. The stimulus words were printed on a Xerox inkjet printer. The font was MS Mincho in Japanese and it was printed in size 48-point in bold black, and was then cut to size and encased in clear plastic film on cards. The stimulus pictures were taken from *'Picture Card, 2001'* (Suzuki, ed., 1996) and the original black-and white pictures were copied and encased in clear plastic film in a file.

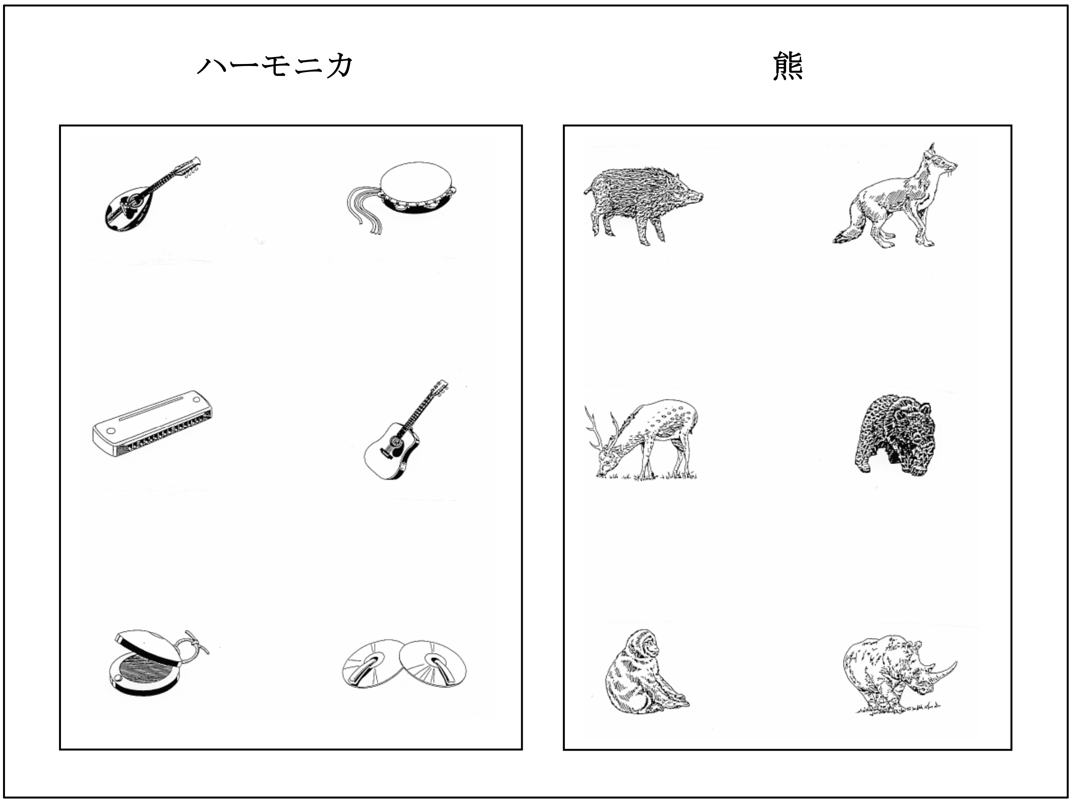


Fig. 34. Examples of tasks from the Written Word Comprehension Test.

d) The Abstract Word Comprehension Test (Uno, ed., 2003)

In this test, 45 abstract words were tested using spoken/written word-picture matching tasks. The written word stimuli were all 2-character Kanji words (e.g. 親切 *kind*, 知識 *knowledge*). In both tasks, the target picture was presented with 2 semantic distracters, 2 phonological distracters and 1 unrelated distracter.

e) The Single-character Kanji Word Synonym Judgment Test (Sato, devised for this thesis):

The test items consist of 52 concrete words and 52 abstract words, all of which were single-character Kanji words (e.g. 窓 *window*, 幻 *phantom*). Patients were asked to match stimuli to the target synonym, which was presented with a semantically associated distracter and a visually similar distracter [e.g. 車 *car* →乗物 *vehicle* (target), 交通 *traffic* (semantic associative), and 編物 knit (visual)]. Each test item was presented visually or orally. The written words were printed with MS Mincho in Japanese by a Xerox inkjet printer and used for visual presentation. In oral presentation, stimuli were repeated when a patient requested.

f) The 70 Picture Naming Test (Sato, devised for this thesis)

Seventy target words were manipulated by familiarity (Amano & Kondo, 1999) and imageability (Wydell, 1991). The target nouns were animate or inanimate objects (e.g. high familiarity and high imageability words: telephone; low familiarity and low imageability word: camel). Since the number of high familiarity words with a low imageability band was small, this test did not contain the words with this condition. The characteristics of the stimuli with 14 words in each of the 5conditions are shown in Table 7. Stimulus pictures taken from 'A standardized set of 260 pictures' created by Snodgrass and Vanderwart (1980) were scanned and were displayed in black on a white background on a 14-inch computer screen, and enlarged to double the size, using Microsoft Power Point 2000.

Table 7 Characterisitcs of stimulus materials of the 70 Picture Naming Test

	High Familiarity	Medium Familiarity		Low Familiarity	
	High Imag.	High Imag.	Low Imag.	High Imag.	Low Imag.
Number	14	14	14	14	14
Mora (range)	3.6 (2-6)	4.1 (3-5)	3.5 (2-5)	3.1 (2-4)	3.0 (2-5)
Familiarity (range)	6.4 (6.3-6.5)	6.2 (6.0-6.3)	6.1 (6.0-6.3)	5.8 (5.5-5.9)	5.8 (5.6-5.9)
Imageability (range)	6.6 (6.2-6.9)	6.6 (6.2-6.8)	5.5 (4.4-6.0)	6.5 (6.2-6.9)	5.4 (4.4-6.0)
Frequency (range)	3.3 (2.4-4.8)	3.0 (1.8-4.0)	2.6 (2.0-3.3)	2.8 (1.5-3.5)	2.6 (1.3-3.5)

Familiarity=Auditory familiarity; Imag.=imageability; Frequency=written word frequency

5.3.2. Assessment of phonological function

1) Overview

The phonological function refers to phonological activation, which does not emerge from written strings and objects/pictures. Phonological assessments were constructed through four kinds of task: i) phonological discrimination, ii) phonological recognition based on segmentation, iii) phonological manipulation, and iv) repetition with 8 tests. While i) and ii) do not require phonological output, iii) and iv) involve articulations. All tasks except phoneme discrimination and mora repetition were manipulated by lexicality (word vs. nonword) or imageability (high vs. low).

2) Materials and Procedure

a) The Phoneme Discrimination Test (Endo, Tsunoda, Yanagi, Ichikawa, & Isahara, 2000)

This test assesses phoneme discriminatory ability and consists of 26 identical pairs and 26 different pairs, which include 10 different phonemes (/d/, /g/, /t/, /z/, /m/, /n/, /k/, /s/, /p/, /b/). Patients were asked to judge whether orally presented stimuli were the same or different. In addition to this original test, patients were asked to repeat 20 single-mora (CV), in which consonant were taken from the original test.

b) The Mora Discrimination Test (Sato, devised for this thesis)

This test assesses mora discriminatory ability. The stimuli of this test were minimal pairs of 60 words (e.g. /ha-ke/ *brush* vs. /ha-ko/ *box*) or 60 nonwords (e.g. /su-ko/ vs. /nu-ko/), which differ only in one phoneme. Patients were required to use same-different judgement in relation to the presented pair. Words were spoken with a natural accent, whereas nonwords were presented with a high-low accent which is common for Japanese nouns in one condition, and with a flat accent for those in another condition.

c) The Mora Recognition Test (Sato, expanded test based on the test devised by Monoi & Sasanuma, 1975)

This test assesses the ability to recognise a mora, which is a minimal phonological unit of spoken Japanese. The original test used 3-mora words, which include /ka/. This test consists of 3-mora words and 3-mora nonwords. Three sets of 48 3-mora spoken words were prepared. In each set one of three morae (/ka/, /su/ and /mo/) was designated, respectively, as the target mora. In each set half of the words included the target (e.g. /ki-N-ka/, /su-mi-re/, /mo-ja-si/) and half did not. The target mora appeared in the initial, middle, or final position in equal proportion (8 for each). Three sets of 48 3-mora nonwords were created from each word in 3 sets of 48 words, either by transposing or by substituting the second and third mora of the base word. Patients were asked to judge whether or not the target mora was included in the individually presented spoken word or nonword stimulus.

d) The Mora Segmentation Test (Sato, expanded test based on the test devised by Monoi & Sasanuma, 1975)

This test evaluates the ability to segment a spoken string consisting of Japanese morae. The original test devised by Sasanuma and Monoi used only 24 3-mora words, which include /ka/. This test consists of 72 3-mora words and 72 3-mora nonwords. The stimuli were the same as in the Mora Recognition Test: 24 3-mora words or nonwords, each including one of the target morae (i.e. /ka/, /su/, /mo/). Patients were asked to indicate the position of the target mora in a spoken word, or nonword, by pointing to an appropriate position selected from the 3 horizontally placed circles representing the 3-mora positions.

e) The Mora Deletion and Mora Concatenation Test (Sato, devised for this thesis)

This test assesses phonological manipulation ability and consists of the mora deletion task and the mora concatenation task. In the mora deletion task, patients were given a spoken word or nonword and asked to delete the initial mora and say what remained. Forty 3-mora words and forty 3-mora nonwords were tested individually. The nonwords were formed from the word stimuli by either transposing or substituting the second and the third mora of the base word (e.g. /hi-yo-ko/ *chick* →/hi-ko-yo/). The mora concatenation task used the same forty 3-mora words and forty 3-mora nonwords as in the mora deletion task. Patients were given a sequence of 3 spoken morae, constituting a word or a nonword, and were asked to concatenate them into an uttered block of speech. In condition one, each of 3morae was presented separately, with a pause at the rate of one mora per second. In condition 2, one mora was presented by a pause of one second, then followed by a continuous sequence of 2 morae.

f) The Word and Nonword Repetition Test (Sato, devised for this thesis)

This test permits assessment of the lexicality effect on immediate repetition. The stimuli consist of 120 Katakana concrete words (3-5 mora), and 120 nonwords (4-mora). The nonwords were created from the 4-mora words in this test. Forty nonwords were formed by transposing the second and the third mora of the base word (e.g. /a-i-ro-N/ *iron*→/a-ro-i-N/); 40 more by replacing one of the constituent morae with different morae (e.g. /su-to-re-su/ *stress*→/su-to-ri-su/); and a further 40 nonwords were formed by randomizing the order of mora sequence (e.g. /ma-ra-so-N/ *marathon*→/so-ma-N-ra/). Patients were asked to repeat each of these words/nonwords which were presented individually.

g) The Immediate and Delayed Repetition Test (Fushimi, unpublished)

This test permits us to assess the effect(s) of imageability and word familiarity on repetition in 2 conditions. The stimuli were 100 words manipulated by familiarity (Amano & Kondo, 1999) and imageability (Ogawa & Inamura, 1974 and Itukushima et al., 1991). The stimuli of this test were identical with the 100 Two-Character Kanji Word Test (Fushimi, unpublished), which is a oral reading task in this thesis, and characteristics of the stimuli was shown in Table 13. This test consists of the two types of repetition. The immediate repetition was the usual repetition task in which patients were required to repeat each word after oral presentation. In the delayed repetition task, following an oral presentation of the stimulus, patients were asked to count from one to five and then to repeat each word.

h) The Serial Repetition Test (Sato, devised for this thesis)

This test evaluates the imageability effect on more demanding repetition tasks. The 3- and 4-mora words manipulated by imageability (Wydell, 1991) with 3 bands (high, medium, and low) were used as the stimuli of this test, which consists of 2-serial recall for 72 words and 3-serial recall for 48 words. Table 8 presents the characteristics of the stimuli in this test.

Table 8 Characteristics of stimulus materials of the Serial Repetition Test

	3 mora words			4 mora words		
	High Imag N=24	Med. Imag. N=24	Low Imag. N=24	High Imag N=24	Med. Imag. N=24	Low Imag. N=24
Imageability (range)	6.7 (6.3-6.9)	5.8 (5.4-6.1)	4.6 (4.0-5.1)	6.7 (6.3-6.9)	5.8 (5.3-6.1)	4.7 (4.0-5.1)
Frequency (range)	3.0 (2.2-4.3)	3.2 (1.7-4.9)	3.1 (1.8-4.3)	3.1 (2.0-4.3)	3.2 (1.8-5.3)	3.5 (1.6-4.8)

Med. = Medium, Imag. = Imageability

The combination of the 3- and 4-mora words was of 4 types (3-3, 3-4, 4-3, and 4-4) for 2-serial recall (e.g. パンダ /pa-N-da/ *panda* - スタジオ /su-ta-ji-o/ *studio*), and 8 types (3-3-3, 3-3,4, 3-4-3, 3-4-4, 4-4-4, 4-3-3, 4-3-4, and 4-4-3) for 3-serial recall (e.g. トランプ /to-ra-N-pu/ *cards* - ラジオ /ra-ji-o/ *radio* - スプーン /su-pu-u-N/ *spoon*). Table 8 shows the characteristics of the stimuli. Patients were asked to recall the multiple words in the same order after oral presentation of the stimuli.

5.3.3. Experiments in Oral Reading

1) Overview

As explained in the experimental design, the oral reading stimuli were manipulated by lexicality, consistency and concreteness/imageability. With regard to lexicality, the single Kana characters were also tested as nonword stimuli, because they have no meaning, and this test allows us to examine Kana character-sound translation directly. Thus, the oral reading stimuli for nonwords consisted of i) single Kana characters, ii) Kanji/Kana nonhomophonic nonwords, and iii) Kanji/Kana pseudohomophones. Meanwhile, oral reading experiments for words were manipulated by i) consistency, ii) concreteness/imageability, and iii) word-length.

The following tests, devised by other researchers, were used in the oral reading experiments of this thesis.

i) The 120 Two-Character Kanji Nonword Reading Test (Fushimi et al., 1999),

ii) The 160 Two-Character Kanji Word Reading Test (Patterson et al., 1995),

iii) The 120 Two-Character Kanji Word Reading Test (Fushimi et al., 1999),

iv) The Early Acquired Two-Character Kanji Word Reading Test (Fushimi, unpublished),

v) The 100 Two-Character Kanji Word Reading Test (Fushimi, unpublished),

vi) The 360 Word Reading Test (Fushimi, unpublished),

vii) The Two-Character Kana and Kanji Word Reading Test (Fushimi, unpublished).

Test i) was used for examining Kanji nonword reading. Test ii), iii) and iv) were used for examining the consistency effect on Kanji word reading. Test v) was used for examining the imageability effect. Test vi) and vii) were used for examining the word-length effect. Since test iv) was used for SO, and both tests vi) and vii) were used for ME, the characteristics of the stimulus materials and procedures in these additional experiments are explained in Chapter 7 (Study 2) and Chapter 8 (Study 3), respectively.

Other oral reading experiments were originally devised for this thesis by the author, using Wydell's (1991) database for imageability (mean rating on 7-point scale by Japanese adults); and the NTT database (Amano & Kondo, 1999, 2000) for word familiarity (mean rating on 7-point scale by Japanese adults) and written word frequency (mean frequency of Asahi daily newspaper over 10 years).

2) Materials and procedure

The characteristics of the stimulus materials and procedures were explained in the order of **A**) nonwords, B) Kanji words manipulated by consistency, and C**)** Kanji/Kana words manipulated by concreteness/imageability. Throughout all oral reading experiments patients were asked to read aloud each written stimulus. These were presented in random order, and were displayed in white on a black background on a 14-inch computer screen, using Microsoft Power Point 2000. The font was MSP Gothic for Japanese and the size of a single-character was 44-point.

A) Nonwords

a) Single-Kana Character Reading Test

This task contained 107 single-Hiragana characters and 107 single-Katakana characters - these represent a single mora and are phonologically equivalent, but their form is different (cursive Hiragana vs. square Katakana). As explained in Chapter 3, single-Kana characters are conventionally divided into 3groups: a) the basic set comprised 46 Kana characters which correspond to V or CV and voiceless sound; b) 25 Kana characters which have a diacritical mark representing the phonetic distinction of the voicing consonant (e.g. ぎ/gi/ in Hiragana, ギ/gi/ in Katakana) or the half-voicing consonant (e.g. ぱ/pa/ in Hiragana, パ/pa/ in Katakana); c) the complex set comprising 36 2-character compounds, corresponding to CjV mora (e.g. きゃ/kja/ in Hiragana, キャ/kja/ in Katakana; ぴゅ/pju/ in Hiragana, ピュ/pju/ in Katakana).

Patients were asked to read aloud single-Kana characters which were presented in random order. Hiragana characters and Katakana characters were tested individually.

b) The Katakana Nonword Reading Test (Sato, devised for this thesis)

This task contained 120 Katakana nonwords (which are the same items as used in the nonword repetition test), and 4-mora nonwords chosen from the transposed set (e.g.アイロン /a-i-ro-N/ *iron*→アロイン/a-ro-i-N/), the substituted set (e.g.ストレス /su-to-re-su/ *stress*→ストリス/su-to-ri-su/), and the randomised set (e.g. マラソン /ma-ra-so-N/ *marathon*→ソマンラ /so-ma-N-ra/). Any Kana character sequence representing CjV mora was not included in the nonwords.

c) The Kanji Nonword Reading Test (Fushimi et al., 1999)

Fushimi et al. (1999) devised 2-character Kanji nonwords, which are a non-real combination of real Kanji characters. This was done by randomly recombining 2 single-character Kanji, each of which was for different 2-character Kanji words (e.g. 集合 *gathering* /sju-gou/, 学生 *student* /gaku-sei/ →集学/sju-gaku/). Such Kanji nonwords are pronounceable based on the knowledge of pronunciation for each constituent Kanji character. Their stimuli contained 120 2-character Kanji nonwords with 20 nonwords in each of the 6 conditions formed by crossing consistency (consistent, inconsistent-biased and inconsistent-ambiguous) and character frequency (high and low).

Table 9 Characteristics of stimulus materials of the Kanji Nonword Reading Test and examples of the stimuli (Adapted from Fushimi et al., 1999)

	High Frequency			Low Frequency		
	Consistent	Biased	Ambiguous	Consistent	Biased	Ambiguous
Character frequency	2.89±0.17	2.93±0.19	2.98±0.14	2.43±0.23	2.35±0.28	2.37±0.26
Typical/neighbours	1.00±0.00	0.67±0.05	0.60±0.05	1.00±0.00	0.77±0.06	0.58±0.07
Example	**集学**	**松合**	**神間**	**満送**	**役岸**	**毛西**
Typical pronunciation	sju-gaku	matsu-ai	siN-ma	maN-sou	yaku-gaN	ke-sai
Alternative pronunciation	-	sjou-gou	kami-kaN	-	eki-kisi	mou-sei

Table 9 shows characteristics of stimulus materials and examples of 6 conditions with the typical and alternative pronunciations, which are adapted from Fushimi et al., 1999).

d) The Kanji Pseudohomophone and Kanji Nonhomophonic Nonword Reading Test (Sato, devised for this thesis)

This test contained 40 Kanji pseudohomophones (i.e. Kanji homophonic nonwords) and 40 Kanji nonhomophonic nonwords. The stimuli of homophonic nonwords were created by changing one constituent character of the 40 2character Kanji /consistent words (20 each of high/low frequency words), devised by Patterson et al. (1995). Twenty homophonic nonwords were made by changing the first constituent character (e.g. 記憶 *memory* /ki-oku/→機憶/ki-oku/), and twenty by changing the second constituent character (e.g. 電気 *electric* /deN-ki/→ 電規 /deN-ki/). The stimuli of nonhomophonic Kanji-nonwords were made by reversing the position of the constituent character of these 40 homophonic Kanji-nonwords (e.g. 機憶/ki-oku/→憶機/oku-ki/). Two sets of stimulus materials comprised 20 homophonic Kanji-nonwords, with each set matching the number of changing positions (the first/second constituent position) and the base word's frequency (high/low), and 20 nonhomophonic Kanji-nonwords, each of which matched the base word's frequency. They were presented in random order and the 2 sets were administered individually.

e) The Hiragana Pseudohomophone Reading Test (Sato, devised for this thesis)

The stimulus materials were Hiragana transcriptions of Katakana/Kanji words in both the Concrete/Abstract Word Reading Test and the Three Kinds of Word Reading Test described below. This test contained 240 Hiragana pseudohomophones created from Katakana words in each of concrete/abstract and high/low imageability conditions (e.g. ランプ *lamp* →らんぷ, モラル *moral* →もらる), and 344 Hiragana pseudohomophones transcribed from Kanji words in each of concrete/abstract and high/low imageability conditions (e.g. 指輪 *ring* →ゆびわ, 名誉 *honor* →めいよ).

B) Kanji words manipulated by consistency

a) The 160 Two-character Kanji Words Reading Test (Patterson et al., 1995)

Patterson et al. (1995) devised the Kanji word list to assess a surface dyslexic patient. The test comprises 160 2-character Kanji words, with 40 words in each of the 4 conditions: consistent words, inconsistent-'regular' words, inconsistent-'irregular' words, and exception words. These are explained below.

Consistent words - each of the 2 constituent characters has only a single ON- reading and no KUN-reading;

<u>Inconsistent-'regular' words</u> - each of the 2 constituent characters has multiple pronunciations, but the target pronunciation is ON-reading (ON-reading compounds);

<u>Inconsistent-'irregular' words</u> – each of the 2 constituent characters has multiple pronunciations, and the target pronunciation is KUN-reading (KUN-reading compounds);

<u>Exception words</u> – the whole word has a unique pronunciation that does not correspond to any ON- or KUN-reading of the constituent Kanji character, and this type of words are known as 'Jukujikun' (see Chapter 3).

The stimuli were also manipulated by 'subjective' word frequency (mean rating by Japanese adults on 7-point scale, Wydell, 1991). Thus, the stimuli comprised 160 2-character Kanji words, with 20 words in each of 8 conditions, achieved by crossing 4 bands of consistency with 2 bands of 'subjective' word frequency (high and low).

b) The 120 Two-Character Kanji Word Reading Test (Fushimi et al., 1999)

Fushimi et al. (1999) devised the Kanji word list to examine the 'consistency effect' on Kanji word reading in normal readers. This comprises 120 2-character Kanji words, with 20 words in each of the 6 conditions, achieved by crossing 3 bands of consistency (consistent, inconsistent-typical and inconsistent-atypical) with 2bands of 'objective' word frequency (National Language Institute, 1970). Their definition of consistency was as follows:

<u>Consistent</u> - each constituent character has identical pronunciation across orthographic neighbours (i.e. all neighbours are friends);

Inconsistent-typical – each constituent character has more than one legitimate pronunciation across orthographic neighbours, but statistically it is the most typical pronunciation of each character that is appropriate to the target word (i.e. friends dominate enemies);

Inconsistent-atypical – each constituent character has more than one legitimate pronunciation, and one or both of the character pronunciations which are appropriate to the target word are not, statistically, the most typical ones (i.e. enemies dominate friends with regard to the first, the second, or both character positions).

Thus, 3 consistency bands were located around different points on a single continuum of balance between friends and enemies. In this regard, Fushimi et al's (1999) consistency is a continuous variable. Table 10 shows the characteristics of stimulus materials and examples of examples of words with the correct and alternative pronunciations, as adapted from Fushimi et al. (1999).

Table 10 Characteristics of the stimulus materials of the 120 Two-Character Kanji Word Reading Test and examples of the stimuli (Adapted from Fushimi et al., 1999)

	High-frequency			Low-frequency		
		Inconsistent			Inconsistent	
	Consistent	Typical	Atypical	Consistent	Typical	Atypical
Word length	3.55±0.51	3.65±0.49	3.45±0.51	3.55±0.51	3.40±0.50	3.50±0.51
Word frequency	1.77±0.23	1.84±0.23	1.72±0.22	0.76±0.06	0.77±0.06	0.78±0.06
Word familiarity	6.12±0.31	6.01±0.36	6.02±0.47	5.38±0.57	5.48±0.49	5.44±0.60
Character frequency	2.71±0.27	2.77±0.23	2.78±0.31	2.61±0.31	2.52±0.32	2.46±0.45
Friends/neighbours	1.00±0.00	0.74±0.07	0.42±0.13	1.00±0.00	0.71±0.07	0.33±0.15
Examples	労働	楽団	場合	満開	郷土	寿命
Correct pronunciation	rou-dou	gaku-daN	ba-ai	maN-kai	kjou-do	zju-mjou
Alternative pronunciation	-	raku-daN	zjou-gou	-	gou-tsutsi	su-mei

C) Kanji/Kana words manipulated in terms of concreteness/imageability

a**) The Concrete/Abstract Word Reading Test** (Sato, devised for this thesis)

This reading test comprised two sets of materials. The Katakana set contained the same 120 Katakana words as used in the word repetition task, with 20 words in each of 6 conditions, formed by crossing 2 bands of concreteness (concrete nouns vs. abstract nouns) with 3 bands of word length (3, 4 and 5 characters) (e.g. テント *tent*, エプロン *apron*, パスポート *passport* for concrete words; スリル *thrill*, ユーモア *humor*, ハーモニー *harmony* for abstract words). The Kanji set contained 104 single-character Kanji words, with 52 words in each of 2 conditions formed by concreteness (concrete nouns vs. abstract nouns) (e.g. 栗 *chestnut*, 愛 *love*). The characteristics of these stimuli materials and examples of the stimuli are shown in Table 11.

Table 11 Characteristics of stimulus materials of the Concrete/Abstract Word Reading Test, and examples of the stimuli

	Katakana		Single-character Kanji	
	Concrete words	Abstract words	Concrete words	Abstract words
	N=60	N=60	N=52	N=52
Mora	3.9	4.0	2.3	2.3
(range)	(3-5)	(3-5)	(2-4)	(2-4)
Familiarity	6.0	6.0	6.1	5.8
(range)	(3.6-6.6)	(3.3-6.7)	(4.6-6.7)	(4.5-6.7)
Imageability	6.6	4.7	6.9	4.8
(range)	(4.3-7.0)	(3.1-6.9)	(6.8-7.0)	(4.1-5.4)
Frequency	2.8	3.7	3.4	3.5
(range)	(1.8-4.3)	(2.0-5.3)	(1.7-4.7)	(0.9-5.1)
Examples	エプロン	スリル	栗	愛
Pronunciation	e-pu-ro-N	su-ri-ru	kuri	ai
Meaning	*apron*	*thrill*	*chestnut*	*love*

b) The Three Kinds of Word Reading Test (Sato, revised for this thesis)

In this experiment imageability (high vs. low) and script type (Katakana, single-character Kanji and 2-character Kanji) were manipulated with 60 words in each of 6 conditions. Characteristics of the stimuli materials and examples of the stimuli are shown in Table 12.

Table 12 Characteristics of stimulus materials of the Three Kins of Word Reading Test, and examples of the stimuli

	Katakana words		Single-char. Kanji words		Two-char.Kanji words	
	High Imag. N=60	Low Imag. N=60	High Imag. N=60	Low Imag. N=60	High Imag. N=60	Low Imag. N=60
Mora (range)	3.9 (3-5)	3.9 (3-5)	2.3 (2-4)	2.3 (2-4)	3.2 (2-4)	3.2 (2-4)
Familiarity (range)	6.0 (5.1-6.3)	6.0 (5.1-6.3)	6.0 (5.1-6.3)	6.0 (5.1-6.3)	6.1 (5.1-6.3)	6.1 (5.1-6.3)
Imageability (range)	6.6 (6.5-6.9)	4.7 (2.4-5.4)	6.7 (6.5-6.9)	4.9 (3.8-5.5)	6.6 (6.4-6.9)	4.8 (4.6-4.9)
Frequency (range)	2.5 (0.3-4.1)	3.1 (1.1-4.6)	3.3 (1.7-4.7)	3.7 (1.9-5.1)	3.3 (1.9-4.5)	3.9 (2.7-4.8)
Examples Pronunciation Meaning	ペンキ pe-N-ki *paint*	アリバイ a-ri-ba-i *alibi*	寺 tera *temple*	謎 nazo *puzzle*	白鳥 haku-cjyo *swan*	期待 ki-tai *expectation*

Imag.= imageability, char. = character

c) The 100 Two-Character Kanji Word Reading Test (Fushimi, unpublished)

The stimulus materials contained 100 2-character Kanji words: these comprised 20 words in each of the 5 conditions and crossing 3 bands of imageability (high, medium, and low) with 2 familiarity bands. Imageability data was based on Ogawa & Inamura (1974) and Itukushima, et al. (1991).

Table 13 Characterisitcs of stimulus materials of the 100 Two-character Kanji Word Test, and examples of the stimuli

	High Familiarity			Low Familiarity	
	High Imag N=20	Medium Imag N=20	Low Imag. N=20	Medium Imag N=20	Low Imag. N=20
Mora (range)	3.6 (3-4)	3.7 (2-4)	3.5 (2-4)	3.7 (3-4)	3.6 (3-4)
Familiarity (range)	6.3 (6.6-6.7)	6.3 (6.1-6.6)	6.3 (6.0-6.5)	5.6 (4.8-6.0)	5.6 (5.1-6.1)
Imageability (range)	6.4 (6.1-6.7)	5.5 (4.8-6.0)	3.9 (2.3-4.7)	5.6 (4.7-6.0)	4.0 (2.4-4.7)
Frequency (range)	3.8 (2.7-4.8)	4.2 (3.2-5.1)	4.5 (3.6-5.1)	3.2 (1.8-4.3)	2.7 (0.0-3.9)
Examples Pronunciation Meaning	温泉 oN-seN *hot spring*	海外 kai-gai *overseas*	予定 yo-tei *schedule*	移住 i-jyu *migration*	敬礼 kei-rei *salute*

Imag.= imageability

Since the number of high imageability words with a low familiarity band was quite small, this test did not contain the words with this condition. Characteristics of the stimuli materials and examples of the stimuli are shown in Table 13.

5.3.4. Experiments with Cross-domain performance

1) Overview

As explained in the experimental design, the 3 principal components (Phonology, Semantics and Orthography) underpin any language performances in the triangle model. It can be assumed that semantic and phonological impairment affect language performance differently. From this point, cross-domain tasks (written word comprehension, word reading and picture naming) were conducted for both Katakana and Kanji words. Furthermore, the phonological cueing effect was examined in both Kanji word naming and picture naming.

2) Materials and Procedure

a) The 80 Katakana Word Test (Sato, devised for this thesis)

As shown in Table 14, the base Katakana words were manipulated by crossing 2 frequency bands (high and low) and 2 familiarity bands (high and low), forming 80 Katakana words with 20 words in each of the 4 conditions.

The 80 Katakana words were printed on a Xerox inkjet printer. The font was MS Mincho, in Japanese, and it was printed in size 48-point in bold black, and then cut to size and encased in clear plastic film on cards. Stimulus pictures were taken from '*Picture Card 2001*' (Esukoaru, 1996) and the original black-and-white pictures were copied and cut to size.

Table 14 Characteristics of Katakana word stimuli for the cross-domain tasks, and examples of Katakana written stimuli

	High Frequency		Low Frequency	
	High Familiarity N=20	Low Familiarity N=20	High Familiarity N=20	Low Familiarity N=20
Moara (range)	3.7 (3-5)	3.7 (3-5)	4.1 (3-5)	4.0 (3-5)
Familiarity (range)	6.4 (6.1-6.6)	6.0 (5.5-6.3)	6.3 (6.1-6.6)	5.9 (4.8-6.3)
Frequency (range)	3.2 (2.9-3.7)	3.1 (2.9-3.7)	2.6 (2.4-2.7)	2.5 (2.3-2.7)
Examples Pronunciation Meaning	**トンネル** to-N-ne-ru *tunnel*	**レスリング** re-su-ri-N-gu *wrestling*	**コアラ** ko-a-ra *koala*	**プロペラ** pu-ro-pe-ra *propeller*

The 80 plastic cards for written Katakana words were presented in random order for oral reading. Then patients were asked to point out the picture which corresponded with the meaning of a Katakana word presented among 4 pictures: the target, the semantic foil, the phonological foil and the unrelated foil (e.g. パンダ *panda* /pa-N-da/, 熊 *bear* /ku-ma/, パンク/pa-N-ku/, and 靴下 *socks* /ku-tu-shi-ta/). After three days later of these oral reading and comprehension tasks picture naming was tested individually.

b) The 80 Single-Character Kanji Word Test (Sato, devised for this thesis)

As shown in Table 15, the base single-character Kanji words comprised 40 high frequency words and 40 low frequency words. The procedure of making the stimuli and of testing oral reading and written word comprehension in this test was the same as the procedure for the previous test.

The picture stimuli of the comprehension tasks for both Kanji words and Hiragana pseudohomophones contained the target, semantic foil, phonological foil, and unrelated foil (e.g. s 皿 /sara/ *plate*, コップ/ko-Q-pu/ *glass*, 猿/saru/ *monkey*, バイオリン /ba-i-o-ri-N/ *violin*). The test order was Kanji word reading/comprehension, picture naming, and Hiragana pseudohomophone reading/comprehension. The time span between each test was 3 days.

Table 15 Characteristics of Kanji word stimuli
for the cross-domain tasks and examples of Kanji written stimuli

	High Frequency words (N=40)	Low Frequency words (N=40)
Moara (range)	2.2 (2-3)	2.4 (2-4)
Familiarity (range)	6.2 (5.3-6.6)	5.2 (3.7-6.1)
Frequency (range)	3.4 (2.7-3.9)	2.2 (1.8-2.7)
Examples Pronunciation Meaning	竹 take *bamboo*	蛙 kaeru *frog*

c) The Two-Character Kanji Word Reading and Picture Naming Test (Sato & Fushimi, 2002)

As shown in Table 16, the stimulus words comprised 120 2-character Kanji words, with 30 words in each of the 4 conditions formed by crossing 2 familiarity bands (high and low) and 2 word-length (in number of morae 3 mora and 4 mora). Each written stimulus was presented in random order and displayed in white on a black background on a 14-inch computer screen by using Microsoft Power point 2000. The font was MSP Gothic for Japanese and the size of a single-character was 44-point. Stimulus pictures taken from *'Picture Card 2001'* were scanned and were displayed on a 14-inch computer screen using Power point 2000.

Patients were asked to name and read aloud 120 pictures and words in an ABBA design. They were given 15 seconds for the first response relating to each item for both word reading and picture naming. If a patient failed to produce the target phonology the initial mora was provided as a cue. If the cue failed to facilitate the correct response, it was increased by one mora and another 15 seconds was given for response. This progressive cueing technique was continued until the patient reached the correct name, but the phonology of the whole word was not given.

Table 16 Characteristics of stimulus materials of the Two-Character Kanji Word Reading and Picture Naming Test, and examples of the written stimuli

	High Familiarity		Low Familiarity	
	3 mora (N=30)	4 mora (N=30)	3 mora (N=30)	4 mora (N=30)
Familiarity (range)	6.1 (5.8-6.6)	6.2 (5.8-6.6)	5.4 (4.5-5.4)	5.4 (4.7-5.7)
Frequency (range)	3.3 (2.3-4.7)	3.3 (2.2-4.8)	2.6 (1.3-3.5)	2.5 (1.4-3.8)
Examples	**映画**	**階段**	**楽譜**	**木馬**
Pronunciation	ei-ga	kai-daN	gaku-fu	moku-ba
Meaning	*cinema*	*stairs*	*musical score*	*wodden horse*

5.4. Procedure of conducting the three individual studies

YT and HW in Study 1, SO in Study 2, and ME in Study 3 were tested using the same experimental tasks, including semantic/phonological tasks, oral reading tasks, and cross-domain tasks, as explained in this Chapter. This provides sufficient data for discussing the three research questions. Moreover, the additional oral reading experiments for SO and ME, which are explained in Chapter 7 and 8 respectively, were carried out in order to clarify the nature of their oral reading performance. These procedures together allow us to i) explore Japanese acquired dyslexia patterns; and ii) verify the semantic impairment hypothesis and the phonological impairment hypothesis.

Chapter 6

Study 1: A Comparative Study of YT and HW

This Chapter presents Study 1, which is a comparative study of YT and HW, who showed phonological impairment and semantic impairment, respectively. Study 1 focuses mainly on i) verifying Japanese acquired dyslexia patterns, deep dyslexia pattern that has not yet clarified, in particular; and ii) examining the Japanese applicability of the two models: the DRC model and the triangle model, including examination of the semantic and phonological impairment hypothesis.

6.1. The research questions for Study 1 and the methodology used to explore them

Study 1 set up the following three research questions. These correspond with the three research questions of this thesis, as explained in Chapter 4. Research question 3 of Study 1 consists of the two sub-questions, which need to address the third research question. In each section, the research question(s), the research methodology are shown.

6.1.1. Research question 1 of Study 1 and the methodology used to explore it

<u>Research question 1</u>

"Do Japanese dyslexic patients show the same effects of psycholinguistic variables as observed in English patients with deep dyslexia and surface dyslexia?

The key point of the oral reading experiments for addressing this research question is that all psycholinguistic variables used for diagnosis of English acquired dyslexia were manipulated in both Kanji and Kana strings, except for consistency, which cannot be manipulated in Kana strings.

In English cases, patients with deep and phonological dyslexia show an impairment of nonword reading, whereas patients with surface dyslexia show an impairment of oral reading of exception words with a low frequency band (i.e. a consistency effect), coupled with preserved nonword reading. So, the oral reading experiment of i) Kanji/Kana nonwords, and ii) the two character Kanji words manipulated by consistency and frequency, were conducted in order to identify deep/phonological dyslexia and surface dyslexia in Japanese.

Moreover, English patients with deep dyslexia show a concreteness/imageability effect (concrete/high imageability words > abstract/low imageability words) on word reading. Deep dyslexia cases occasionally show a pseudohomophone effect (pseudohomophone reading > nonhomophonic nonword reading). Therefore, the oral reading experiments of iii) Kanji/Kana words manipulated by concreteness/imageability, and iv) Kanji/Kana pseudohomophones were also conducted.

6.1.2. Research question 2 of Study 1 and the methodology used to investigate it

Research question 2

" Are Japanese deep dyslexia and surface dyslexia Kana and Kanji script-specific reading disorders, respectively?"

The method for addressing this research question is re-analysis of YT's and HW's results in the oral reading experiments for research question 1 in terms of the Kanji vs. Kana framework.

The classical case studies in Japanese dyslexia research described deep dyslexia as showing i) an impairment of single-Kana character reading, ii) severe impairment of Kana word reading compared to Kanji word reading, iii) a concreteness effect on Kanji word reading, and iv) the occurrence of semantic errors in Kanji word reading and visual errors in Kana word reading. Taking i) and ii), the Japanese version of deep dyslexia has been treated as a Kana script-specific reading disorder. Meanwhile, the classical case studies treated the Japanese version of surface dyslexia as a Kanji script-specific reading disorder, because the classical cases showed i) impaired Kanji word reading, and ii) preserved Kana word reading. That is, it was pointed out that classical deep dyslexia and surface dyslexia in Japanese show the double-dissociation between Kanji and Kana (deep dyslexia: Kanji word reading > Kana word reading; surface dyslexia: Kanji word reading < Kana word reading).

As explained in Chapter 3, the methodological problems of the classical case studies - in which a) Kana pseudohomophones were used as 'Kana words', and b) Kanji words with no manipulation of consistency were used - led to doubt about this double dissociation. Thus, there is a strong possibility that a Kana script-dependent dyslexic pattern in the classical deep dyslexia reflects a 'lexicality effect' (i.e. Kanji words > Kana pseudohomophones), and that a Kanji script-dependent dyslexic pattern in the classical surface dyslexia reflects a 'consistency effect' (i.e. transparent Kana words> opaque Kanji words in print-sound correspondence).

To verify this reasoning of 'a false effect of the script-type', one needs to test i) whether Kana word reading is worse than Kanji word reading, and ii) whether Kanji word reading is better than Kana pseudohomophones in patients with deep dyslexia.

Moreover, one needs to test iii) the consistency effect in Kanji words (i.e. consistent words > inconsistent words), and iv) whether oral reading of consistent Kanji words is worse than Kana word reading in patients with surface dyslexia.

Thus, YT's and HW's results in the oral reading experiments for research question 1 were re-analysed using the framework of Kanji strings vs. Kana strings. The following comparisons were conducted: i) between the oral reading accuracy of Kanji words and of Kana words, ii) between the oral reading accuracy of Kanji words and of Hiragana pseudohomophones transcribed from Kanji words, iii) between the oral reading accuracy of Katakana words and of Hiragana pseudohomophones, and iv) between the oral reading accuracy of Kana pseudohomophones and of Kanji pseudohomophones.

6.1.3. Research question 3 of Study 1 and the methodology used to explore it

Research question 3 of Study 1 consists of the two sub-questions, which themselves need to address the third research question of this thesis. One is testing the phonological/semantic impairment hypothesis based on the triangle model, and the other is examining the Japanese versions of the DRC model and the triangle model.

Research question 3-1

"Can one observe the co-occurrence of phonological impairment and deep/phonological dyslexia, and the co-occurrence of semantic impairment and surface dyslexia?"

This research question is examining the phonological impairment hypothesis and the semantic impairment hypothesis, which are based on the triangle model. The former hypothesis predicts that impairment of phonological function leads to deep/phonological dyslexia, and the latter hypothesis predicts that impairment of semantic function leads to surface dyslexia.

Thus, the various semantic and phonological tasks were administered prior to the oral reading experiments in order to address this research question. In addition, cross-domain tasks were administered. This is because the triangle model, which is the theoretical framework of the phonological/semantic impairment hypothesis, predicts that phonological impairment and semantic impairment would lead to distinctive performance in cross-domain tasks and phonological cueing. The results of these additional experiments test the phonological impairment and semantic impairment hypotheses in different ways.

Research question 3-2

"Can the Japanese versions of the DRC model and the triangle model explain Japanese dyslexia patterns?"

For addressing this research question, all results for the previous research questions (1, 2 and 3-1) of Study 1 are used. The nature of Japanese deep dyslexia has not yet been clarified, because the deep dyslexia pattern was only reported by the classical case studies and these had methodological problems. Meanwhile, the recent case studies, which used well-manipulated reading stimuli, reported phonological dyslexics and surface dyslexics who showed the same psycholinguistic variables effects observed in English cases. The interpretations of these dyslexic patterns have already been presented in Chapter 3, using the Japanese versions of the DRC model and the triangle model, and showing that the two models can explain phonological and surface dyslexia in Japanese. Therefore, the main question is whether or not the two models can explain Japanese deep dyslexia.

6.2. The organisation of the data presentation

The results of YT's and HW's performance in the experimental tasks are presented in the order of 1) the evaluation of semantic and phonological function, 2) the oral reading experiments for identifying the type of acquired dyslexia, 3) the oral reading experiments for exploring Japanese deep dyslexia, and 4) a re-analysis of the results of 2) and 3) using the Kanji vs. Kana framework. Finally, the results of the cross-domain tasks are presented.

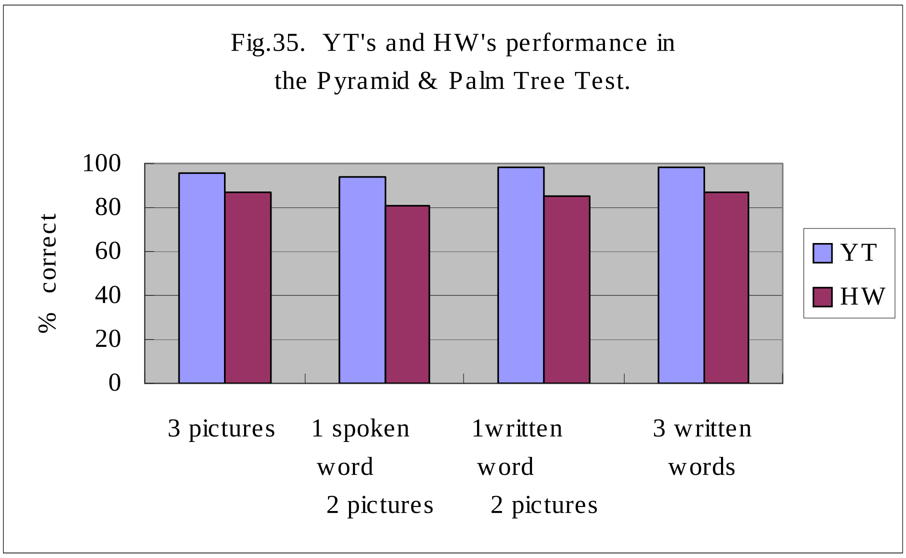
The results of the oral reading experiments were divided into the three parts. The first part presents the results of a) oral reading of Kanji/Kana nonhomophonic nonwords, and b) oral reading of two-character Kanji words manipulated by consistency. This section focuses on whether YT and HW show the variables effects for diagnosing acquired dyslexia type, as have been used for English cases. If either case showed an impairment of nonword reading the case would be deep dyslexia or phonological dyslexia. If either case showed i) a consistency effect, and ii) preserved nonword reading, the case should be surface dyslexia. The second part presents the results of a) oral reading of Kanji/Kana words manipulated by concreteness/imageability, b) oral reading of Kanji/Kana pseudohomophones. This section focuses on capturing the characteristics of Japanese deep/phonological dyslexia and clarifies the nature of dyslexic patterns demonstrated by the subjects. The third part presents the re-analysis of the oral reading data in order to examine the script-type effect, using the framework of Kanji vs. Kana

6.3. The evaluation of semantic and phonological function

6.3.1. The evaluation of semantic function

1) Semantic knowledge, word comprehension, and picture naming

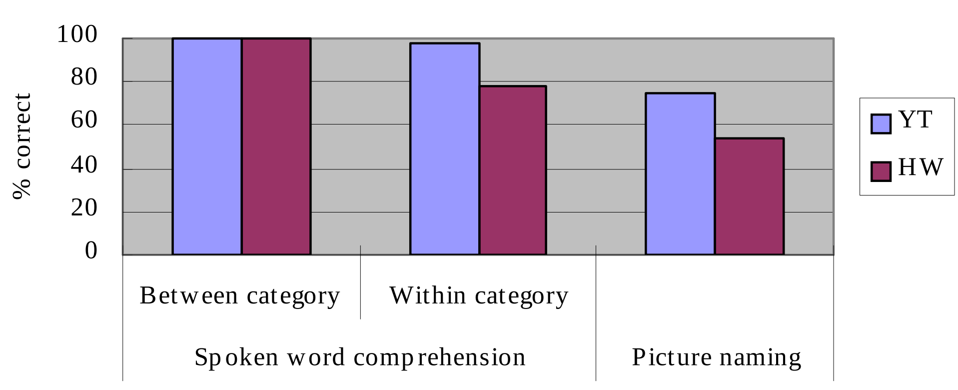
Figure 35 shows YT's and HW's performance in Pyramid and Palm Tree Test.



YT's semantic associative knowledge was well preserved in the nonlinguistic condition (3 pictures: 50/52, 96%), the linguistic condition (3 written words: 51/52, 98%), and cross-modality conditions (1 written word and 2 pictures: 51/52, 98%; 1 spoken word and 2 pictures: 49/52, 94%). HW's score was worse than YT's score in all conditions (3 pictures: 45/52, 87%; 3 written words: 45/52, 87%; 1 written word and 2 pictures: 44/52, 85%; 1 spoken word and 2 pictures: 42/52, 81%). A statistically significant difference was found in the 1 written word and 2 pictures condition (χ^2 =5.96, $p < 0.02$) and the 3 written words condition (χ^2 =4.88, $p<0.03$).

Figure 36 presents the results of the two cases in the Tiger and Lion Test**.** While it was not difficult for HW to understand concrete spoken words in the between-category condition (60/60, 100%), he failed to understand the same target words in the within-category condition (47/60, 78%). The difference between two conditions was significant (χ^2 =14.58, p = 0.0001). This suggests semantic impairment in HW.

Fig. 36. YT's and HW's performance in the Tiger & Lion Test.



YT's spoken word comprehension was very good and there was no difference between the two conditions (between-category condition: 60/60, 100%; within-category condition: 59/60, 98%). In the within-category condition YT's score was significantly better than HW's score (χ^2 =10.58, $p < 0.002$). YT's superiority over HW was also found in the picture-naming task (χ^2 =5.17, $p < 0.03$), in which HW showed severe anomia (32/60, 53%), whereas YT's naming disorder was moderate (44/60, 73%).

2) Single-word comprehension and abstract knowledge

Figure 37 presents the results of the Written Concrete Words Test (in which written word comprehension was evaluated in the within-category condition), and of the Abstract Word Comprehension Test. YT demonstrated well preserved written word comprehension for both concrete words (Kanji words: 41/42, 98%; Katakana words:

41/42, 98%) and abstract words (43/45, 96%), and her auditory comprehension of abstract words was also very good (44/45, 98%). In contrast, HW's written concrete word comprehension was impaired (Kanji words: 38/42, 90%; Katakana words: 36/42, 86%), and his Katakana concrete word comprehension was significantly worse than YT's performance (χ^2 =3.89, $p < 0.05$). HW's abstract word comprehension was moderately impaired in relation to both written and spoken word (36/45, 80%, 34/45, 76%, respectively), and it was significantly worse than YT's performance (χ^2=5.08, $p < 0.03$; χ^2=9.62, $p < 0.002$, respectively).

Fig. 37 YT's and HW's performance in the Written Concrete Word Comprehension Test and the Abstract Word Comprehension Test.

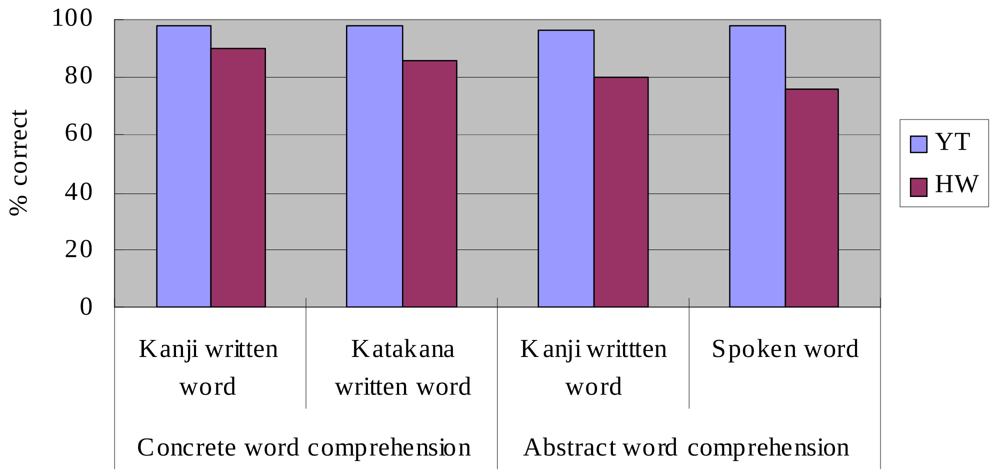


Fig. 38. YT's and HW's performance in the Single-Character Kanji Word Synonym Judgment Test.

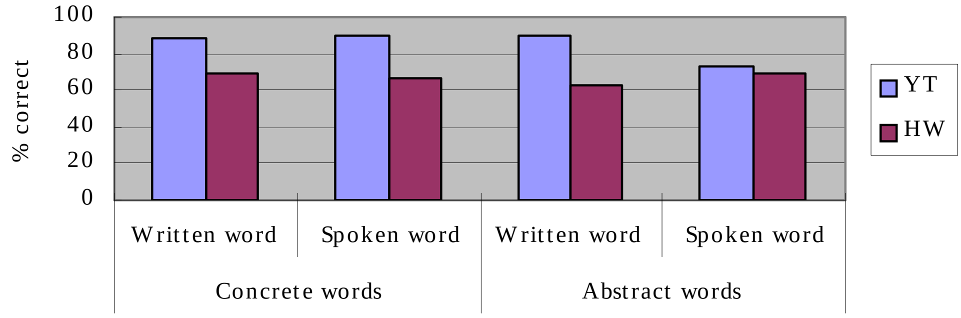
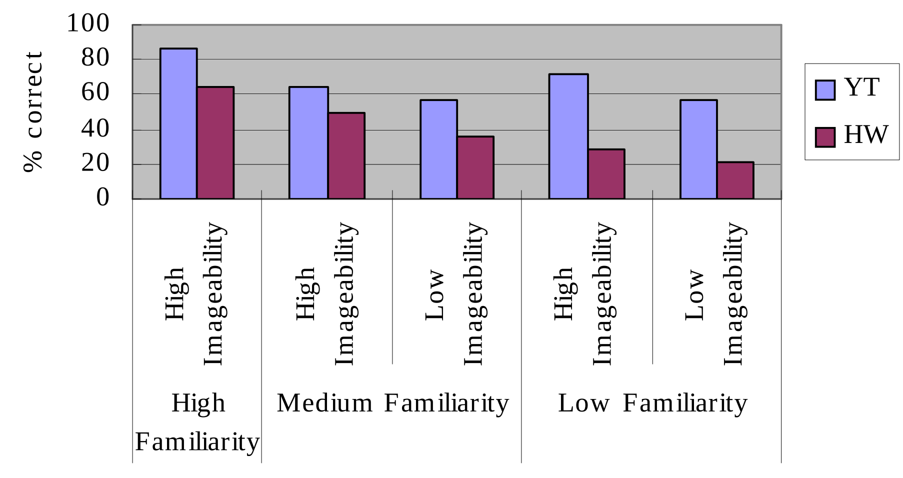


Figure 38 shows YT's and HW's performance in the Single-Character Kanji Synonym Judgment Test. YT's synonym judgment was fairly well preserved and there was no concreteness effect on written word synonym judgment (written concrete words: 46/52, 88%; written abstract words: 47/52, 90%). However, YT's abstract word synonym judgment with auditory presentation was impaired (spoken concrete words: 47/52, 90%: spoken abstract words: 38/52, 73%), and YT showed both a concreteness effect and a modality effect ($\chi^2=5.22$, $p < 0.03$ in both case). On the other hand, HW's performance had deteriorated in all conditions (written concrete words: 36/52, 69%; written abstract words: 33/52, 63%; spoken concrete words: 35/52, 67%; spoken abstract words: 36/52, 69%) and his score, except for the spoken abstract word task, was significantly worse than YT's score. ($\chi^2=5.77$, $p < 0.02$ for written concrete words; $\chi^2=10.62$, $p < 0.002$ for written abstract words; $\chi^2=8.30$, $p < 0.005$ for spoken concrete words).

3) The Seventy Picture Naming Test

As shown in Fig. 39, both cases showed a picture-naming deficit, but YT's accuracy was better than HW's (YT: 47/70, 67%; HW: 28/70, 40%). YT's performance was better than HW's in every condition, and this difference was statistically significant for low familiarity/high imageability words (10/14, 71% > 4/14, 29%, $\chi^2=5.14$, $p < 0.03$) and was marginal for low familiarity/low imageability words (8/14, 57% > 3/14, 21%, $\chi^2=3.74$, $p = 0.05$). Both familiarity and imageability influenced HW's naming performance, but this was not the case for YT. A simultaneous multiple logistic regression analysis on correct responses, with 4 predictors (i.e. spoken word familiarity (Amano & Kondo, 1999); imageability (Wydell, 1991); printed word frequency (Amano & Kondo, 2000; in log10-transformed value); and word length (i.e. number of morae), revealed a significant effect of word length (Walt = 5.734, p < 0.002) for YT’s naming performance, and of word frequency (Walt = 4.459, p < 0.04) for HW’s performance. This suggests that the source of picture naming difficulty for YT and HW would be different.

Fig. 39. YT's and HW's performance in the 70 Picture Naming Test.



4) Summary of YT's and HW's semantic function

YT showed well-preserved semantic associative knowledge and spoken and written word comprehension, including both concrete and abstract words, though it was not easy for her to match the orally presented abstract word to its synonym.

In contrast, HW’s performance in all semantic tasks had deteriorated. Difficulty in distinguishing semantically similar word meanings was one of the notable characteristics of HW’s semantic impairment. This resulted in a significant difference in concrete word comprehension between the within-category and between-category conditions (100% vs. 78%). HW's understanding of abstract nouns had deteriorated in both the spoken and written word comprehension tasks (80% and 76%, respectively), and his synonym judgement for both concrete and abstract words was impaired, and showed no modality effect (63-69%). HW's picture naming was severely impaired and his accuracy was significantly lower than that of YT (40% < 67%).

To summarise, HW showed semantic impairment in the various tasks whereas YT demonstrated preserved semantic function, including abstract word comprehension.

6.3.2. The evaluation of phonological function

1) Phonological discrimination and mora repetition

As shown in Table 17, HW's phonological discrimination ability was intact. YT's performance in these tasks was also preserved, but her mora discrimination for nonwords was slightly impaired.

Table 17 YT's and HW's performance in phonological discrimination and mora repetition

(% correct)

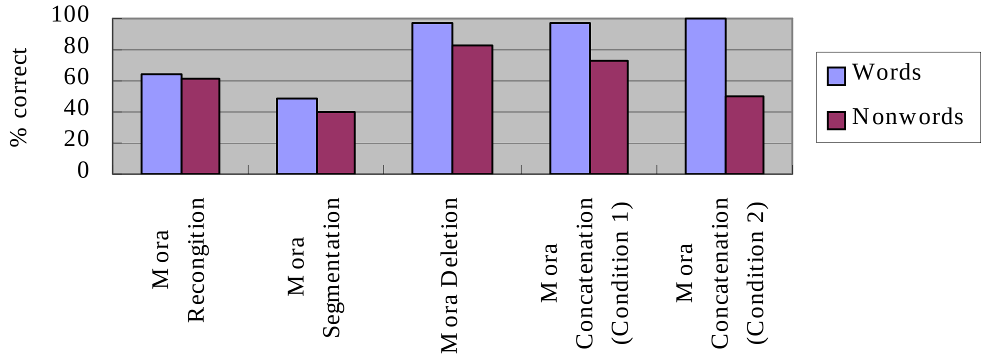
	Phoneme discrimination (N=52	Mora discrimination for Word (N=60)	Mora discrimination for Nonword (N=60)	Single mora repetition (N=20)
YT	100	100	86.7 (*) 93.3 (**)	100
HW	100	100	100 (*) 100 (**)	100

* high-low accent; ** flat accent

2) Phonological manipulation

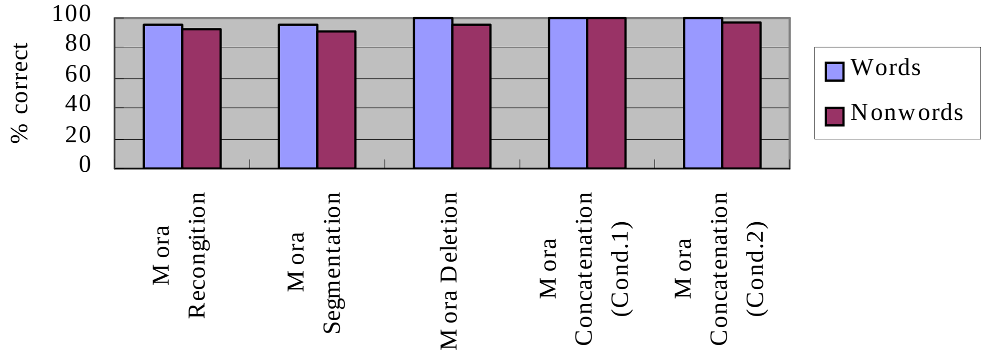
Figure 40 presents YT's performance in various phonological manipulation tasks. YT demonstrated a marked difficulty in mora segmentation and mora recognition for both words (36/72, 50% and 93/144, 65%, respectively) and nonwords (29/72, 40% and 89/144, 62%, respectively). While YT could well manipulate mora deletion and mora concatenation for words, her manipulation for nonwords was impaired (mora concatenation: 33/40, 83%; mora concatenation in condition 1: 29/40, 73%; mora concatenation in condition 2: 20/40, 50%). A lexicality effect was striking in the mora concatenation task under both condition 1 (i.e. each mora presented per second) and condition 2 (i.e. one mora presented per second, followed by a continuous sequence of two morae) (χ^2 =11.11, $p < 0.001$, χ^2 =26.67, $p < 0.0001$, respectively). In this task, YT made lexicalisation errors (e.g. /a-ro-i-N/→/a-i-ro-N/ *iron*) in both conditions (4/12, 33%; 8/20, 40%; respectively).

Fig. 40. YT's performance in phonological manipulation tasks.



In contrast, HW's performance in phonological manipulation, with both words and nonwords, was very good (Fig.41).

Fig. 41. HW's performance in phonological manipulation tasks.



3) Immediate repetition of words/nonwords, and delayed and serial repetition of words

Table 18 presents YT's and HW's performance in the Word and Nonword Repetition Test. YT’s repetition ability was strongly influenced by lexicality ($\chi^2 =41.60$, $p < 0.0001$).

Table 18 YT's and HW's performance in the Word and Nonword Repetition Test (% correct)

	Words (N=120)	Nonwords (N=120)
YT	97.5	65.0
HW	100	96.7

Fig. 42. YT's and HW's performance in the Immediate and Delayed Retepetition Test

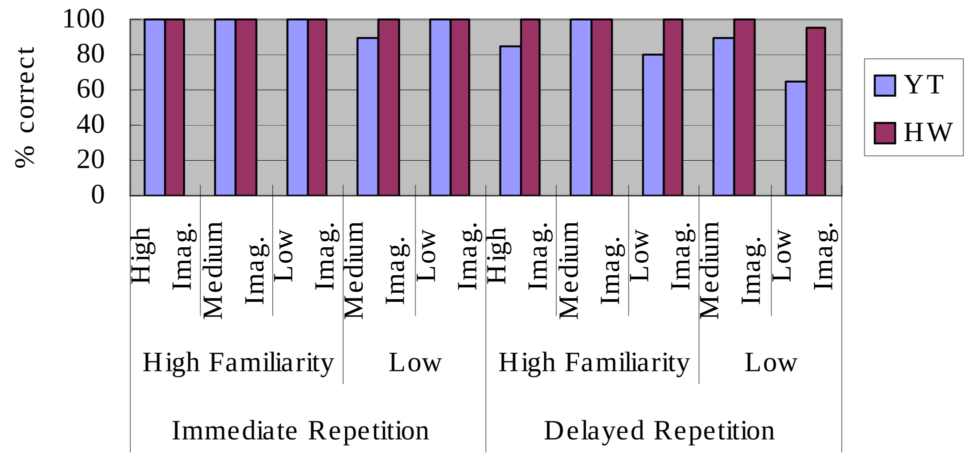
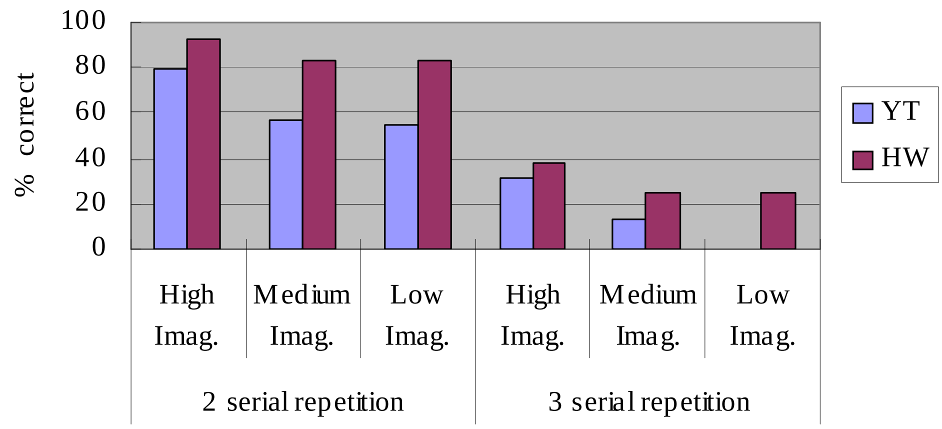


Figure 42 shows YT's and HW's performance in the Immediate and Delayed Repetition Test. Although YT's immediate repetition of words was intact, her delayed repetition of words was modulated by imageability and familiarity, in which her performance had most deteriorated in low imageability/ low familiarity words (13/20, 65%). YT made lexicalisation errors (9/42, 21%), but the majority of her errors were phonologically similar to the target (the average number of morae overlapped to the target 4-mora nonwords was 2.40). On the other hand, HW's performance in repetition tasks in all conditions was very good, though he made self-corrections (20/117, 17%) for nonword repetition. A statistically significant difference between HW and YT was found in the delayed repetition of low imageability words in both high and low familiarity bands (χ^2 =4.44, $p < 0.04$ and χ^2 =5.63, $p < 0.02$, respectively).

Figure 43 shows the YT's and HW's results in the Serial Repetition Test, which is a more demanding phonological task.

Fig. 43. YT's and HW's performance in the Serial Repetition Test.



YT's 3-serial repetition was severely impaired (over all, 7/48, 15%), and was modulated by imageability (high imageability words: 5/16, 31%; medium imageability words: 2/16, 13%; low imageability words: 0%). However, YT showed relatively preserved 2-serial repetition for high imageability words in particular (19/24, 79%). An imageability effect on YT's performance was found in 3-serial repetition at the high vs. low imageability band (χ^2 =5.93, $p < 0.02$) and a trend was detected in 2-serial recall at the high vs. medium/low imageability band (χ^2=3.37, p = 0.06).

HW's performance in 2-serial repetition was fairly good (62/72, 86%), whereas his ability had deteriorated dramatically in 3-serial repetition (14/48, 29%). The superiority of HW's performance over YT's was statistically significant for medium and low imageability words in 2-serial repetition (χ^2=4.75, $p < 0.03$), and for low imageability words in 3-serial repetition (χ^2=4.36, $p < 0.04$).

4) Summary of YT's and HW's phonological function

Among the phonological tasks phonological discrimination was preserved in both YT and HW. While HW's phonological manipulation was quite good, YT's ability had deteriorated severely in the mora segmentation tasks (50% for words, 40% for nonwords). A remarkable lexicality effect was observed in the mora concatenation tasks (100% vs. 50%). A lexicality effect on YT's word repetition was also striking (98% vs. 65%). In more demanding repetition tasks such as delayed and serial repetition, YT's performance was modulated by imageability. However, this semantic variable did not affect HW's performance in these tasks.

To summarise these results, HW's phonological ability was well preserved, whereas YT's phonological manipulation ability was impaired and was influenced by lexicality and imageability. YT demonstrated i) a remarkable lexicality effect on word repetition and mora concatenation, and ii) an imageability effect on serial repetition.

6.3.3. Characteristics of YT's and HW's principal impairment

The detailed assessments for the semantic and phonological function of the two neurological cases revealed a sharp contrast between them in terms of the locus of principal impairment. YT demonstrated phonological impairment with well-preserved semantics, including abstract knowledge, whereas HW showed semantic impairment with well-preserved phonology. This contrast was very clear. Thus, YT and HW are appropriate subjects for examining the phonological impairment and semantic impairment hypotheses.

It is worth noting that YT, who has phonological impairment coupled with intact semantics, showed semantic variables effects on her phonological performance (i.e. a lexicality effect on phonological manipulation and immediate repetition; and an imageability effect on serial repetition). The strength of this semantic support is graded by the property of the stimuli, where higher imageability words would supply stronger activation and nonwords cannot provide any additional activation. Therefore, it appears that these semantic variables effects in YT's phonological performance reflect YT's pathologically reduced phonological activation and the interaction between semantics and phonology.

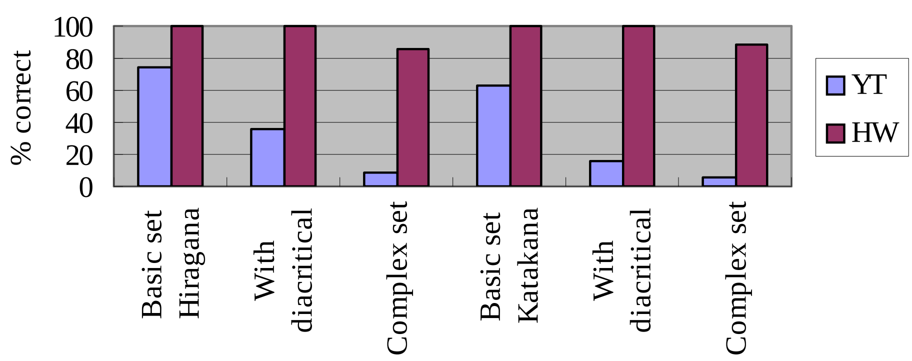
6.4. The oral reading experiments for the diagnosis of acquired dyslexia type

6.4.1. Oral reading of nonwords

1) Single Kana characters

Figure 44 presents YT's and HW's performance in oral reading of both single-Hiragana characters and single-Katakana characters. The difference in accuracy between the two cases was striking (YT vs. HW: 46/107, 43% vs. 102/107, 95% for Hiragana characters; 35/107, 33% vs. 103/107, 96% for Katakana characters). Although YT's oral reading was relatively good for the basic set (34/46, 74% for Hiragana, 29/46, 63% for Katakana), her performance had deteriorated severely in the diacritical set (which represents voicing-consonants and half-voicing consonants), and in the complex set, which represent CjV mora (the diacritical set: 9/25, 36% for Hiragana, 4/25, 16% for Katakana; the complex set: 3/36, 8% for Hiragana, 2/36, 6% for Katakana).

Fig. 44. YT's and HW's performance in single Kana character reading.

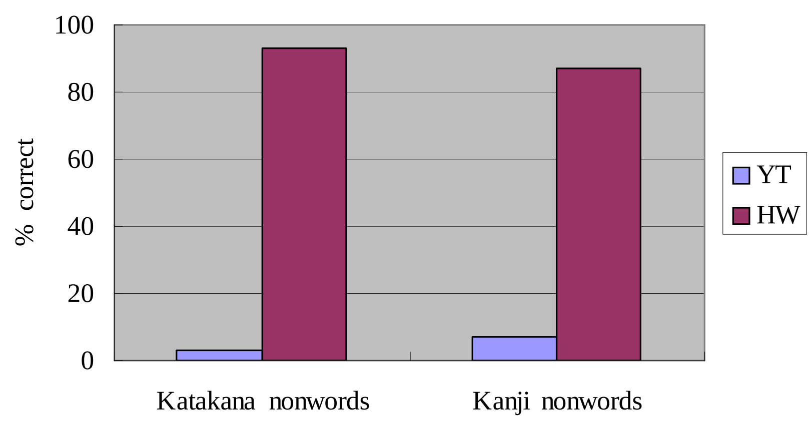


In contrast, HW's single-Kana character reading was preserved, though in the 'complex set' HW's oral reading performance had declined slightly (31/36, 86% for Hiragana; 32/36, 89% for Katakana).

2) Kana nonwords

As shown in the left half of Fig.45, YT's Katakana nonword reading had nearly disrupted (3/120, 3%). In contrast, HW's Katakana nonword reading was preserved (112/120, 93%).

Fig.45. YT's and HW's performance in Nonword Reading.



The majority of YT's reading errors was visual and was therefore phonologically similar to the target (102/117, 87%; e.g. コンラブ /ko-N-ra-bu/ →/o-N-ra-bu/), and included in a number of lexicalisation errors (61/102, 60%; e.g. ソマンラ /so-ma-N-ra/ →/so-ra-ma-me/ *broad bean*). It should be noted that YT produced one lexicalisation-then-semantic error /o-N-ga-ku/ *music* for オルグン/o-ru-gu-N/, which was formed from オルガン/o-ru-ga-N/ *organ*. In some cases, YT was aware that her oral reading was incorrect, saying that her response was not for the target, but YT could not inhibit her lexical capture.

3) Kanji nonwords (Fushimi et al., 1999)

The right half of Fig.45 presents YT's and HW's oral reading performance for Kanji nonwords. YT's Kanji nonword reading was severely impaired (8/120, 7%) as was her Kana nonword reading. In contrast, HW's Kanji nonword reading was very good (104/120, 87%).

In the case of YT's errors for Kanji nonword reading, about half included correct pronunciation of either the first or the second constituent-Kanji character (63/112, 53%). These errors will be classified as 'visual (and also phonological) errors', including a substantial number of lexicalisation errors (57/63, 90%) as in 電続 /deN-zoku/ →電話 /deN-wa/ *telephone*. Among the non-visual errors (33/112), lexical and non-lexical errors (23/33 vs. 6/33) were observed. In many of the lexical errors YT produced the pronunciation of words, which were semantically related to either of the constituent-Kanji characters (e.g. 教池→先生 *teacher*, in which that the bound morpheme 教 meaning *teach* was supposed to evoke semantically associated word *teacher* 先生). 'Don't know' responses or no response did not occur frequently (16/112, 14%).

Table 19 HW's performance in two-character Kanji nonword reading

	High Frequency			Low Frequency		
	Consistent	Biased	Ambiguous	Consistent	Biased	Ambiguous
Pronunciation correct in normal	0.92	0.93	0.88	0.92	0.83	0.85
Typical/correct in normal	0.99	0.81	0.41	1.00	0.78	0.39
Proportion correct in HW	0.90	1.00	0.90	0.80	0.80	0.80
Typical response in HW	0.80	0.65	0.25	0.80	0.30	0.15
LARC response in HW	0.10	0.35	0.65	0.00	0.50	0.65
Typical/correct response in HW	0.89	0.65	0.28	1.00	0.38	0.19

Normal data: Fushimi et al. (1999)

The upper part of Table 19 describes the average rate of correct reading aloud of Kanji nonwords by normal subjects (Fushimi et al., 1999). Their overall accuracy was 89%, ranging from 83% to 93% across 6 conditions. The lower part of Table 19 presents HW's oral reading performance for Kanji nonwords in the 6 conditions.

HW's accuracy was modulated by character frequency (56/60, 93% in a high character-frequency band and 48/60, 80% in a low character-frequency band; $\chi^2 = 4.62$, $p < 0.04$), but his overall accuracy (87%) was in the normal range. The typical response, which refers to the most typical pronunciations of both constituent characters, occurred most frequently for consistent nonwords. The rate of typical response was correspondent to the degree of consistency (i.e. consistent, biased, and ambiguous). A simultaneous multiple logistic regression analysis on typical responses, with 2 categorical predictors – character frequency (high and low), and consistency (consistent, consistent-biased, and inconsistent-ambiguous) - revealed a significant effect of consistency (Wald = 24.86, $p < 0.00001$).

3) Summary of YT's and HW's oral reading of nonword strings

YT demonstrated profound difficulty in Kana and Kanji nonword reading (3% and 7%, respectively) and her single-Kana character reading had also deteriorated (43%). In contrast, HW's oral reading performance for single-Kana characters and both Katakana and Kanji nonwords was very good.

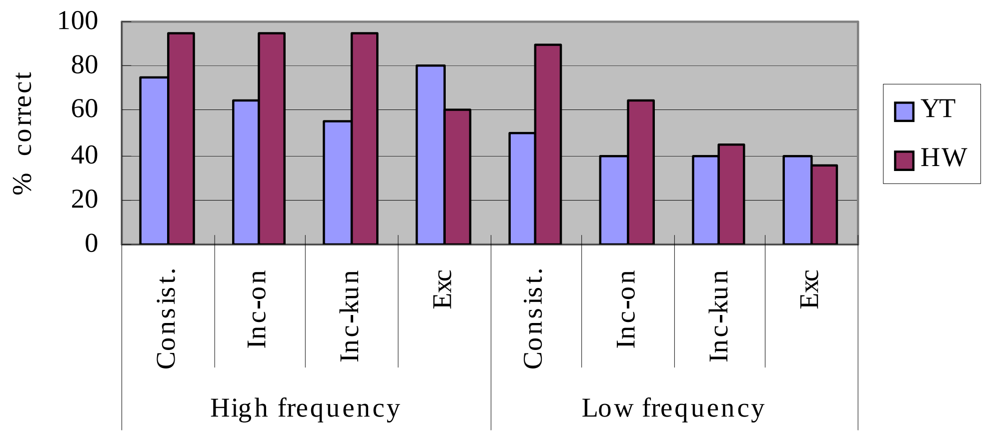
6.4.2. Oral reading of Kanji words manipulated by consistency

1) The two-character Kanji words devised by Patterson et al. (1995)

As shown in Fig.46, there was no consistency effect in YT's performance (e.g. YT's accuracy for exception words of a high frequency band was 16/20, 80%). YT's overall accuracy was 56% (89/160) which was modulated by word frequency (high frequency words: 55/80, 69% vs. low frequency words: 34/80, 43%; $\chi^2 = 7.42$, $p < 0.001$).

In contrast, HW showed a graded consistency effect on oral reading of low frequency words (consistent: 18/20, 90%; inconsistent-ON: 13/20, 65%; inconsistent-KUN: 9/20, 45%; and 7/20, 35%). HW's overall accuracy was 73% and his reading performance was modulated by frequency (69/80, 86%, vs. 47/80, 59%; χ^2 =15.17, $p < 0.0001$), but even for high frequency words HW's accuracy of exception words was remarkably impaired (12/20, 60%).

Fig. 46. YT's and HW's performance in the 160 Two-Character Kanji Word Reading Test (Stimuli taken from Patterson et al.1995).



Error analysis

Table 20-1 and Table 20-2 show YT's and HW's error pattern, respectively, in this experiment. The nature of the error types was quite different between YT and HW. No response (18/71, 25%) and semantic error (14/71, 20%) were YT's main error types, whereas HW did not make 'no response' errors and made only one semantic error. Instead, HW mainly made LARC errors (e.g. 風情/fu-zei/ *taste* →/fuu-jyo/) or 'one character correct' responses (e.g. 手鏡/te-kagami/ *hand glass* →/te-gami/), in which the pronunciation of one but not both of the constituent characters in two-character Kanji words was correct. Although YT also made LARC errors (9/71, 13%), HW produced a much higher proportion of this type of error (24/43, 56%).

Table 20-1 Number of error types by YT in the four consistency conditions of the 160 Two-Character Kanji Word Reading Test

	Consist.	Inc-ON	Inc-KUN	Exceptioı	Total
LARC error	0	5	2	2	9
One character correct	0	0	1	0	1
Phonological error	2	1	2	1	6
Semantic error	2	3	5	4	14
Semantic/Visual error	4	1	0	2	7
Visual error	1	0	2	0	3
Other	2	3	4	2	11
Semantic & LARC	0	2	0	0	2
No response	4	4	5	5	18

Table 20-2 Number of error types by HW in the four consistency conditions of the 160 Two-Character Kanji Word Reading Test

	Consist.	Inc-ON	Inc-KUN	Exception	Total
LARC error	0	5	5	14	24
One character correct	0	2	6	3	11
Phonological error	3	0	0	1	4
Semantic error	0	0	1	0	1
Semantic/Visual error	0	0	0	1	1
Visual error	0	0	0	1	1
Other	0	1	0	0	1

The proportion of HW’s LARC errors was not correspondent to the consistency condition (inconsistent-ON: 5/8, 63%; inconsistent-KUN: 5/12, 42%; exception: 14/21, 67%). This result was not consonant with the error pattern of TI (Fushimi et al., 2003a), who showed an inverse consistency effect in the rate of LARC errors (i.e. exception words lead to the most frequent occurrence of LARC error). Why did HW not show an inverse effect of consistency for LARC errors?

One possibility seems to relate to the problem of categorical definition about consistency itself. That is, categorical consistency, as defined by Patterson et al. (1995), might confound a basic word property like word familiarity. Table 21 describes both familiarity and frequency (mean) for the two-character Kanji word stimuli of Patterson et al. (1995)'s list. These characteristics of the stimuli were calculated using the NTT database (Amano & Kondo, 1999, 2000).

Table 21 Characteristics of the stimulus materials (mean) for the 160 two-character Kanji Words used in Patterson et al.(1995).

	High frequency				Low frequency			
	Consist.	Inc-ON	Inc-KUN	Exception	Consist.	Inc-ON	Inc-KUN	Exception
Familiarity (FA+FV)	6.12	6.17	6.01	5.83	5.51	5.54	5.18	5.03
Spoken word familiarity (FA)	5.94	5.96	5.93	5.84	5.39	5.32	5.15	4.97
Written word familiarity (FV)	6.16	6.21	6.03	5.79	5.53	5.56	5.11	5.01
Word frequency	3.85	3.81	3.54	2.81	2.88	3.08	2.15	2.47

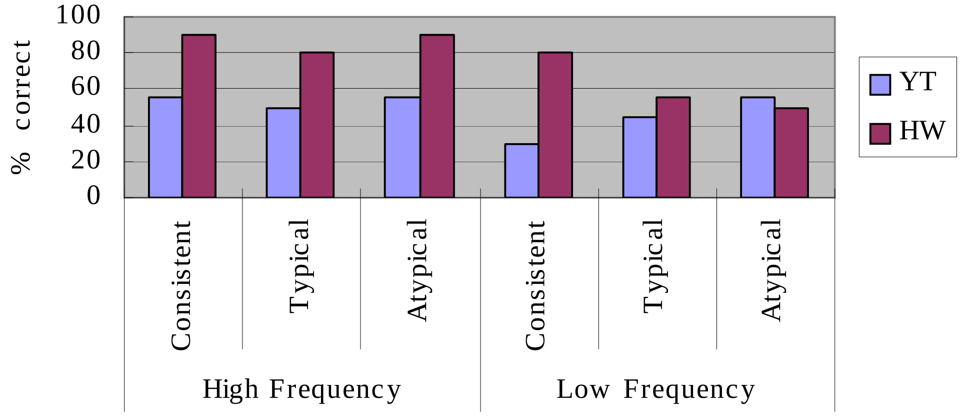
This analysis revealed that word familiarity and frequency were not well controlled in the stimuli, where familiarity and frequency were lowest in exception words for a high frequency band, and familiarity of exception words and frequency of inconsistent-KUN were lowest for a low frequency band. It is likely that HW's 'consistency effect' on these words reflected a multiple variables influence and so HW did not show an inverse consistency effect in LARC errors. Therefore, further investigation is needed to examine the consistency effect on oral reading accuracy and the inverse consistency effect on the rate of LARC errors.

2) The two-character Kanji words devised by Fushimi et al. (1999)

Figure 47 presents YT's and HW's accuracy in oral reading of Fushimi et al's (1999) two-character Kanji words, which were manipulated by statistically defined consistency. Again, YT did not show a consistency effect. YT's overall accuracy was 48% and her performance was modulated by frequency (high frequency words: 32/60, 53% vs. low frequency words: 26/60, 43%), but this was not statistically significant. On the other hand, HW's overall accuracy was 74% and his reading performance was modulated by word frequency (high frequency words: 52/60, 87%

vs. low frequency words: 37/60, 62%; χ^2=9.79, $p < 0.002$). A consistency effect was found in his oral reading of low frequency words (consistent words: 16/20, 80% vs. atypical words: 10/20, 50%, χ^2=3.96, $p < 0.05$).

Fig. 47. YT's and HW's performance in the 120 Two-Character Kanji Word Reading Test (Stimuli taken from Fushimi et al. 1999).



A simultaneous multiple logistic regression analysis on correct responses, with 9 predictors (i.e. consistency, word familiarity, word frequency, character frequency, character familiarity, number of morae (i.e. word length), number of strokes (i.e. visual complexity), age of acquisition, and ON/KUN reading), revealed a significant effect of word familiarity (Wald = 12.758, $p < 0.001$) and consistency (Wald = 4.671, $p < 0.04$) on HW's oral reading performance.

Error analysis

YT made various types of error, including LARC errors, but her errors for Kanji word reading were characterised by a high proportion of semantic and semantic/visual errors (Table 22-1**)**. As shown in Table 22-2, HW also made various types of error; however, his characteristic errors were LARC errors (e.g. 小雨 /ko-same/ *light rain*→/ko-ame/) and visual errors, in which a constituent character's pronunciation is correct and reading response as a whole is similar to the target (e.g. 食品 /sjoku-hiN/ *food*→/syou-hiN/). The proportion of HW's LARC errors showed a reverse pattern of consistency, which was more pronounced for low-frequency rather than high-frequency words.

Table 22-1 The proportion of main errors made by YT in the 120 Two-Character Kanji Word Reading Test

	High-frequency			Low-frequency		
		Inconsistent			Inconsistent	
	Consistent	Typical	Atypical	Consistent	Typical	Atypical
LARC	0.00	0.05	0.00	0.00	0.05	0.05
Visual	0.05	0.05	0.05	0.10	0.15	0.05
Semantic	0.05	0.05	0.15	0.10	0.30	0.05
Semantic/Visual	0.10	0.15	0.10	0.20	0.00	0.10
DK	0.15	0.10	0.15	0.20	0.05	0.05

Table 22-2 The proportion of main errors made by HW in the 120 Two-Character Kanji Word Reading Test

	High-frequency			Low-frequency		
		Inconsistent			Inconsistent	
	Consistent	Typical	Atypical	Consistent	Typical	Atypical
LARC	0.00	0.05	0.15	0.05	0.20	0.45
Visual	0.00	0.00	0.05	0.05	0.15	0.20
Semantic	0.00	0.00	0.00	0.00	0.05	0.00
Semantic/Visual	0.00	0.05	0.00	0.10	0.10	0.15
DK	0.00	0.00	0.00	0.00	0.00	0.00

3) Summary of YT's and HW's oral reading of Kanji words for detecting a consistency effect

HW demonstrated a consistency effect in both two-character Kanji word lists compiled by Patterson et al. (1995) and Fushimi et al. (1999). The majority of HW's oral reading errors were LARC errors and showed an inverse consistency effect on the occurrence of LARC errors in oral reading of the two-character Kanji words devised by Fushimi et al (1999). In contrast, YT did not show consistency effects in the either of the experiments.

6.4.3. Characteristics of YT's and HW's dyslexic pattern

1) The double dissociation of oral reading performance between atypical Kanji words and Kanji nonwords

YT and HW showed quite distinctive performances in the oral reading experiments. YT's oral reading for both Kana and Kanji nonwords had deteriorated severely, whereas HW's nonword reading was preserved. Moreover, YT did not show a consistency effect on Kanji word reading, whereas HW showed a consistency effect on the 2-character Kanji words devised by Patterson et al. (1995) and Fushimi et al. (1999). YT and HW showed the double dissociation of oral reading accuracy between Kanji nonwords and low frequency/atypical Kanji words (YT: 7% < 55%; HW: 87% > 50%, respectively). Therefore, it can be stated that YT's and HW's dyslexic patterns were qualitatively different.

2) The diagnosis of dyslexia type

Since deep and phonological dyslexics in alphabetic scripts show impairment of nonword reading, and surface dyslexics in alphabetic scripts show a consistency effect coupled with preserved nonword reading, YT should show deep or phonological dyslexia in Japanese and HW's dyslexic pattern can be diagnosed as surface dyslexia.

6.4.4. Comments on the surface dyslexia pattern observed in HW

HW, who showed semantic impairment, demonstrated a consistency effect, which is a defining feature for surface dyslexia in English. HW's dyslexic pattern was similar to the oral reading performance by the recent surface dyslexia cases in Japanese (e.g. TI: Fushimi et al., 2003a). HW's oral reading of low frequency/inconsistent Kanji words was impaired compared to the oral reading of consistent Kanji words (i.e. consistency effect). HW's oral reading accuracy of low frequency/typical words was slightly better than low/frequency atypical words (55% > 50%), but there was no statistical significance. That is, HW did not demonstrate the graded consistency effect (consistent words > inconsistent-typical words > inconsistent-atypical words) reported in other Japanese surface dyslexic cases with semantic dementia (TI and MN: Fushimi et al., 2003a, 2003b, respectively). Despite this difference, HW's demonstration of a consistency effect and preserved Kanji nonword reading satisfy the criteria for surface dyslexia. So, it is clear that HW showed surface dyslexia in Japanese.

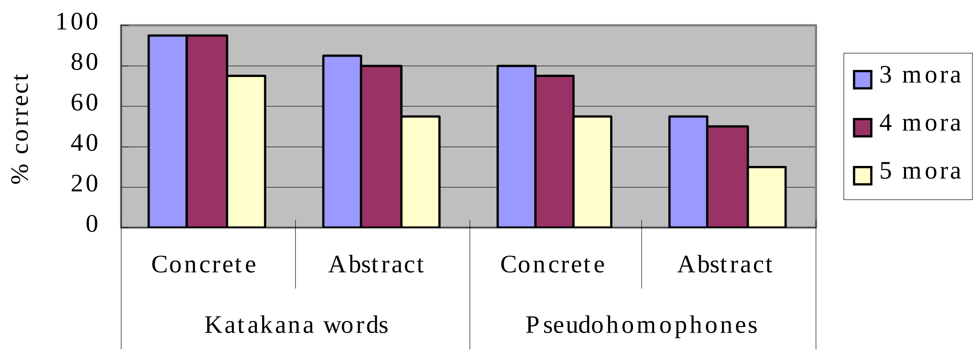
6.5. The oral reading experiments for exploring Japanese deep dyslexia

6.5.1. Oral reading of Kanji/Kana words, manipulated in terms of concreteness/imageability

1) Kanji/Kana words manipulated in terms of concreteness

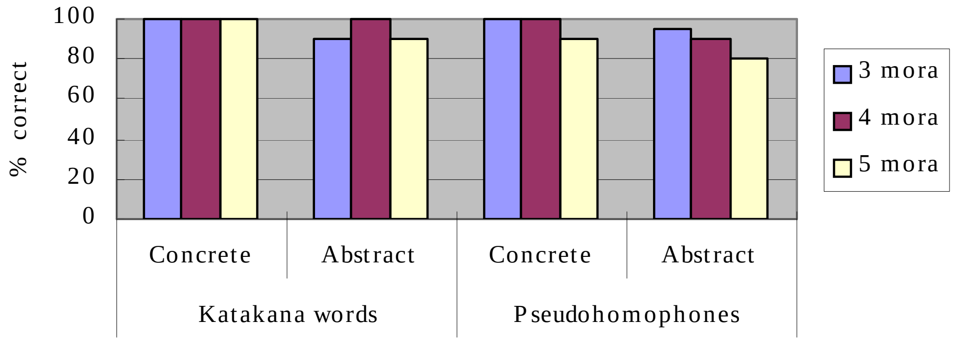
The left half of Fig.48 shows YT's reading performance in concrete/abstract Katakana words.

Fig. 48. YT's oral reading performance for Katakana cocnrete/abstract words and their Hiragana pseudohomophones.



YT's oral reading was better for concrete than for abstract words (53/60, 88% > 44/60, 73%: χ^2=4.36, $p < 0.04$), and was modulated by word-length (3- and 4-mora concrete words: 19/20, 95%; 5-mora concrete words: 15/20, 75%; 3-mora abstract words: 17/20, 85%; 4-mora abstract words: 16/20, 80%, 5-mora abstract words: 11/20, 55%). Statistical tests revealed the word-length effect in abstract words (3 mora words vs. 5 mora words: χ^2=4.29, $p < 0.04$). A simultaneous multiple logistic regression analysis with 4 predictors: imageability (Wydell, 1991), familiarity, word frequency, number of morae (i.e. word length), revealed a significant imageability effect (Wald = 4.27, p <0.04) and marginal word-length effect (Wald = 3.69, p = 0.055).

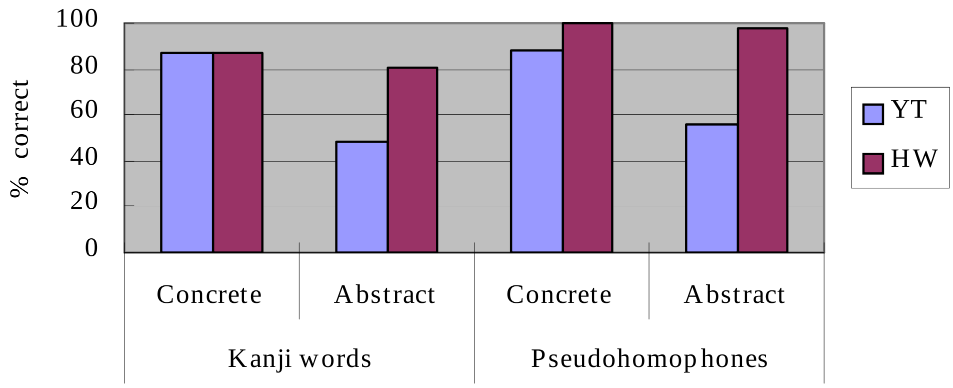
Fig. 49. HW's oral reading performance for Katakana concrete/abstract words and their Hiragana pseudohomophones.



In contrast, as shown in the left half of Fig.49, HW did not show a concreteness effect on these Katakana words (concrete words: 60/60, 100%; abstract words: 56/60, 93%). Although HW's oral reading of Katakana words was preserved, he often produced multiple responses for an oral reading stimulus.

The left half of Fig. 50 displays YT's and HW's oral reading performance for single-character Kanji words.

Fig. 50. YT'sand HW's oral reading performance for Kanji cocnrete/abstract words and their Hiragana pseudohomophones.



YT showed a marked concreteness effect (concrete words vs. abstract words: 45/52, 87% vs. 25/52, 48%: χ^2=17.48, $p < 0.0001$). A simultaneous multiple logistic regression analysis on her correct Kanji word reading, using the same 4 predictors as in the analysis with concrete/abstract Katakana words, revealed significant effects of imageability (Wald = 7.47, $p < 0.007$) and familiarity (Wald = 6.48, $p < 0.02$). On the other hand, HW's overall accuracy of single-character Kanji word reading was better than YT's (87/104, 87% > 70/104, 67%), and there was no concreteness effect on his reading performance.

<u>Error analysis</u>

Table 23 shows the proportion of error types by YT and HW in oral reading of Katakana words and single-character Kanji words as a function of concreteness.

Table 23 The proportion of error types by YT and HW in the Concrete/Abstract Reading Test

		Number of errors	Semantic	Circum.	Sem/visual	Phono.W	Phono.NW	LARC	Unrelated	DK/NR
YT	Concrete Katakana word	10	0.00	0.00	0.10	0.20	0.40	-	0.30	0.00
	Abstract Katakana word	19	0.05	0.00	0.00	0.32	0.26	-	0.26	0.11
	Concrete 1-charac.Kanji word	19	0.21	0.37	0.00	0.05	0.00	0.00	0.26	0.11
	Abstract 1 charac.Kanji word	31	0.35	0.10	0.13	0.00	0.00	0.10	0.16	0.16
HW	Concrete Katakana word	9	0.00	0.00	0.00	0.00	0.56	-	0.33	0.00
	Abstract Katakana word	16	0.00	0.00	0.00	0.13	0.75	-	0.13	0.00
	Concrete 1-charac.Kanji word	43	0.12	0.12	0.02	0.09	0.05	0.09	0.52	0.00
	Abstract 1 charac.Kanji word	30	0.17	0.00	0.03	0.23	0.00	0.30	0.26	0.00

Circum.= circumlocution; Sem.= semantic;
Phono.W:phonologically similar word; Phono.NW:phonologically similar nonword;
DK/NR: don't know or no response; W: word; NW:nonword

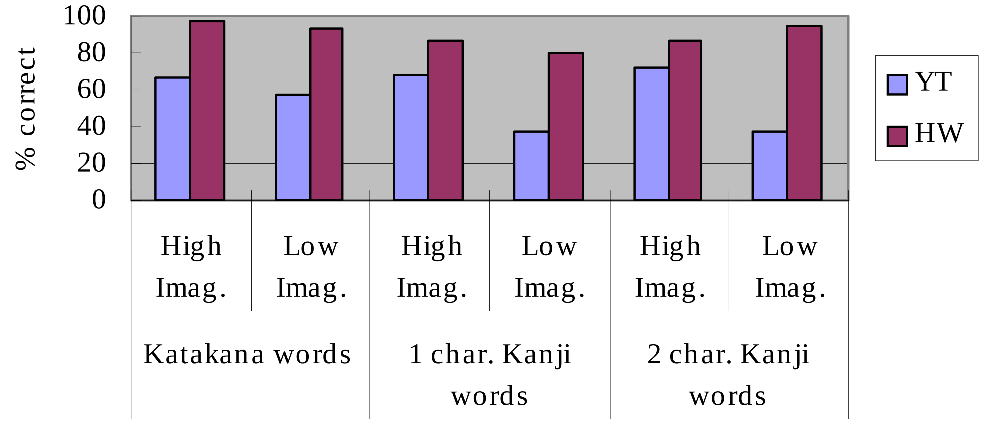
In Katakana word reading, the majority of YT's errors were words or nonwords bearing phonological (therefore visual in Kana script) resemblance to the target words (e.g. リサーチ/ri-sa-a-chi/ *research*→リザーブ/ri-za-a-bu/ *reserve*, ヒヤシンス/hi-ya-shi-N-su/ *hyacinth*→ /ri-ya-shi-N-su/) (phonologically similar words: 8/29, 28%; phonologically similar nonwords: 9/29, 31%). YT also produced unrelated response (e.g. テレパシー /te-re-pa-si/ *telepathy* → /pu-ra-bu/) (7/29, 26%). More importantly, it should be emphasised that YT made only one semantic error (i.e.スペア *spare*→キー*key*). This was a semantic associative error and not a typical co-ordinate semantic error (e.g. music→orchestra). The vast majority of HW's errors were phonological similar nonwords (17/25, 68%), followed by unrelated errors (5/25, 20%).

In single-character Kanji word reading, YT made substantial semantic errors (e.g. 誠 /makoto/ *truth* →正義 /sei-gi/ *justice*) (15/50, 30%) and circumlocution including a semantically related gesture/onomatopoetic response (10/50, 20%), which occurred more frequently in concrete words than in abstract words. YT also made semantic/visual errors (4/50, 8%), but did not make visual errors. Meanwhile, the majority of HW's errors were unrelated errors (30/73, 41%), followed by LARC errors, and phonological resemblance errors (13/73, 18% each).

2) Kanji/Kana words manipulated in terms of imageability

Figure 51 presents YT's and HW's oral reading performance in the Three Kinds of Word Reading Test in which Katakana and Kanji words were manipulated in terms of imageability. YT demonstrated a striking imageability effect on both types of Kanji word reading (high imageability words vs. low imageability words: 41/60, 68% vs. 22/60, 37% for single-character Kanji word, χ^2=12.06, $p < 0.001$; 43/60, 72% vs. 22/60, 37% for two-character Kanji words, χ^2=14.80, $p= 0.0001$). As far as YT's Katakana word reading was concerned, there was a numerical difference between high and low imageability words (40/60, 67% vs. 34/60, 57%), but this was not statistically significant. A simultaneous multiple logistic regression analysis on YT's correct responses in Katakana word reading, with imageability, familiarity and number of mora (i.e. word length) as predictors, also did not show an imageability effect (Wald = 0.992).

Fig. 51. YT's and HW's performance in the Three Kinds of Word Reading Test.



In contrast, an imageability effect was not found in HW's oral reading performance (high imageability words vs. low imageability words: 58/60, 97% vs. 56/60, 93% for Katakana words; 52/60, 87% vs. 48/60, 80% for single-character Kanji words; 52/60, 87% vs. 67/60, 95% for two-character Kanji words). The proportion of self-correction was higher in HW (Katakana words: 15/120, 13%; single-character Kanji words: 19/120, 16%; two-character Kanji words: 15/120, 13%) than in YT (12/120, 10%; 7/120, 6%; 8/120, 7%, respectively).

Error analysis

Tables 24 and Table 25 show the proportion of YT's and HW's error types in the Three Kinds of Word Reading Test as a function of imageability, respectively.

YT's differential error pattern between Katakana and Kanji words was observed in this experiment. A phonologically similar response (e.g. ドラム/do-ra-mu/

drum→ドラマ /do-ra-ma/ *drama*; タイトル /ta-i-to-ru/ *title*→/ta-ku-to-ru/) (phonologically similar words: 14/61, 23%; phonologically similar nonwords: 16/61, 26%)was the main error, and only two semantic errors and one semantic/visual error (コブラ *cobra* →コアラ *koala*) were observed in YT's Katakana word reading. One of her semantic errors was a semantic associative error (ポテト *potato*→ チップ *chip*) and the other was finally self-corrected (スカーフ scarf → ネックレス necklace →スカート skirt →スカーフ scarf).

Table 24 The proportion of error types by YT in the Three Kinds of Word Reading Test

		Number of errors	Semantic	Circum.	Sem./Visual	Phono.W	Phono.NW	LARC	Unrelated	DK/NR
Katakana word	High Imag.	29	0.07	0.17	0.07	0.28	0.10	-	0.17	0.14
	Low Imag.	32	0.00	0.00	0.00	0.19	0.41	-	0.29	0.13
1-character Kanji word	High Imag.	30	0.30	0.27	0.00	0.07	0.00	0.00	0.23	0.13
	Low Imag.	42	0.14	0.07	0.19	0.02	0.00	0.07	0.19	0.31
2-character Kanji word	High Imag.	29	0.14	0.10	0.24	0.10	0.07	0.10	0.21	0.03
	Low Imag.	46	0.09	0.09	0.11	0.22	0.00	0.04	0.13	0.33

Table 25 The proportion of error types by HW in the Three Kinds of Word Reading Test

		Number of errors	Semantic	Circum.	Sem./Visual	Phono.W	Phono.NW	LARC	Unrelated	Visual
Katakana word	High Imag.	12	0.00	0.00	0.00	0.25	0.75	-	0.00	-
	Low Imag.	19	0.00	0.00	0.00	0.32	0.68	-	0.00	-
1-character Kanji word	High Imag.	28	0.04	0.07	0.04	0.25	0.07	0.04	0.46	0.04
	Low Imag.	35	0.03	0.00	0.06	0.11	0.03	0.23	0.51	0.03
2-character Kanji word	High Imag.	41	0.10	0.00	0.02	0.24	0.12	0.27	0.24	0.02
	Low Imag.	13	0.00	0.00	0.08	0.38	0.38	0.00	0.15	0.00

Circum.= circumlocution; Sem.= semantic;
Phono.W:phonologically similar word; Phono.NW:phonologically similar nonword;
DK/NR: don't know or no response; W: word; NW:nonword

In contrast, in Kanji word reading YT made semantic errors (e.g. 作業 /sa-gjo/ *work* → 労働者 /rou-dou-ʃa/ *laborer*; 街路 /gai-ro/ *street*→ 並木道 /na-mi-ki-michi/ *avenue*) (single-character Kanji words: 15/72, 21%; two-character Kanji words: 8/75, 11%), circumlocution or semantically related gestures or onomatopoetic expressions (single-character Kanji words: 11/72, 15%; two-character Kanji words: 7/75, 9%) and semantic/visual errors (e.g. 味 /a-ji/ *taste*

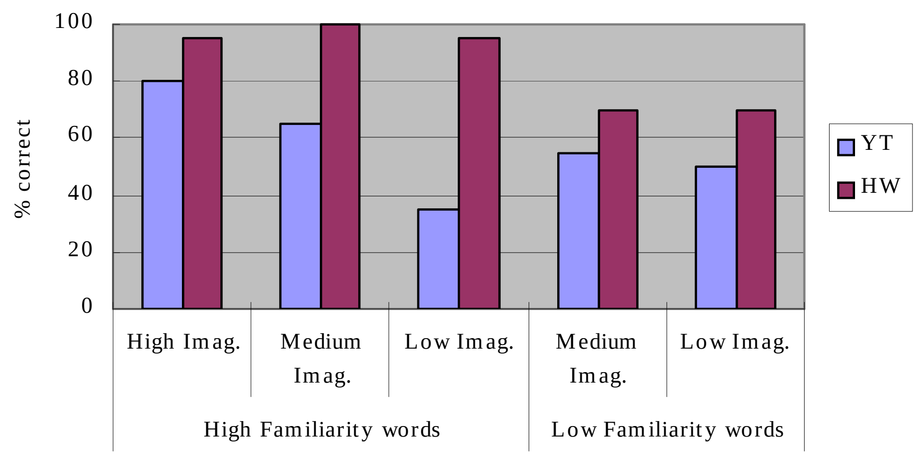
→味覚 /mi-kaku/ *the sense of taste*; 闇 /ya-mi/ *darkness* → 闇夜 /yami-yo/ *moonless night*; 順位 /juN-i/ *ranking* →順番 /juN-baN/ *order*) (single-character Kanji words: 8/72, 11%; two-character Kanji words: 11/75, 15%) . It is worth noting that semantic errors occurred more frequently in oral reading of high imageability words than of low imageability words, and semantic/visual errors were observed more frequently in oral reading of low imageability words than of high imageability words, as shown in Table 25. YT also produced unrelated errors (single-character Kanji words: 15/72, 21%; two-character Kanji words: 12/75, 16%, e.g. 論文 /roN-buN/ paper →/doN-kjo/) and 'don't know' or no responses (single-character Kanji words: 17/72, 24%; two-character Kanji words: 16/75, 21%). Although phonological similar errors were observed, the proportion of this error type was different depending on the number of Kanji character (single-character Kanji words: 3/72, 4%; two-character Kanji words: 14/75, 19%). Two visual errors (包帯/hou-tai/ *bandage* →包丁/hou-cyou/ *kitchen knife*; 毛虫/ke-mushi/ *caterpillar* →毛布 /mou-fu/ *blanket*) were only occurred in two-character Kanji word reading (2/75, 3%).

With regard to HW's reading errors, phonological resemblance to the target words was his dominant error type in both Katakana word reading (31/31, 100%) and two-character Kanji word reading (24/54, 44%). In oral reading of single-character Kanji words, the vast majority of HW's errors were unrelated errors (31/63, 49%). In Kanji word reading, LARC errors (single-character Kanji words: 9/63, 14%; two-character Kanji words: 11/54, 20%) were other characteristic error made by HW. HW produced a limited number of visual errors, which are not phonologically similar to the target (e.g. 音 /o-to/ *sound* →昔 /mu-ka-shi/ *old times*).

3) Oral reading of Kanji words manipulated by imageability and familiarity

As shown in Fig. 52, in YT's reading performance, an imageability effect was found at a high familiarity band (from high to medium, low imageability: 16/20, 80% > 13/20, 65%> 7/20, 35%; high vs. low imageability: χ^2=8.29, $p < 0.01$), but imageability was not found at low a familiarity band.

Fig. 52. YT's and HW's performance in the 100 Two-Character Kanji Word Test.



A simultaneous multiple logistic regression analysis on YT's correct responses, with 10 factors - number of mora, word familiarity, word frequency, imageability, ON-KUN reading difference, character familiarity, character frequency, number of stroke, age of acquisition, and consistency - revealed significant effects of imageability (Wald = 9.245, $p < 0.003$), consistency (Wald = 5.866, $p < 0.02$), and the number of strokes (Wald = 4.679, $p < 0.04$).

Meanwhile, HW's reading performance was modulated by familiarity (high familiarity words: 58/60, 97% vs. low familiarity words: 28/40, 70%: χ^2=14.18, $p < 0.0001$), but not by imageability. A simultaneous multiple logistic regression analysis on HW's correct responses, with the same 10 factors as for YT, revealed a significant effect of familiarity (Wald = 4.839, $p < 0.03$), and consistency (Wald = 3.839, $p < 0.05$). In both cases, error patterns were similar to the results of the previous two-character Kanji word reading.

4) Summary of oral reading of Kanji/Kana words for detecting concreteness/imageability effect

YT demonstrated a remarkable concreteness/imageability effect on Kanji word reading (concrete/abstract words: 87% vs. 48%; high/low imageability words: 70% vs. 37%). YT's Katakana word reading was modulated by concreteness/imageability and word-length (concrete/abstract words: 95% vs. 85% for 3 mora words, 95% vs. 80% for 4 mora words, 75% vs. 55% for 5 mora words; high/low imageability words: 67% vs. 57%). That is, concreteness/imageability effect was greater in Kanji word reading than in Kana word reading (Kanji words vs. Kanji words: 87% > 48%, ($p < 0.0001$) vs. 88% > 73%, ($p < 0.05$) for concrete/abstract words; 70% > 37%, ($p < 0.001$) vs. 67% > 57%, ($p = 0.26$) for high/low imageability words). YT’s oral reading error pattern was different, depending on the script type. Semantic errors (36/197, 18%), semantic/visual errors (23/197, 12%) and semantically associated responses with gestures and or onomatopoetic expressions (28/197, 14%) were prominent (87/197, 44%) for oral reading of Kanji words. YT made a few phonological errors (18/197, 9%) and visual errors (2/197, 1%). In contrast, phonological (i.e. visual) errors was YT's dominant error type (47/90, 52%) in Kana word reading and YT produced only a limited number of semantic errors (3/90, 3%) and semantic/visual errors (3/90, 3%). This different error pattern, depending on the script type, was consistent with the prediction presented in Chapter 4 and also the description in the classical case studies for the Japanese version of deep dyslexia.

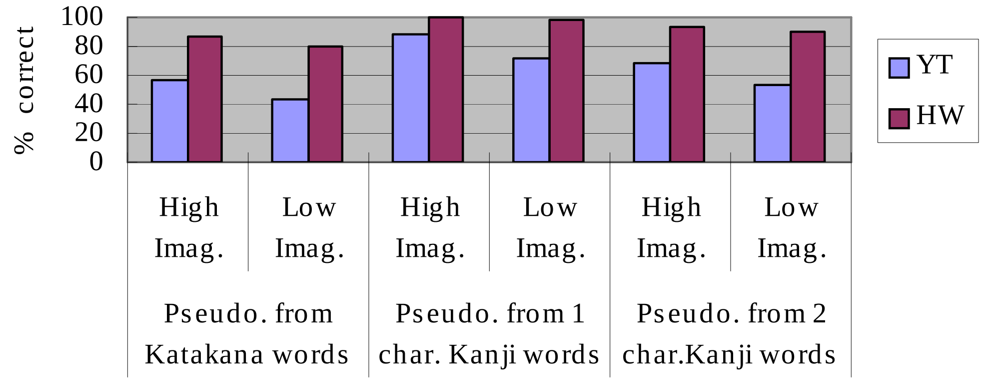
HW did not show any concreteness/imageability effect on his word reading. Phonological errors were HW's dominant error type in Kana word reading (50/56, 89%), and he mainly produced unrelated responses (73/190, 38%), phonological errors (51/190, 27%) and LARC errors (33/190, 17%) in Kanji word reading.

6.5.2. Oral reading of Kanji/Kana pseudohomophones

1) Kana pseudohomophones

The results of YT's and HW's oral reading for Hiragana pseudohomophones, transcribed from Katakana words and single-character Kanji words which consisted of concrete words and abstract words, are shown in the right half of Fig. 48, Fig. 49 and Fig. 50.

Fig. 53. YT's and HW's oral reading performance for Hiragana pseudohomophones transcribed from the stimuli of the Three Kinds of Word Reading Test.



char.= character

Figure 53 also presents YT's and HW's reading performance for Hiragana pseudohomophones, transcribed from Katakana words and Kanji words which were manipulated in terms of imageability. YT's oral reading of Hiragana pseudohomophones was modulated by the concreteness/imageability of the base Katakana words (concrete vs. abstract: 70% > 48%; high imageability vs. low imageability: 57% > 43%) and also of the base Kanji words (concrete vs. abstract: 88% > 56%; %; high imageability vs. low imageability: 78% > 63%). It was clear that YT's oral reading of Kana pseudohomophones was much better than of Kana nonhomophonic nonwords (3%), as presented in section 6.4.1.

Meanwhile, HW showed well-preserved oral reading of Hiragana pseudohomophones throughout all tasks, but he sometimes produced multiple responses for an oral reading stimulus. His oral reading was slightly modulated by the concreteness/imageability of the base Katakana words (concrete vs. abstract: 97% > 88%; high imageability vs. low imageability: 87% > 80%), but was not clearly modulated by the concreteness/imageability of the base Kanji words (concrete vs. abstract: 100% > 98%; high imageability vs. low imageability: 97% > 94%). HW's oral reading accuracy of Kana pseudohomophones was fairly good, and the majority of them were better than Kana nonhomophonic nonwords (93%) in the section 6.4.1.

Error analysis

Table 26 presents YT's and HW's error pattern in oral reading of Hiragana pseudohomophones transcribed from Katakana and Kanji concrete/abstract words as a function of the concreteness of the base words. In oral reading of Hiragana transcriptions from Katakana words, YT frequently produced a phonologically similar word error (24/55, 44%), followed by 'don't know' or no response (22/55, 40%), whereas a phonologically similar nonword response was HW's dominant error

(28/29, 97%). In oral reading of Hiragana transcriptions from Kanji words, an unrelated word response was the main error type for both YT and HW (98/124, 79% and 24/34, 71%, respectively).

Table 26 The proportions of error types in YT's and HW's oral reading Hiragana pseudohomophones transcribed from Katakana and Kanji concrete/abstract words

			Number of errors	Phono. W	Phono. NW	Sem./SV	Unrelated W	Unrelated NW	DK/NR
YT	Pseudo.form Katakana word	Concrete	21	0.24	0.19	0.05	0.10	0.05	0.38
		Abstract	34	0.29	0.15	0.00	0.03	0.12	0.41
	Pseudo.from 1 char.Kanji word	Concrete	65	0.02	0.03	0.02	0.80	0.08	0.06
		Abstract	59	0.05	0.02	0.03	0.68	0.02	0.20
HW	Pseudo.form Katakana word	Concrete	11	0.09	0.91	0.00	0.00	0.00	0.00
		Abstract	18	0.22	0.72	0.06	0.00	0.00	0.00
	Pseudo.from 1 char.Kanji word	Concrete	22	0.14	0.09	0.00	0.77	0.00	0.00
		Abstract	12	0.25	0.17	0.00	0.58	0.00	0.00

Phono.W:phonologically similar word; Phono.NW:phonologically similar nonword; DK/NR: don't know or no response
W: word; NW:nonword

As shown in Table 27 and Table 28, both YT and HW made a variety of types of error in oral reading of pseudohomophones transcribed from the stimuli of the Three Kinds of Word Reading Test. This was a function of the imageability of the base words.

Table 27 The proportions of error types in YT's oral reading of Hiragana pseudohomophones transcribed from the stimuli of the three Kinds of Word Reading Test

		Number of errors	Semantic	Circum.	Sem./Visual	Phono.W	Phono.NW	Unrelated W	Unrelated NW	DK/NR
Pseudo.form Katakana W.	H Imag.	35	0.03	0.00	0.00	0.43	0.17	0.17	0.03	0.17
	L Imag.	39	0.00	0.00	0.00	0.28	0.23	0.21	0.10	0.18
Pseudo.from 1 char.kanji W.	H Imag.	10	0.10	0.00	0.30	0.40	0.00	0.10	0.00	0.10
	L Imag.	28	0.11	0.00	0.04	0.50	0.14	0.18	0.00	0.03
Pseudo.from 2 char.kanji W.	H Imag.	29	0.00	0.10	0.00	0.41	0.17	0.07	0.03	0.21
	L Imag.	39	0.00	0.03	0.03	0.31	0.13	0.13	0.08	0.31

Table 28 The proportions of error types in HW's oral reading of Hiragana pseudohomophones transcribed from the stimuli of the three Kinds of Word Reading Test

		Number of errors	Semantic	Sem./Visua	Phono.W	Phono.NW	Unrelated W	Unrelated NW
Pseudo.form Katakana W.	H Imag.	15	0.00	0.00	0.33	0.67	0.00	0.00
	L Imag.	13	0.00	0.00	0.00	1.00	0.00	0.00
Pseudo.from 1 char.kanji W.	H Imag.	7	0.00	0.00	0.43	0.43	0.00	0.14
	L Imag.	2	0.00	0.00	1.00	0.00	0.00	0.00
Pseudo.from 2 char.kanji W.	H Imag.	19	0.05	0.05	0.32	0.53	0.00	0.05
	L Imag.	16	0.00	0.00	0.13	0.56	0.06	0.25

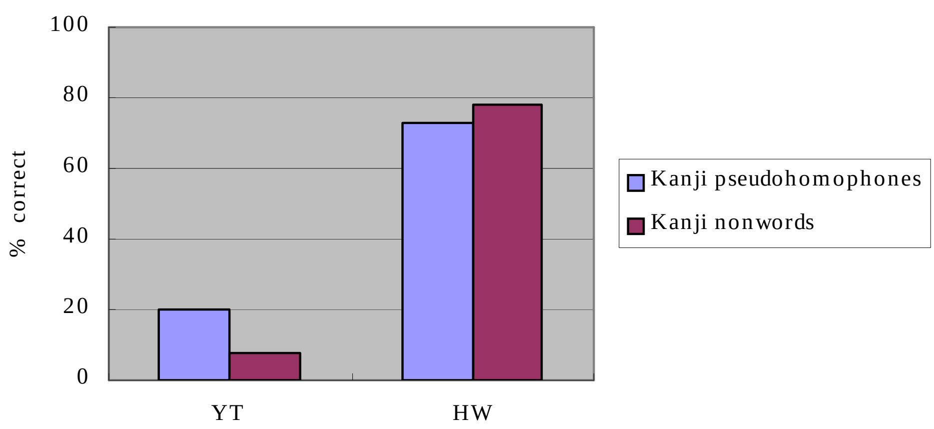
Phono.W:phonologically similar word; Phono.NW:phonologically similar nonword; DK/NR: don't know or no response
W: word; NW:nonword

The majority of errors, in both cases, were phonological resemblance to the target stimuli, but HW produced more phonologically similar nonword responses (phonologically similar words vs. phonologically similar nonwords: 68/180, 38% > 29/180, 16% in YT, 18/72, 25% < 45/72, 63% in HW).

2) Kanji pseudohomophones

Figure 54 presents YT's and HW's results in the Homophonic Kanji nonword and Nonhomophonic Kanji Nonword Reading Test. Both types of reading stimuli were created by synthesising constituent Kanji characters for the consistent words of Patterson et al.'s (1995) list. YT showed marked impairment of oral reading of Kanji pseudohomophones (i.e. homophonic nonwords written in Kanji character), though her accuracy of oral reading of Kanji pseudohomophones was higher than that of her oral reading of Kanji nonwords (i.e. nonhomophonic nonwords written in Kanji character) (8/40, 20% and 3/40, 8%, respectively). This was not statistically significant.

Fig. 54. YT's and HW's performance in the Kanji Pseudohomophones and Kanji Nonhomophonic Nonword Reading Test.



In contrast, HW's oral reading of Kanji pseudohomophones (29/40, 73%) was slightly worse than of Kanji nonhomophonic nonwords (31/40, 78%), though his oral reading of both types of nonwords was well preserved.

Error analysis

YT produced various kinds of reading errors without prominent errors, whereas HW made prominent phonologically similar errors (Table 29).

Table 29 The proportion of error types in YT's and HW's oral reading of Kanji pseudohomophones and Kanji nonhomophonic nonwords

		Number of errors	Semantic	Visual	Phonological	Incompleted	Unrelated	Other	DK/NR
YT	Pseudo.	39	0.15	0.21	0.15	0.15	0.15	0.03	0.15
	Nonwords	37	0.14	0.22	0.06	0.11	0.19	0.03	0.27
HW	Pseudo.	15	0.00	0.00	0.93	0.00	0.07	0.00	0.00
	Nonwords	16	0.00	0.25	0.75	0.00	0.00	0.00	0.00

Pseudo.= Kanji pseudohomophones
Nonwords = Kanji nonhomophonic nonwords

3) **Summary of pseudohomophone reading**

YT’s oral reading performance for Hiragana pseudohomophones was fairly good, but was modulated by concreteness/imageability and word-length of the base word (e.g. 3 mora concrete/abstract words vs. 5 mora concrete/abstract words: 80% and 65% vs. 55% and 30%). YT showed superiority of Kana pseudohomophone over Kana nonhomophonic nonwords (overall average, 82% > 3%). In contrast, YT's oral reading of Kanji pseudohomophones had deteriorated, though she showed a numerical advantage of Kanji pseudohomophones over Kanji nonwords (20% > 8%). Meanwhile, HW's oral reading of both Kana and Kanji pseudohomophones was well preserved, as with Kana/Kanji nonhomophonic nonwords.

6.5.3. Comments on the deep dyslexia pattern observed in YT

YT's dyslexic pattern can be summarised as follows:

i) YT's oral reading of both Kana and Kanji nonwords was remarkably impaired. The lexicalisation error was YT's main error type in nonword reading.

ii) YT showed a concreteness/imageability effect on both Kana and Kanji word reading. This effect was greater in Kanji word reading than in Kana word reading.

iii) YT showed superiority of Kana/Kanji pseudohomophone reading over Kana/Kanji nonhomophonic nonword reading. The pseudohomophone effect was statistically significant in Kana strings.

iv) YT made semantic errors and semantic/visual errors in Kanji word reading, whereas these types of errors were rarely observed in Kana word reading where phonological (i.e. visual in Kana script) errors were dominant.

Thus, YT demonstrated the same psycholinguistic variables effects as observed in English deep/phonological dyslexia, although YT's variables effect was slightly modulated by the script type. However, YT's error pattern differed depending on the script type. If one follows the diagnostic criteria for deep and phonological dyslexia in English, in which appearance/disappearance of semantic errors is used for distinguishing the two types of acquired dyslexia, YT demonstrated deep dyslexia for Kanji strings and phonological dyslexia for Kana strings. Since YT actually made semantic errors in word reading, her dyslexic pattern as a whole can be categorised as deep dyslexia. So, YT's dyslexic pattern seems to be a unique characteristic of deep dyslexia in Japanese, which has the distinctive bi-scripts: morphographic Kanji and phonographic Kana.

6.6. The analysis of Japanese dyslexic patterns using the Kanji vs. Kana framework

This section presents the results of re-analysing YT's and HW's oral reading accuracy in order to examine the bi-scriptal influence on oral reading and to verify the script-dependent dyslexic patterns reported in the classical cases.

6.6.1. The analysis of word reading using the Kanji vs. Kana framework

1) A comparison of the oral reading accuracy of Kanji and Kana word reading

a. Deep dyslexia

YT's oral reading accuracy of Kanji words and Kana words for concrete/high imageability words did not differ between the two (Kanji words vs. Kana words: 45/52, 87% ≒ 53/60, 88% for concrete words; 84/120, 70% [single-character words: 41/60, 68%; two-character words: 43/60, 72%] ≒ 40/60, 67% for high imageability words). YT's oral reading accuracy of Kana words was better than of Kanji words for abstract/low imageability words reading (Kanji words vs. Kana words: 25/52, 48% < 44/60, 73% for abstract words, $\chi^2 = 7.51$, $p < 0.01$; 44/120, 37% [in both single-character and two-character Kanji words] < 34/60, 57% for low imageability words, $\chi^2 = 6.52$, $p < 0.02$).

b. Surface dyslexia

In HW's oral reading accuracy of words manipulated by concreteness/imageability, Kana word reading was better than Kanji word reading in almost all conditions (Kanji words vs. Kana words: 45/52, 87% < 60/60, 100% for concrete words; 52/60, 87% [in both single-character and two-character Kanji words] < 58/60, 97% for high imageability words; 42/52, 81% < 56/60, 93% for abstract words; 48/60, 80% [in single-character Kanji words] < 56/60, 93% for low imageability words). However, HW's oral reading accuracy of two-character Kanji words was slightly better than Kana word reading in low imageability words (57/60, 95% > 56/60, 93%). HW's oral reading accuracy of high frequency/consistent Kanji words (19/20, 95% for Patterson et al.'s list; 18/20, 90% for Fushimi et al.'s list) was also similar to his oral reading accuracy of Kana word reading overall (230/240, 96%).

6.6.2. The analysis of pseudohomophone reading using the Kanji vs. Kana framework

1) A comparison of oral reading accuracy of Kanji words and Hiragana pseudohomophones transcribed from Kanji words

a. Deep dyslexia

YT's oral reading accuracy of Hiragana pseudohomophones transcribed from Kanji words was similar to, or better than that of the base Kanji words (Kanji words vs. Hiragana pseudohomophones: 45/52, 87% ≒ 46/52, 88% for concrete items; 84/120, 70% [single-character words: 41/60, 68%; two-character words: 43/60, 72%] < 94/120, 78% for high imageability items; 25/52, 48% <29/52, 56% for abstract words). This difference was highest for low imageability items (Kanji words vs. Hiragana pseudohomophones: 44/120, 37% [in both single-character and two-character Kanji words] < 75/120, 63%).

b. Surface dyslexia

HW's oral reading accuracy of Hiragana pseudohomophones transcribed from Kanji words was better than that of the base Kanji words (Kanji words vs. Hiragana pseudohomophones: 45/52, 87% < 52/52, 100% for concrete items; 104/120, 87% [in both single-character and two-character Kanji words] < 116/120, 97% for high imageability items; 42/52, 81% < 51/52, 98% for abstract items; 105/120, 88% [single-character words: 38/60, 80%; two-character words: 57/60, 95%] < 113/120, 94% for low imageability items).

2) A comparison of oral reading accuracy of Katakana words and Hiragana pseudohomophones transcribed from Katakana words

a. Deep dyslexia

YT's oral reading accuracy of Hiragana pseudohomophones transcribed from Katakana words was worse than that of the base Katakana words (Katakana words vs. Hiragana pseudohomophones: 53/60, 88% > 42/60, 70% for concrete items; 44/60, 73% > 29/60, 48% for abstract items; 40/60, 67% > 34/60, 57% for high imageability items; 34/60, 57% > 26/60, 43% for low imageability items). This difference was statistically significant in concrete/abstract items (χ^2=6.11, $p < 0.02$ for concrete items; χ^2=7.87, $p < 0.001$).

b. Surface dyslexia

HW's oral reading accuracy of Hiragana pseudohomophones transcribed from Katakana words was similar to that of the base Katakana words manipulated by concreteness (Katakana words vs. Hiragana pseudohomophones: 60/60, 100% ≒ 58/60, 97% for concrete items; 56/60, 93% ≒ 53/60, 88% for abstract items). HW's oral reading accuracy of Hiragana pseudohomophones transcribed from Katakana words manipulated by imageability was worse than that of the base Katakana words (Katakana words vs. Hiragana pseudohomophones: 58/60, 97% > 52/60, 87% for high imageability items, χ^2=3.93, $p < 0.05$; 56/60, 93% > 48/60, 80%, for low imageability items, χ^2=4.62, $p < 0.04$).

3) A comparison of oral reading accuracy of Kana pseudohomophones and Kanji pseudohomophones

a. Deep dyslexia

YT's oral reading accuracy of Hiragana pseudohomophones transcribed from Katakana and Kanji words (30-88%) was better than that of Kanji pseudohomophones created from consistent Kanji words (20%). Concreteness/imageability and the number of mora (i.e. word-length) of the base words affected YT's oral reading accuracy of Hiragana pseudohomophones (e.g. transcriptions of 3-mora Katakana concrete words vs. 5-mora Katakana abstract words: 80% vs. 30%).

YT's pseudohomophone reading was worse than her word reading and better than her nonhomophonic nonword reading in both Kana and Kanji strings. That is, YT showed a lexicality effect in both strings (words vs. pseudohomophones vs. nonhomophonic nonwords: 171/240, 71% > 375/584, 64% > 3/120, 3% for Kana strings; 198/344, 58% > 8/40, 20% > 11/160, 7% for Kanji strings), but she showed a distinguishable pattern between Kana and Kanji strings, which emerged from the different accuracy of Kana/Kanji pseudohomophones.

b. Surface dyslexia

HW's oral reading accuracy of Hiragana pseudohomophones transcribed from Kanji and Katakana words manipulated by concreteness/imageability (80-100%) was better than that of Kanji pseudohomophones (73%). HW's oral reading of Kanji pseudohomophones (29/40, 73%) was worse than his Kanji word reading (296/344, 86%), but HW's oral reading of Kana pseudohomophones (549/584, 94%) was similar to this oral reading of Kana words (332/344, 97%) and Kana nonhomophonic nonwords (112/120, 93%).

6.6.3. The bi-scriptal influence on Japanese dyslexic patterns observed in YT and HW

1) Deep dyslexia

a. Verification of the classical deep dyslexia pattern in Japanese

The re-analyses of YT's oral reading accuracy, using the framework of Kanji vs. Kana, revealed that i) YT's oral reading accuracy of Kana words was not worse than that of Kanji words, and ii) YT's oral reading accuracy of Kana pseudohomophones was not worse than that of the base Kanji words.

That is, YT, who showed the same psycholinguistic variables effects of English deep dyslexia, did not demonstrate the superiority of Kanji word reading over Kana word reading that was reported in the classical deep dyslexic cases. Therefore, it can be concluded that Japanese deep dyslexia is not a Kana script-specific reading disorder.

b. Summary and interpretation of the bi-scriptal influence observed in YT's oral reading performance

The script-type influence on YT's oral reading performance is summarised as four points and they can be interpreted in terms of pronunciation predictability and lexicality.

i) YT's oral reading accuracy of Kana words was better than of Kanji words for abstract/low imageability words.

ii) YT's oral reading accuracy of Hiragana pseudohomophones was better than of the base Kanji words for abstract, high/low imageability words.

iii) YT's oral reading accuracy of Hiragana pseudohomophones was worse than of the base Katakana words.

iv) YT's oral reading accuracy of Hiragana pseudohomophones was better than of

Kanji pseudohomophones.

Due to iv) and YT's disrupted oral reading for both Kanji and Kana nonhomophonic nonwords, the pseudohomophone effect (pseudohomophones > nonhomophonic nonwords) was greater in Kana strings than Kanji strings.

Although abstract/low imageability words are prone to error, and lexicality affects oral reading performance in deep dyslexia, a much higher pronunciation predictability for Kana than for Kanji led to i) and ii). Although pronunciation predictability of Kana words and Kana pseudohomophones is equal, different orthographic familiarity (or orthographic lexicality) between Katakana words and Hiragana pseudohomophones led to iii). That is, iii) can be described as orthographic familiarity effect (or orthographic lexicality effect). Meanwhile, both different pronunciation predictability and different orthographic lexicality for Kana/Kanji pseudohomophones led to iv). This is because orthographic familiarity for Kana pseudohomophones created by phonographic Kana characters is higher than for Kanji pseudohomophones synthesised by morphographic Kanji characters.

Thus, different reading accuracy between Kanji and Kana strings observed in YT's performance was not 'real' script-type effect.

2) Surface dyslexia

a. Verification of the classical surface dyslexia pattern in Japanese

The re-analyses of HW's oral reading performance revealed that i) HW's oral reading accuracy of Kana words was better than that of Kanji words in almost all conditions, but ii) HW's accuracy of Kanji words was slightly better than that of Kana words for low imageability words; and iii) HW's accuracy of high frequency/consistent Kanji words was similar to that of Kana words.

That is, HW did not always demonstrate the superiority of Kana word reading over Kanji word reading that was treated as a defining characteristic of Japanese surface dyslexia in the classical case studies. More importantly, iii) indicates that higher accuracy of Kana words reflects consistency effect and does not show the script-type effect. Therefore, it can be concluded that Japanese surface dyslexia is not a Kanji script-specific disorder.

b. Summary and interpretation of the bi-scriptal influence observed in HW's oral reading performance

HW's oral reading of Kana strings was better than that of Kanji strings with the exception of word reading as mentioned above. Since Kana characters have a much higher pronunciation predictability than Kanji characters, due to consistent character-sound correspondence, oral reading of Kana strings (i.e. words, pseudohomophones and nonhomophonic nonwords) is preserved in surface dyslexia which is governed by consistency. Thus, HW's preserved oral reading of Kana strings can be interpreted as a part of the consistency effect.

6.6.4. Characteristics of Japanese deep dyslexia and surface dyslexia observed in YT and HW respectively

Both YT and HW showed the same psycholinguistic variables effects which are diagnostic characteristics for deep dyslexia and surface dyslexia, respectively, in English. When one uses the framework of Kanji vs. Kana for describing their oral reading performance, several distinctive reading patterns for Kanji and Kana strings can be seen. This is because Kanji and Kana scripts are radically different in terms of 'pronunciation predictability' and lexicality. So, different reading accuracy of

Kanji and Kana strings are not 'real' script-type effects but rather are the influence of psycholinguistic variables.

YT's deep dyslexia pattern can be characterised as lexicality-governed reading performance which is consonant with deep and phonological dyslexia in English. YT's oral reading accuracy of both Kanji and Kana strings showed a gradient of concrete/high imageability words > abstract/low imageability words > pseudohomophones > nonhomophonic nonwords. YT's Kanji/Kana nonhomophonic nonword reading was nearly disrupted, in which she made a lot of 'lexicalisation errors'. Although YT's oral reading accuracy of Kanji and Kana words was similar, YT demonstrated a larger pseudohomophone effect in Kana strings than in Kanji strings. This is because lexicality of Kana pseudohomophones is higher than that of Kanji pseudohomophones, and pronunciation predictability of Kana strings is higher than that of Kanji strings.

In contrast, HW's surface dyslexia pattern can be characterised as consistency-governed reading performance which is consonant with surface dyslexia in English. Since Kana script has a considerably higher 'pronunciation predictability' than Kanji script, oral reading of Kana strings is noticeably preserved in surface dyslexia. This led to a misunderstanding in the classical case studies, which treated Japanese surface dyslexia as a Kanji-specific reading disorder. However, preserved oral reading of Kana strings in Japanese surface dyslexia can be interpreted as a part of a consistency effect. Thus, the worst accuracy of low frequency/atypical Kanji word coupled with preserved Kanji nonword reading, which was demonstrated by HW, are essential characteristics for surface dyslexia in Japanese.

6. 7. The impact of the principal impairment on language performance

The phonological impairment and semantic impairment hypotheses are based on the triangle model which formulates the view that any language performance can be explained by bi-directional communication between the three domains or principal components (i.e. semantics, phonology, and orthography). Using this view, one can predict (or explain) that phonological impairment and semantic impairment have differential effects on language performance. If so, such results become supportive data for the phonological impairment and semantic impairment hypotheses.

Thus, this section presents the results of YT's and HW's performance in the cross-domain tasks: written word comprehension, picture naming, and oral reading, and the cueing effect on both oral reading and picture naming. This exploration would give us a further understanding of the impact of semantic impairment and phonological impairment on language performance, including oral reading.

6.7.1. Cross-domain effect

1) Oral reading, written word comprehension, and picture naming for Katakana words

Figure 55 and Figure 56 present YT's and HW's results in the 80 Katakana Word Test, respectively. The different performance pattern between the two cases was found in written word comprehension and oral reading. While YT's comprehension was better than her oral reading in all 4 conditions (overall accuracy: 78/80, 98% > 63/80, 79%), HW's comprehension was worse than his oral reading in 3 conditions (overall accuracy: 52/60, 87% < 57/60, 95%), except for the high familiarity/frequency condition. Thus, the performance accuracy was written word comprehension > oral reading > picture naming in YT's performance, but oral reading ≧ written word comprehension > picture naming in HW's performance.

HW demonstrated noticeable cross-domain performance in which he could read aloud Katakana words without comprehension (8/80, 10%).

Fig. 55. YT's performance in the cross-domain tasks for Katakana words.

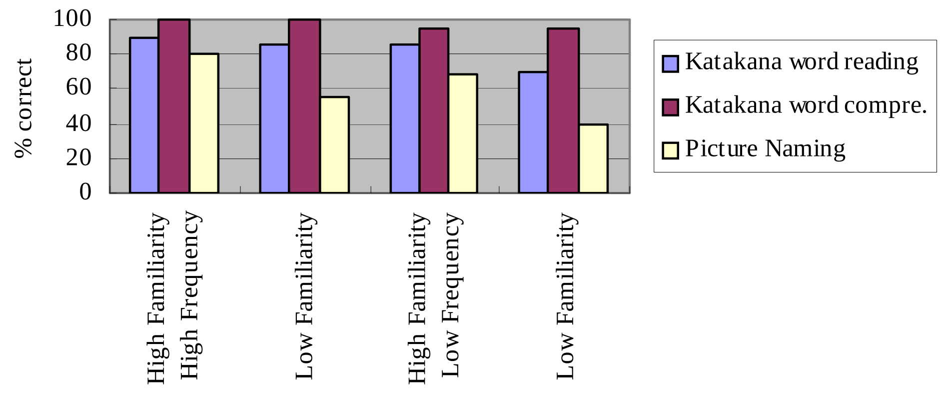
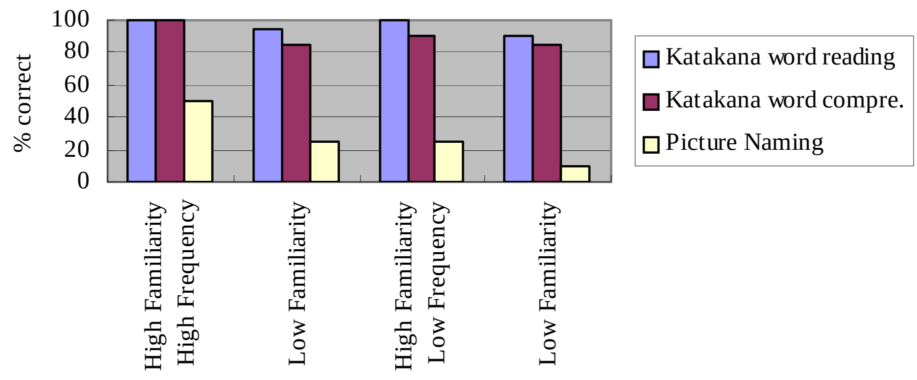


Fig. 56. HW's performance in the cross-domain tasks for Katakana words.



Error analysis

Tables 30-1 and Table 30-2 show an error analysis for YT’s and HW’s word reading and picture naming as a function of frequency.

Table 30-1 The proportion of error types in YT's performance in the cross domain tasks for Katakana words

		Number of errors	Semantic	Circum.	Sem./Visual	Phono.W	Phono.NW	Unrelated	DK/NR
Oral reading	H Freq.	10	0.00	0.00	0.10	0.40	0.50	0.00	0.00
	L Freq.	17	0.00	0.06	0.00	0.29	0.29	0.30	0.06
Picture naming	H Freq.	16	0.31	0.00	-	0.06	0.25	0.19	0.19
	L Freq.	23	0.35	0.00	-	0.09	0.30	0.00	0.26

Table 30-2 The proportion of error types in HW's performance in the cross domain-tasks for Katakana words

		Number of errors	Semantic	Sem./Visual	Phono.W	Phono.NW	Unrelated	DK/NR
Oral reading	H Freq.	6	0.00	0.00	0.17	0.67	0.17	0.00
	L Freq.	13	0.00	0.08	0.38	0.54	0.00	0.00
Picture naming	H Freq.	48	0.31	-	0.06	0.25	0.19	0.19
	L Freq.	45	0.35	-	0.09	0.30	0.00	0.26

Circum.=circumlocution; Sem/Visual= sematnic and visually similar;DK/NR: don't know or no response
Phono.W:phonologically similar word; Phono.NW:phonologically similar nonword.

In oral reading, YT and HW showed a similar error pattern, in which the major type was phonological resemblance, followed by unrelated errors. In picture naming, both cases made substantial semantic errors. YT produced a lot of phonological errors, whereas HW’s prominent error was circumlocution. With regard to the error type for written word comprehension, semantic error was dominant in YT (2/2, 100%) and HW (7/8, 88%).

2) Oral reading, written word comprehension, and picture naming for single character Kanji words

Figure 57 and Figure 58 present YT’s and HW’s performance in the 80 single-character Kanji Word Test, respectively. For both YT and HW, accuracy of picture naming and word reading was similar at both high and low frequency bands. Both cases also showed preserved comprehension for written Kanji words (YT: 78/80, 98%; HW: 76/80, 95%) and Hiragana pseudohomophones (YT: 79/80, 99%; HW: 78/80, 98%), though this was slightly less accurate in the low frequency band.

Fig.57. YT's performance in cross-domain tasks for single-character Kanji words.

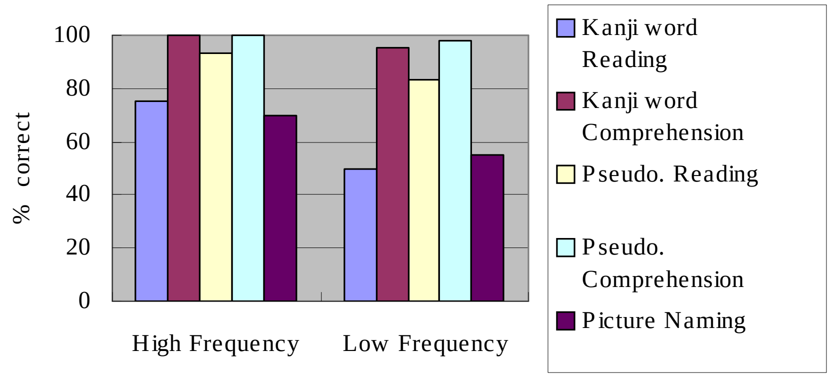
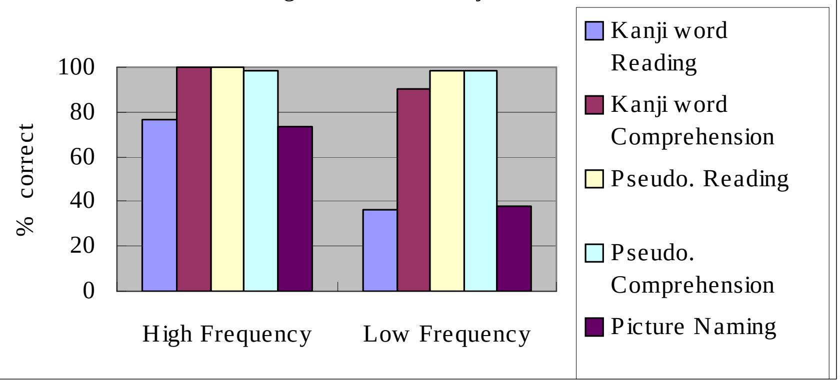


Fig.58. HW's performance in cross-domain tasks for single-character Kanji words.



For YT, the order of performance accuracy was written word comprehension >oral reading of Kana pseudohomophones >picture naming≒oral reading of Kanji words. For HW, oral reading of Kana pseudohomophones at a low frequency band was better than his Kanji written word comprehension. This was different from YT’s performance.

Error analysis

Table 31-1 and Table 31-2 show an error analysis for YT's and HW's oral reading of Kanji word and Hiragana pseudohomophones, and for their picture naming as a function of frequency. In Kanji word reading YT made a higher proportion of semantic errors and ‘don’t know‘/no responses. HW's prominent error was circumlocution followed by semantic error. Their error pattern in picture naming was approximately similar to that in Kanji word reading. In oral reading of Hiragana pseudohomophones YT made a significant proportion of phonologically similar words to the target, whereas HW’s main error types were phonologically similar nonword/word, and unrelated responses. With regard to comprehension, both cases made only semantic errors.

Table 31-1 The proportion of error types in YT's performance in the cross-domain tasks for single-character Kanji words

		Number of errors	Semantic	Circum.	Sem./Visual	Phono.W	Phono.NW	LARC	Unrelated	DK/NR
Kanji Reading	H Freq.	17	0.53	0.12	0.06	0.06	0.00	0.18	0.00	0.06
	L Freq.	21	0.52	0.00	0.14	0.09	0.00	0.00	0.00	0.24
Pseudo. Reading	H Freq.	3	0.00	0.00	0.00	0.67	0.00	-	0.33	0.00
	L Freq.	9	0.33	0.00	0.00	0.56	0.00	-	0.11	0.00
Picture Naming	H Freq.	14	0.50	0.21	0.00	0.00	0.07	-	0.00	0.21
	L Freq.	24	0.58	0.08	0.00	0.00	0.00	-	0.13	0.21

Table 31-2 The proportion of error types in HW's performance in the cross-domain tasks for single-character Kanji words

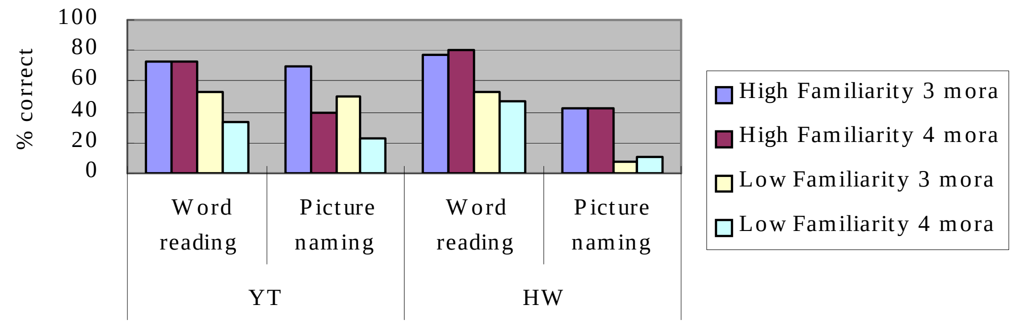
		Number of errors	Semantic	Circum.	Sem./Visual	Visual	Phono.W	Phono.NW	LARC	Unrelated	DK/NR
Kanji Reading	H Freq.	27	0.22	0.33	0.00	0.00	0.22	0.00	0.07	0.15	0.00
	L Freq.	48	0.29	0.31	0.02	0.08	0.06	0.02	0.06	0.15	0.00
Pseudo. Reading	H Freq.	6	0.00	0.00	0.00	0.00	0.33	0.33	-	0.33	0.00
	L Freq.	5	0.20	0.00	0.00	0.00	0.00	0.20	-	0.60	0.00
Picture Naming	H Freq.	26	0.54	0.27	0.00	0.00	0.04	0.04	-	0.12	0.00
	L Freq.	46	0.59	0.26	0.00	0.00	0.04	0.02	-	0.07	0.02

Circum.=circumlocution; Sem/Visual= sematnic and visually similar;DK/NR: don't know or no response
Phono.W:phonologically similar word; Phono.NW:phonologically similar nonword.

3) Oral reading and picture naming for two-character Kanji words manipulated by the number of mora and familiarity

Figure 59 presents the YT’s and HW’s results in the Two-Character Kanji Word Reading and Picture Naming Test. A modality effect was salient in HW's performance. HW demonstrated a prominent superiority of Kanji word reading over picture naming (77/120, 64% > 31/120, 26%; χ^2 =36.63, $p < 0.0001$) compared to YT’s performance (70/120, 58% > 55/120, 46%; χ^2 =3.76, p =0.05).

Fig. 59. YT's and HW's performance in Kanji word reading and picture naming of the cross-domain test.



Both familiarity and the number of mora influenced YT's performance in both word reading (high familiarity/ 3- and 4-mora words: 22/30, 73%; low familiarity/ 3-mora words: 16/30, 53%, 4-mora words: 10/30, 33%) and picture naming (high familiarity/ 3-mora words: 21/30, 70%, 4-mora words: 12/30, 40%; low familiarity/ 3-mora words: 15/30, 50%, 4-mora words: 7/30, 23%). A familiarity effect was more noticeable than a word length effect in YT's word reading (the difference of accuracy for high/low familiarity words and 3-/4-mora words: 30% > 10%). The opposite pattern was found in YT's picture naming (the difference of accuracy for high/low familiarity words and 3-/4-mora words: 19% < 29%).

In contrast, word-length did not influence HW's performance in either word reading or picture naming. For HW, a familiarity effect was more noticeable in picture naming than in word reading (the difference of accuracy for high/low familiarity words: 35% > 29%).

Error analysis

Table 32-1 and Table 32-2 present the proportion of error types for YT's and HW's performance in the Two-Character Kanji Word Reading and Picture Naming Test. YT's prominent error types were phonological, semantic/visual, and semantic in word reading, and her dominant error in picture naming was semantic followed by no response. Meanwhile, the vast majority of HW's errors in oral reading were unrelated errors and LARC errors, but his dominant error in picture naming was circumlocution and semantic paraphasia.

Table 32-1 The proportion of error types inYT's and HW's oral reading in the Two-Character Kanji Word Reading/Picture Naming Test

	No. of error	semantic	sem./vis	phono.	LARC	unrel.	no resp.
YT	50	0.20	0.22	0.30	0.08	0.12	0.08
HW	43	0.07	0.05	0.24	0.31	0.40	0.00

Table 32-2 The proportion of error types in YT's and HW's picture naming in the Two-Character Kanji Word Reading/Picture Naming Test

	No. of error	semantic	cir.	phono	unrel.	no resp.
YT	65	0.57	0.05	0.08	0.02	0.29
HW	89	0.33	0.49	0.04	0.06	0.08

Note: sem/vis: semantic and visual; phono:phonological; cir: circumlocution; unrel.:unrelated.
no resp.: no response

4) The difference in the cross-domain effect on YT's and HW's performance

The accuracy of cross-domain tasks for YT and HW was different, depending on the script type of written words. In their cross-domain performance for Katakana words, the order of YT’s accuracy was word comprehension > word reading > picture naming, whereas for HW the order was word reading > word comprehension > picture naming. In their cross-domain performance for Kanji words, the order of YT's and HW's accuracy was word comprehension > oral reading of Hiragana pseudohomophones > Kanji word reading > picture naming. This difference reflects the differential impact of semantic and phonological impairment on reading and on written word comprehension, suggesting that oral reading of Kanji words requires more semantic support than for oral reading of Kana strings.

With regard to picture naming, YT's performance in picture naming was better than HW's performance in all three kinds of tasks (for Katakana words, single-character/ two-character Kanji words). This suggests that the degree of HW's semantic impairment had more impact on picture naming, which requires semantically mediated phonological activation, than did the degree of YT's phonological impairment.

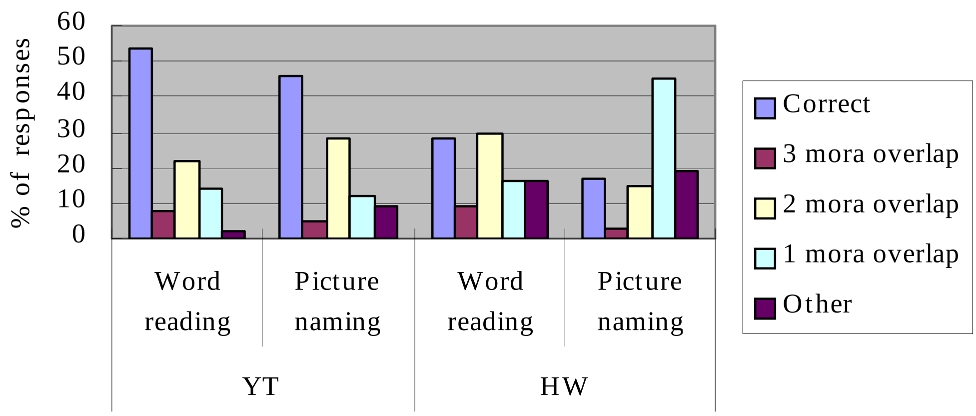
These findings suggest that cross-domain effects appear to reflect the difference of task demand and the nature of impairment (i.e. phonological impairment or semantic impairment).

6.7.2. Phonological cueing effect on oral reading and picture naming

1) The initial phonological cueing effect on oral reading and picture naming

Figure 60 presents YT's and HW's performance using the initial phonological cue in the Two-Character Kanji Word Reading and Picture Naming Test.

Fig.60. The proportion of YT's and HW's Kanji word reading and picture naming with the initial phonological cue.



The rate of facilitation after the initial mora cue for YT was greater than for HW (54% vs. 28% for word reading; 46% vs. 17% for picture naming). In both cases, the rate of correct response with the first phonological cue in word reading was higher than that in picture naming.

YT's and HW's implicit phonological activation by the initial phonological cue was distinguishable. This difference was remarkable in picture naming. In picture naming, YT produced not only more correct responses but also more phonologically similar responses, which overlapped 2 or 3 mora to the target (33% and 18%, respectively). In contrast, HW produced a striking proportion of responses which were semantically unrelated and which phonologically only included one mora of the target (45 %), or no sharing mora (19 %). In the case of word reading by the initial phonological cue, the proportion of 2 mora-overlapped responses was slightly higher for HW than for YT (31% >22%), though no overlap response was noticeable for HW compared to YT (16% > 2%).

2) The progressive phonological cueing effect on oral reading and picture naming

Table 33 and Table 34 describe a phonological cueing effect on YT's and HW's performance in both word reading and picture naming respectively, and this is presented in relation to their first error type. Like the successful initial cue, the proportion of the items with successful cueing (i.e. the rate of facilitation after a progressive phonological cue) for YT was greater than for HW (92% vs. 79 % for word reading; 91% vs. 75% for picture naming). YT's mean number of morae in successful cueing was lower than HW's, and the numerical difference between the two cases was 0.53 for word reading and 0.69 for picture naming.

Table 33 YT's performance in the Two-Character Kanji Word Reading and Picture Naming Test

Reading aloud	correct	Error type in the first response: sem	sv	phon	larc	unrel.	no resp.	total or mean
No. of items	70	10	11	15	4	6	4	50
Proportion to total errors		0.20	0.22	0.30	0.08	0.12	0.08	1.00
No. of items with successful first cue	-	8	6	5	2	3	3	27
proportion to No. of items		0.80	0.55	0.33	0.50	0.50	0.75	0.54
No. of items with successful cues	-	10	10	13	4	5	4	46
proportion to No. of items		1.00	0.91	0.87	1.00	0.83	1.00	0.92
Mean No. of morae of stimulus words	3.46	3.50	3.73	3.53	3.25	3.83	3.25	3.50
Mean uniqueness point of stimulus words	3.39	3.20	3.55	3.27	3.25	3.67	3.25	3.38
Mean No. of morae in successful cue	-	1.20	1.82	2.00	1.50	2.00	1.25	1.70
Mean of uniqueness point minus successful cue	-	2.00	1.73	1.27	1.75	1.67	2.00	1.66

Picturte naming	correct	Error type in the first response: sem	cirs.	phon	unrel.	no resp.	total or mean
No. of items	55	37	3	5	1	19	65
Proportion to total errors		0.57	0.05	0.08	0.02	0.29	1.00
No. of items with successful first cue	-	20	2	0	0	8	30
proportion to No. of items		0.54	0.67	0.00	0.00	0.42	0.46
No. of items with successful cues	-	35	2	3	1	18	59
proportion to No. of items		0.95	0.67	0.60	1.00	0.95	0.91
Mean No. of morae of stimulus words	3.35	3.62	3.33	3.40	4.00	3.74	3.50
Mean uniqueness point of stimulus words	3.25	3.49	3.33	3.00	4.00	3.58	3.38
Mean No. of morae in successful cue		1.73	1.67	2.80	2.00	1.84	1.85
Mean of uniqueness point minus successful cue		1.76	1.67	0.20	2.00	1.74	1.63

Note.sem: semantic; sv: semantic/visual; circ: circumlocution; phon: phonological; unrel: unrelated; no resp.:no response.

Table 34 HW's performance in the Two-Character Kanji Word Reading and Picture Naming Test

Reading aloud	correct	Error type in the first response: sem	sv	phon	larc	unrel.	no resp.	total or mean
No. of items	77	3	2	17	16	5	0	43
Proportion to total errors	-	0.07	0.05	0.40	0.37	0.12	0.00	1.00
No. of items with successful first cue		1	0	4	5	2	-	12
proportion to No. of items		0.33	0.00	0.24	0.31	0.40		0.28
No. of items with successful cues	-	3	2	13	12	4	-	34
proportion to No. of items		1.00	1.00	0.76	0.75	0.80		0.79
Mean No. of morae of stimulus words	3.49	3.67	4.00	3.53	3.44	3.40	-	3.50
Mean uniqueness point of stimulus words	3.38	3.33	4.00	3.35	3.31	3.40	-	3.38
Mean No. of morae in successful cue	-	2.00	2.00	2.41	2.25	1.80	-	2.23
Mean of uniqueness point minus successful cue	-	1.33	2.00	0.94	1.06	1.60	-	1.14

Picturte naming	correct	Error type in first response: sem	cirs.	phon	unrel.	no resp.	total or mean
No. of items	31	29	44	4	5	7	89
Proportion to total errors		0.33	0.49	0.04	0.06	0.08	1.00
No. of items with successful first cue	-	6	8	0	0	1	15
proportion to No. of items		0.21	0.18	0.00	0.00	0.14	0.17
No. of items with successful cues	-	22	32	3	3	7	67
proportion to No. of items		0.76	0.73	0.75	0.60	1.00	0.75
Mean No. of morae of stimulus words	3.52	3.52	3.48	3.00	3.40	3.86	3.50
Mean uniqueness point of stimulus words	3.45	3.34	3.39	2.50	3.40	3.57	3.38
Mean No. of morae in successful cue	-	2.41	2.45	2.25	2.80	2.29	2.44
Mean of uniqueness point minus successful cue	-	0.93	0.93	0.25	0.60	1.29	0.91

Note.sem: semantic; sv: semantic/visual; circ: circumlocution; phon: phonological; unrel: unrelated; no resp.:no response.

YT’s mean number of morae in successful cueing was lower than HW’s, and the numerical difference between the two cases was 0.53 for word reading and 0.69 for picture naming. With regard to implicit phonological activation by progressive cueing, Table 33 and Table 34 also present the numerical value of the mean uniqueness point of stimulus words minus the mean number of morae in successful cueing in relation to the first error type. Using this value, the order of the ease of phonological facilitation was YT's word reading (1.66), YT's picture naming (1.63), HW's word reading (1.14), and HW's picture naming (0.91).

In YT's word reading semantic errors and no response showed the highest ease of phonological facilitation (2.0), whereas phonologically similar errors showed the lowest (1.27). In YT's picture naming the difference of ease of facilitation between semantic errors and phonological errors was more salient (1.76 vs. 0.20). A similar trend in the difference of ease of facilitation between semantic and phonological errors was found in HW's performance (word reading: 1.33 vs. 0.94; picture naming: 0.93 vs. 0.25). LARC errors in HW's word reading (1.06) and phonological errors in HW's picture naming (0.25) also showed an under-average ease of phonological facilitation.

3) The difference in the phonological cueing effect between YT's and HW's oral reading and picture naming

The initial phonological cueing effect on YT's word reading and picture naming was more efficient than in HW's performance. HW produced a substantial proportion of unrelated errors in picture naming task which included only the mora cue or totally unrelated response to the target. The mean number of morae needed for successful cueing and the value of ease of phonological facilitation indicated that additional phonological information facilitates YT's performance more than HW's in both word reading and picture naming (the ease of facilitation: YT's word reading ≒ YT's picture naming > HW's word reading > HW's picture naming). More importantly, all of YT's semantic errors in word reading and most of her semantic errors in picture naming disappeared with the use of phonological cueing.

In contrast, additional phonological information was less effective for facilitating HW's semantic errors in picture naming. For both cases their phonological errors in word reading and picture naming showed that the weakest facilitation.

6.7.3. Interpretations of the impact of phonological and semantic impairment on language performance observed in YT and HW

The qualitative difference between phonological and semantic impairment affected not only the cross-domain effect but also the cueing effect. YT, with phonological impairment, showed a word-length effect and good facilitation of oral reading and picture naming by aided by phonological cueing. Thus, almost all of her semantic errors in both tasks disappeared with the use of phonological cueing. This suggests that phonological impairment is a source of YT's semantic errors in both word reading and picture naming. Meanwhile, HW, with semantic impairment, showed severe impairment of oral reading and picture naming which were modulated by familiarity and frequency. The initial phonological cue was not so effective in facilitating HW's oral reading and picture naming and led to high proportion of unrelated responses. This suggests that HW's semantic activation is abnormally reduced and communication between phonology and semantics has also deteriorated. Therefore, these differences observed between YT's and HW's cross-domain task performances appear to reflect their principal impairment.

6.8. Discussion

6.8.1. The conclusion of research question 1

<u>Research question 1</u>

"Do Japanese dyslexic patients show the same effects of psycholinguistic variables as observed in English dyslexic patients?"

The answer to this research question was 'Yes'.

The two subjects of Study 1, YT and HW, demonstrated the same variables effects reported in English deep dyslexia and surface dyslexia, respectively. This was consonant with the prediction of this thesis as presented in Chapter 4.

YT demonstrated i) profound difficulty in Kanji/Kana nonword reading, in which she made a number of lexicalisation errors; ii) a concreteness/imageability effect on Kanji/Kana word reading, in which oral reading of abstract/low imageability words was more impaired than of concrete/high imageability words; and iii) superiority of Kanji/Kana pseudohomophone reading over Kanji/Kana nonhomophonic nonword reading. These variables effects on YT's oral reading performance are consistent with the oral reading performance of English deep dyslexia or phonological dyslexia.

However, YT's error pattern in word reading differed depending of the script-type. YT made substantial semantic errors, semantic/visual errors and semantically related responses (circumlocution, semantically related gestures or onomatopoetic expressions) in Kanji word reading, but these errors were rarely occurred in Kana word reading where her dominant error was phonologically (thus, visually) similar errors. This different error pattern was also described in the Japanese deep dyslexia of the classical case studies, in which Kana pseudohomophones were used as 'Kana words'. YT also showed a greater concreteness/imageability effect in Kanji word reading than in Kana word reading. It is obvious that these script-type differences in YT's oral reading performance are related to the distinctive characteristics of Kanji and Kana (the interpretation of this phenomenon will be presented in the later section, 6.8.3). Thus, if one follows the diagnostic criteria for deep and phonological dyslexia in English, in which the appearance/disappearance of semantic errors is used for distinguishing the two types of acquired dyslexia, YT manifested deep dyslexia for Kanji and phonological dyslexia for Kana. This study, however, argues that YT's dyslexic pattern is a typical oral reading performance of deep dyslexia in Japanese. This is because a different error pattern in the oral reading of Kanji words and Kana words can be treated as a language-specific characteristic which is attributable to the bi-script system in Japanese and different character-sound consistency for Kanji/Kana words. Therefore, concomitant deep and phonological dyslexia form a unique characteristic of YT's dyslexia pattern and can be treated as a diagnostic characteristic of Japanese deep dyslexia.

Meanwhile, HW demonstrated i) impaired oral reading of inconsistent Kanji words with a low frequency band (consistency effect); ii) production of LARC errors, which are a legitimate pronunciation for constituent Kanji characters but are inappropriate for the target Kanji words, with an ‘inverse’ consistency effect (i.e. the proportion of LARC errors was higher in reading aloud atypical words than in consistent words); and iii) preserved reading of Kanji/Kana nonwords. These characteristics of HW's oral reading performance are consistent with English surface dyslexia. Also, HW's dyslexic pattern is identical to the oral reading performance of the recent cases of Japanese surface dyslexia whose etiologies were all semantic dementia. Thus, it is reasonable to claim that HW's dyslexic pattern is a typical form of surface dyslexia in Japanese.

6.8.2. The conclusion of research question 2

Research question 2

" Are Japanese deep dyslexia and surface dyslexia script-specific reading disorders, respectively?"

The answer to this research question was 'No'.

YT demonstrated a lexicality effect on oral reading of both Kanji strings and Kana strings (Kanji/Kana words > Kanji/Kana pseudohomophones > Kanji/Kana nonhomophonic nonwords). The analysis of YT's oral reading performance using the Kanji vs. Kana framework revealed that YT did not show a superiority of Kanji word reading over oral reading of Kana words and Kana pseudohomophones, as demonstrated by the classical cases of deep dyslexia. All evidence suggests that Japanese deep dyslexia is not a Kana-specific reading disorder.

The analysis of YT's oral reading performance using the Kanji vs. Kana framework further revealed that i) oral reading accuracy of Kana words was better than of Kanji words for abstract/low imageability words; ii) the orthographic familiarity effect (i.e. words > pseudohomophones) was greater in Kanji strings than Kana strings; and iii) the pseudohomophone effect (i.e. pseudohomophones > nonhomophonic nonwords) was greater in Kana strings than Kanji strings. These characteristics of YT's dyslexic pattern can be explained by the difference of both pronunciation predictability and lexicality between Kanji and Kana strings. A much higher pronunciation predictability of Kana words than Kanji words led to i) above. Both a higher pronunciation predictability of

Kana characters than Kanji characters, and a higher orthographic lexicality of Kana pseudohomophones than Kanji pseudohomophones led to ii) and iii). That is, the bi-scriptal influences observed in YT's oral reading performance are attributable to the different psycholinguistic natures of Kanji and Kana strings.

The analysis of HW's oral reading performance using Kanji vs. Kana framework revealed that the oral reading accuracy of consistent Kanji words with a high frequency band and of Kana words was similar. These suggests that Japanese surface dyslexia is not a Kanji-specific reading disorder, as pointed out in the classical case studies which did not use Kanji word stimuli manipulated by consistency. Since the transparent Kana script has a consistent print-sound correspondence, highly preserved oral reading of Kana strings can be interpreted as a part of a consistency effect.

Therefore, the analyses of YT's and HW's oral reading performance in terms of the Kanji vs. Kana framework strongly deny the view that Japanese dyslexia patterns are script-dependent.

6.8.3. The conclusion of research question 3

Research question 3-1

"Can one observe the co-occurrence of phonological impairment and deep/phonological dyslexia, and the co-occurrence of semantic impairment and surface dyslexia?"

The answer to this research question was 'Yes'.

Study 1, a comparative study of the two distinctive dyslexic patients, revealed the association between phonological impairment and deep dyslexia in YT, and between semantic impairment and surface dyslexia in HW.

The detailed assessments of semantic and phonological function revealed that YT had phonological impairment with preserved semantic function, including abstract knowledge, and HW had semantic impairment which led to the difficulty of distinguishing semantically related words, coupled with preserved phonological function. The demonstration that YT, with phonological impairment, showed deep dyslexia, and that HW, with semantic impairment, showed surface dyslexia was consistent with the phonological impairment and semantic impairment hypotheses, respectively.

Since the phonological impairment hypothesis treats deep dyslexia as a severe form of phonological dyslexia, the co-occurrence of phonological impairment and deep dyslexia is not enough to support the phonological impairment hypothesis. Therefore, it is necessary to make a comparison between YT's performance in phonological tasks and oral reading tasks and that of the recent cases of phonological dyslexia in the same kinds of tasks.

The accuracy of mora concatenation for nonwords by TY (Sasanuma et al., 1996) and HM (Mori & Nakamura, 2003) was 95% and 93%, respectively. Mora identification by HM and Case K (Kato et al., 2004) was 92% and 90%, respectively. Thus, YT's performance in mora concatenation for nonwords (73%) and mora identification of 3-mora words, which required the ability of mora segmentation, (65%) was poorer than that of these phonological dyslexia patients (TY, HM and Case K). Moreover, YT's nonword reading was more severely impaired compared to these three cases. YT's accuracy of single Hiragana character reading was 43%, whereas their accuracy was 82% in TY, 85% in HM, and 96% in Case K. While YT's oral reading accuracy of Kana nonhomophonic nonwords was only 3%, they showed moderate impairment of Kana nonhomophonic nonword reading (40% for TY, 41% for HM, and 57% for Case K). Hence, YT had more severe phonological impairment and nonword reading than these recent cases of phonological dyslexia.

Meanwhile, a phonological dyslexia case, KT (Patterson et al., 1996), showed a similar degree of impairment of phonological manipulation and nonword reading to YT. KT's accuracy of mora concatenation and mora identification was 57% and 56%, respectively. KT could only read 26% of Hiragana characters and could not read Kana nonwords at all. In the original paper (Patterson et al., 1996) it was reported that KT had preserved word reading (concrete Kanji words: 90%, abstract Kanji words: 97%; Hiragana words: 98%, Katakana words: 91%). However, the additional investigation by Fushimi et al. (2000b) and Fushimi (2005) revealed that KT's word reading was impaired and that KT showed an imageability effect on both Kanji and Kana words (high imageability words vs. low imageability words: Kanji words-80% vs. 69%; Kana words-69% vs. 51%). That is, KT showed a similar degree of phonological impairment to YT, and also like YT, showed an imageability effect on Kanji/Kana word reading. Although the error pattern of KT's word reading was not reported, it is unlikely that KT did not produce semantic errors in Kanji word reading. So, it appears that KT would show a similar dyslexic pattern to YT's. These considerations support the phonological impairment hypothesis, in which deep dyslexia is treated as a severe form of phonological dyslexia.

Furthermore, the results of the cross-domain tasks revealed that phonological and semantic impairment affect not only oral reading but also other language performance with a differential impact. In particular, YT's and HW's performance with the phonological cue for oral reading and picture naming revealed this difference. Given the initial phonological cue, oral reading and picture naming by YT, with phonological impairment, were better facilitated than for HW. HW, with semantic impairment, produced substantial unrelated responses after the initial phonological cue in both oral reading and picture naming. However, there was not a large difference between YT's and HW's final facilitation by the progressive phonological cue, suggesting a joint contribution of phonology and semantics for oral reading and picture naming. YT's and HW's performance in the cross-domain tasks suggests the reliability of the triangle model, which provides the view that “three principal components (i.e. Phonology, Semantics, and Orthography) underpin a variety of mental activities” (Lambon Ralph & Patterson, 2005). Since the two hypotheses about oral reading performances have been proposed within this paradigm, YT's and HW's results in the cross-domain tasks can indirectly support the phonological/semantic impairment hypotheses.

Research question 3-

"Can the Japanese versions of the DRC model and the triangle model explain Japanese dyslexia patterns?"

The answer to this research question is given in the following considerations.

a. The interpretation of Japanese deep dyslexia pattern observed in YT

<The Japanese version of the DRC model>

The Japanese version of the DRC model can basically explain YT's dyslexic pattern - Japanese deep dyslexia - as a severe impairment of the non-lexical route and mild impairment of the lexical routes. The profound deficit of nonword reading can be explained as a severe impairment of the non-lexical route. The concreteness/imageability effect can be explained as the reflection of a higher activation of the lexical-semantic route for concrete/high imageability words than for abstract/low imageability words, with a mild deficit of this procedure. The superiority of pseudohomophones over nonhomophonic nonwords (pseudohomophone effect) can be explained as the use of additional information from the lexical routes for oral reading of pseudohomophones, since pseudohomophones can activate orthographic neighbours in orthographic input lexicon, but nonhomophonic nonwords have no orthographic neighbours.

The problem for interpretation of YT's dyslexia pattern using this model is how to explain i) the different error pattern in word reading, and ii) the different degree of concreteness/imageability effect on word reading depending on the script type.

The non-lexical route can encode the difference between transparent Kana character-sound correspondence and opaque Kanji character-sound correspondence, because of the character-sound correspondence rule system (see Fig. 20). So, this model can explain the non-lexical route is more efficient for Kana strings than for Kanji strings. The Japanese version of the DRC model, however, cannot encode the difference of lexicality between Kanji and Kana characters, because this model differentiates between whole-word level processing (i.e. the lexical routes) and sub-word level processing (i.e. the non-lexical route). In such a model, which does not assume the character-level's connection between orthography and semantics, the lexicality of constituent Kanji characters cannot be encoded. Thus, this model needs an additional assumption in order to explain prominent semantic errors and a greater concreteness/imageability effect in

Kanji word reading. If the lexical-semantic route is more efficient for Kanji words than for Kana words, this model can explain these Japanese-specific characteristics in deep dyslexia as an increased dependency of the lexical routes due to a severe impairment of the non-lexical route. Therefore, Study 1 proposes the modified Japanese version of the DRC model, which assumes that the efficacy of the lexical-semantic route for Kanji is more efficient than that for Kana.

<The Japanese version of the triangle model>

The Japanese version of the triangle model offers the explanation for YT's dyslexic pattern (i.e. Japanese deep dyslexia) as follows:

YT's phonological impairment led to insufficient computation from orthography to phonology (O→P) and exaggeration of the semantic procedure for oral reading (O→S→P). As a result, oral reading of nonwords, which have no semantic representation, became most difficult and led to substantial lexicalisation errors, and semantic variables such as a concreteness/imageability affected oral reading performance, in which reading aloud of abstract/low imageability words was prone to error. This is the basic mechanism for the manifestation of deep/phonological dyslexia.

This model interprets prominent semantic errors and a greater concreteness/ imageability effect in Kanji word reading, which were observed in YT, by different connection weight for the two scripts. Since Kana characters are highly transparent, the direct computation (O→P) is learned more easily and then there would be less pressure to learn the semantic procedure (O→S→P). In contrast, the O→S→P computation for Kanji would continue to be learned because the direct computation (O→P) is less efficient for opaque Kanji characters. As a result, the connection weight between Orthography and Semantics for Kanji would become much stronger than for Kana. That is, the O→S→P computation is more efficient for Kanji than for Kana. This is sharp contrast to the O→P computation, which is more efficient for Kana than for Kanji.

Phonological impairment (i.e. the damage of Phonology) exaggerates the reliance on the semantic procedure (O→S→P) for oral reading of Kanji words, and more efficient O→S→P computation for Kanji than for Kana leads to i) prominent semantic errors and ii) a larger degree of concreteness/imageability effect in Kanji word reading. In contrast, the highly efficient O→P computation for transparent Kana and less efficient O→S computation for Kana than for Kanji do not increase the reliance on the semantic procedure despite phonological impairment. This leads to substantial proportion of phonological (i.e. visual) errors in Kana word reading, but rare occurrence of semantic errors.

Taking these rationales, the Japanese version of the triangle model can interpret Japanese-specific characteristics in deep dyslexia. This is because the weighted connections between Orthography and Semantics in this model can encode the difference between Kanji and Kana characters as the system's knowledge during learning.

b. The interpretation of the Japanese surface dyslexia pattern observed in HW

<The Japanese version of the DRC model>

The Japanese version of the DRC model explains HW's dyslexic pattern (i.e. Japanese surface dyslexia) as a selective impairment of the lexical routes. The non-lexical route, which is governed by the character-sound rule system, can provide the correct pronunciation for transparent Kana strings, consistent Kanji words, and Kanji nonwords, but produces incorrect pronunciations for inconsistent Kanji words (i.e.

inconsistent-typical words and inconsistent-atypical words) which have no consistent correspondence between the constituent character and its phonological counterpart. Since the lexical routes are a frequency-modulated computation, the impairment of inconsistent words is salient for low frequency words.

The damage of the lexical-nonsemantic route led to increasing activation of orthographic neighbours by word stimuli results in LARC errors, which are an alternative pronunciation of constituent character(s) and wrong pronunciation in the target word (e.g. 歌声/uta-goe/ *singing voice*→/ka-sei/: /ka/ is correct pronunciation for 歌唱/ka-ʃo/ *singing*; /sei/ is correct pronunciation for 美声/bi-sei/ *beautiful voice*). The proportion of HW's LARC errors showed an inverse consistency effect, in which atypical words led to more LARC errors than those associated with inconsistent typical words. This is because the typical pronunciation of the constituent character(s) has a stronger activation in the lexical-nonsemantic route.

<The Japanese version of the triangle model>

The Japanese version of the triangle model interprets HW's dyslexic pattern as an intact O→P computation coupled with reduced support from semantics. When the semantic function is impaired as with HW, the semantic contribution for oral reading decreased and the reliance of the direct O→P computation increased. As a result, oral reading of inconsistent Kanji words - which have a lower character-sound correspondence and need semantic support (O→S→P, or O→P⇔S) for correct reading - is prone to error. In contrast, oral reading of Kana strings and consistent Kanji words, which all have consistent character-sound correspondences, is preserved due to an intact O→P computation. Semantic impairment does not affect oral reading of Kanji nonwords, which do not have semantic representations.

Since alternative pronunciations for constituent Kanji character(s) in the target words cannot be inhibited, due to semantic impairment in the system, HW made a number of LARC errors which were inappropriate pronunciation of the target words, but were legitimate for constituent characters in other Kanji words. HW's inverse consistency effect in LARC errors reflects a statistically higher possibility to produce alternative pronunciations for atypical words.

Taking into account all the above interpretation, **the answer to research question 3-2 is 'No'** for the Japanese version of the DRC model**, but 'Yes'** for the Japanese version of the triangle model. This is because the Japanese version of the DRC model needs an additional assumption about the lexical-semantic route in order to explain the Japanese deep dyslexia pattern observed in YT.

6.9. The contribution of Study 1 to acquired dyslexia research

Firstly, Study 1 has shed new light on the Japanese deep dyslexia pattern using well-manipulated reading stimuli, and has first clarified the characteristics of Japanese deep dyslexia (i.e. concomitant deep dyslexia for Kanji and phonological dyslexia for Kana).

Secondly, Study 1 demonstrated the co-occurrence of phonological impairment and deep dyslexia, and the co-occurrence of semantic impairment and surface dyslexia. This is the first demonstration of the two associations in a single-study and also the first demonstration using non-alphabetic orthography.

Thirdly, Study 1 showed that a neurological patient, who was not suffering from semantic dementia, manifested Japanese surface dyslexia.

Fourthly, Study 1 examined the Japanese applicability of the DRC model and the triangle model for explaining Japanese acquired dyslexia and clarified the difference between the two models' interpretations.

Fifthly, Study 1 proposed the modified Japanese versions of the DRC model in order to explain the Japanese deep dyslexia pattern.

Chapter 7

Study 2: A Case Study of SO

This Chapter presents Study 2 which is a case study of SO who showed severe semantic impairment, together with preserved phonological function. In this study HW's performances in Study 1 are used as control data. Study 2 focuses on i) clarifying a severe form of Japanese surface dyslexia while proposing a new method of detecting a consistency effect for severe cases; and ii) examining whether the Japanese versions of the DRC model and the triangle model can explain a severe form of surface dyslexia pattern in Japanese.

7.1. The research questions in Study 2 and the methodology used to explore them

Study 2 sets up the following three research questions which correspond to the three research questions of this thesis as explained in Chapter 4. In each section both the research questions for Study 2 and the methodology are shown.

7.1.1. Research question 1 of Study 2 and the methodology used to explore it

<u>Research question 1</u>

"What is a severe type of Japanese surface dyslexia like?

Based on HW's demonstration of co-occurrence of semantic impairment and surface dyslexia in Study 1, one can predict that a patient with semantic impairment should show a surface dyslexic pattern. The question is whether a patient who has a more severe semantic impairment than HW would show the same surface dyslexic pattern (i.e. a consistency effect on Kanji word reading and preserved Kanji nonword reading) as HW and as recent cases of Japanese surface dyslexia (e.g. TI; Fushimi et al, 2003). Thus, SO's semantic and phonological functions were evaluated and compared to HW's performance as control data. Then the oral reading experiments of i) Kanji/Kana nonwords, and ii) the two character Kanji words manipulated by consistency were conducted in order to clarify the surface dyslexia pattern. Because SO's severe oral reading disorder required alternative word stimuli and a new analysis for detecting a consistency effect (which is a defining characteristic of surface dyslexia) Kanji word stimuli taken from early-acquired Kanji words and manipulated by consistency (Fushimi, unpublished) were used in addition to the word lists of Patterson et al. (1995) and Fushimi et al. (1999).

Since SO had severe semantic impairment, one might expect that both semantic variables and lexicality would affect SO's oral reading performance. Thus, the oral reading experiments of iii) Kanji/Kana words manipulated by concreteness/ imageability, and iv) Kanji/Kana pseudohomophones, were administered.

Through these investigations the characteristics of SO's dyslexic pattern are revealed and are compared with HW's surface dyslexia pattern.

7.1.2. Research question 2 of Study 2 and the methodology used to explore it

Research question 2

"Is a severe form of Japanese surface dyslexia a Kanji script-specific reading disorder?"

The classical cases of Japanese surface dyslexia (e.g. Sasanuma, 1980a) manifested a striking preservation of oral reading of both single Kana characters and

Kana pseudohomophones[1], coupled with a profound impairment of oral reading of Kanji words. If SO showed a similar pattern to such classical cases of Japanese surface dyslexia, such a 'false script-type effect' - which is attributable to high 'pronunciation predictability' for Kana - could be verified by examining a consistency effect on Kanji word reading, and by comparing the reading accuracy between consistent Kanji words and Kana words/ pseudohomophones. It is very important to distinguish between the 'script-type effects' and psycholinguistic variables effects, in order to clarify the characteristics of acquired dyslexia in bi-scriptal Japanese.

Thus, SO's results in the oral reading experiments were re-analysed using the framework of Kanji strings vs. Kana strings. The re-analysis was conducted using the following comparisons of reading accuracy: i) between Kanji words and Kana words; ii) between Kanji words and Hiragana pseudohomophones; iii) between Katakana words and Hiragana pseudohomophones; and iv) between Kana pseudohomophones and Kanji pseudohomophones.

7.1.3. Research question 3 of Study 2 and the methodology used to explore it

<u>Research question 3</u>

"Can the Japanese versions of the DRC model and the triangle model explain the co-occurrence of severe semantic impairment and a severe form of surface dyslexia in Japanese?"

The semantic impairment hypothesis predicts that semantic impairment leads to a surface dyslexic pattern, but it does not explicitly predict that the degree of semantic impairment influences the variation of the surface dyslexia pattern. This is in

[1] The classical case studies for Japanese surface dyslexia used Kana pseudohomophones transcribed from Kanji words as 'Kana words'.

contrast with the phonological impairment hypothesis, which predicts that severe phonological impairment leads to a severe form of phonological dyslexia, corresponding to a deep dyslexic pattern. Research question 3 of Study 2 addresses whether severe semantic impairment leads to a severe form of surface dyslexia in Japanese. This is testing a reliability of the triangle model which is the underlying theory for the semantic impairment hypothesis, and also testing the DRC model which does not predict a causal relationship between semantic impairment and surface dyslexia.

Thus, SO's semantic/phonological function was evaluated and his performance in the oral reading experiments was compared to HW's performance. Moreover SO's performance in the cross-domain tasks was analysed in comparison to HW's performance. This is because the triangle model predicts that severe semantic impairment would lead to a more distinctive performance in cross-domain tasks and phonological cueing effects than that produced by a moderate semantic impairment.

7.2. The organisation of the data presentation

The results of SO's performance in the experimental tasks are presented with HW's results in the order of 1) the evaluation of semantic and phonological functions; 2) the oral reading experiments for identifying a surface dyslexic pattern; 3) the oral reading experiments for examining the influence of semantic variables and lexicality; and 4) a re-analysis of the results of 2) and 3) for evaluating the script-type effect. Finally, the results of cross-domain tasks are presented.

The results of the oral reading experiments were divided into the three parts. The first part presents the results of a) oral reading of Kanji/Kana nonhomophonic nonwords, and b) oral reading of two-character Kanji words manipulated by consistency. This section focuses on whether SO demonstrates the same effect of psycholinguistic variable as observed in English surface dyslexia and in the recent Japanese cases of surface dyslexia including HW in study 1.

The second part presents the results of a) oral reading of Kanji/Kana words manipulated by concreteness/imageability, and b) oral reading of Kanji/Kana pseudohomophones. This section focuses on capturing the influence of semantic variables and lexicality on oral reading performance in a severe case of surface dyslexia in Japanese.

The third part presents the re-analysis of the oral reading data in order to examine the script-type effect. This is because the classical case studies in Japanese dyslexia research reported the Japanese version of surface dyslexia as a Kanji script-specific reading disorder.

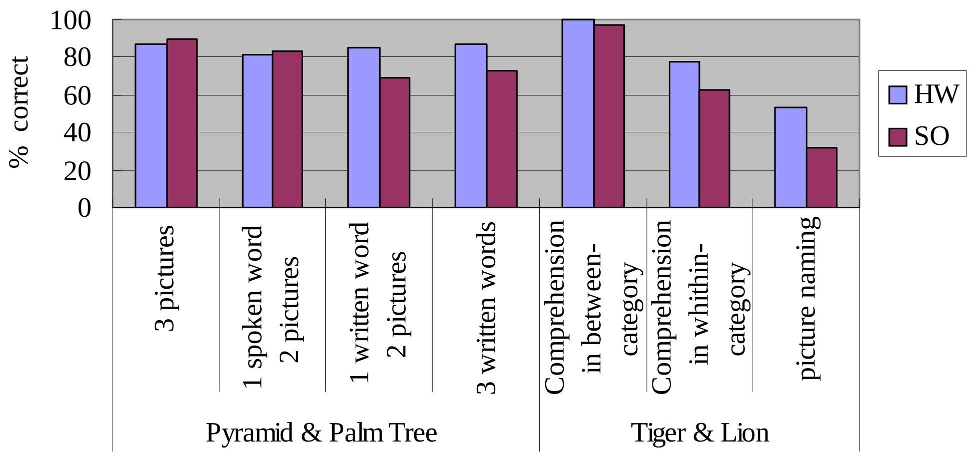
7.3. The evaluation of semantic and phonological function

7.3.1. The evaluation of semantic function

1) Semantic knowledge, word comprehension and picture naming

Figure 61 shows SO's performance in the Pyramid and Palm Tree Test and the Tiger and Lion Test with a presentation of HW's profile. With the exception of the associative semantic task with 3 pictures and 1 spoken word/ 2 pictures, SO's accuracy in word comprehension and picture naming was lower than HW's. This difference in picture naming (19/60, 32% vs. 32/60, 53%) was statistically significant (χ^2=5.76, $p < 0.02$). Though SO's understanding of word meaning in the different category condition (i.e. between-category) was very good (58/60, 97%), his spoken word comprehension reduced remarkably in the same category condition (i.e. within-category) (38/60, 63%). This difference was significant (χ^2 =20.83, $p < 0.0001$) and larger than that in HW, as shown in Fig. 61. This suggests that difficulty in distinguishing between semantically similar meanings is the nature of SO's semantic impairment.

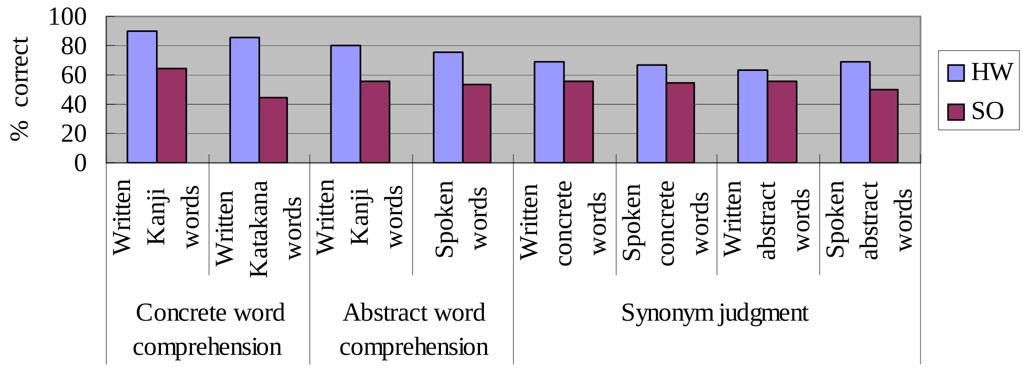
Fig. 61. SO' and HW's performance in the Pyramid & Palm TreeTest and the Tiger & Lion Test.



2) Single-word comprehension and abstract knowledge

Figure 62 presents SO’s single word comprehension in the Written Concrete Word Comprehension Test, the Abstract Word Comprehension Test, and the Single-Character Kanji Word Synonym Judgment Test with a presentation of HW’s profile.

Fig. 62. SO's and HW's performance in the Written Concrete Word Comprehension Test, the Abstract Word Comprehension Test, and the Single-Character Kanji Word Synonym Judgement Test.



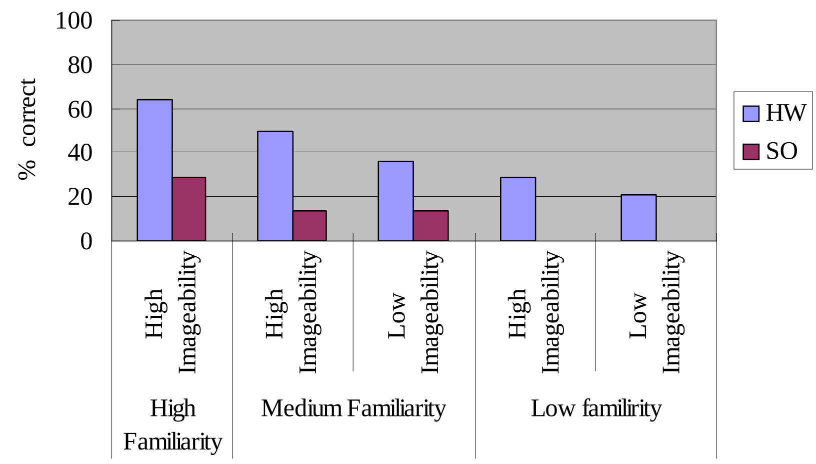
SO’s written word comprehension for both Kanji words and Katakana words in the same category (i.e. within-category) condition had deteriorated further than HW’s (χ^2 =8.23, $p < 0.01$, χ^2 =15.22, $p < 0.0001$, respectively). SO’s written word comprehension in Kanji words was better than in Katakana words (27/42, 64% > 19/42, 45%), but this numerical difference was not statistically significant. SO’s abstract word comprehension with both visual and auditory modality (25/45, 56% and 24/45, 53%, respectively) had also deteriorated further than HW’s (χ^2 =6.16, $p < 0.02$; χ^2 =4.85, $p < 0.03$, respectively).

In the synonym judgment test, SO’s performance was impaired, but there was no concreteness effect (concrete words vs. abstract words; visual modality: 29/52, 56% vs. 29/52, 56%; auditory modality: 28/52, 54% vs. 26/52, 50%). Again, SO's performance was less accurate than HW's.

3) 70 picture naming test

As shown in Fig.63, the 70 picture naming test revealed SO's striking anomia. SO's picture naming performance was influenced by familiarity. He could not name any low familiarity words at all. SO's picture naming was significantly worse than HW's (8/70, 11% vs. 28/70, 40%; $\chi^2 = 14.96$, $p < 0.0001$).

Fig. 63. SO's and HW's performance in the 70 Picture Naming Test.



4) Summary of SO's semantic function

SO's associative semantic knowledge had deteriorated, and he showed great difficulty in distinguishing semantically similar word meaning for both spoken and written words, and marked anomia. SO's accuracy in all semantic tasks was lower than HW's. This suggests that the degree of SO's semantic impairment was more severe than HW's.

7.3.2. The evaluation of phonological function

1) Phonological discrimination and mora repetition

Table 35 presents SO’s performance in phonological discrimination tasks together with a presentation of HW’s profile. Like HW, SO’s phonological discrimination ability was preserved.

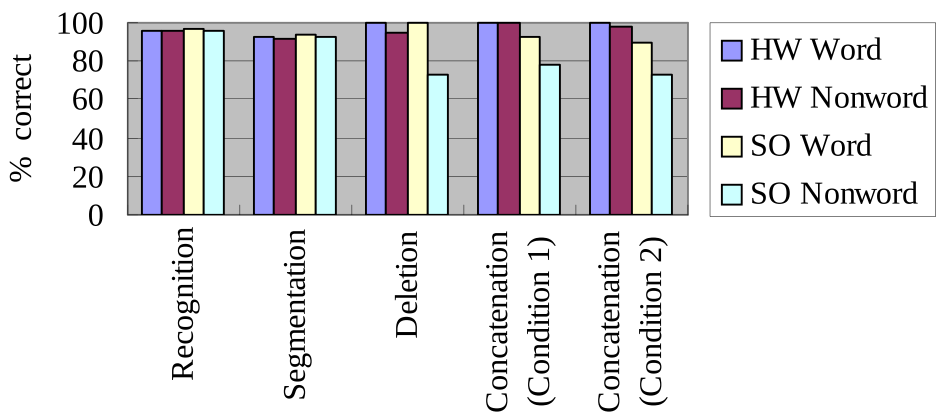
Table 35 SO's and HW's performance in phonological discrimination and single mora repetition (% correct)

	Phoneme discrimination (N=52)	Mora discrimination for Word (N=60)	Mora discrimination for Nonword (N=60)	Single mora reptition (N=20)
HW	100	100	100	100
SO	96	100	98	95

2) Phonological manipulation

Figure 64 displays SO’s performance in phonological manipulation tasks with a presentation of HW’s profile.

Fig. 64. SO's and HW's perofrmance in phonological manipulation tasks.



In mora recognition, mora segmentation with both words and nonwords, and in mora deletion with words, SO demonstrated his preserved phonological ability.

However, SO's performance in mora deletion with nonwords had deteriorated. That is, there was a lexicality effect in this task (mora deletion: 40/40, 100% for words vs. 29/40, 73% for nonwords; $\chi^2 = 12.75$, $p < 0.001$). The advantage of words over nonwords was also observed in mora concatenation (condition 1- 37/40 for words, 93% vs. 31/40, 78% for nonwords, $\chi^2 = 3.53$, $p = 0.06$; condition 2- 36/40, 90% for words vs. 29/40, 73% for nonwords, $\chi^2 = 4.03$, $p < 0.05$).

3) Immediate repetition of word/nonword, delayed and serial repetition of word

Table 36 presents SO's and HW's performance in the Word and Nonword Repetition Test. SO showed a preserved ability for repetition of words, but his nonword repetition had deteriorated ($\chi^2 = 15.34$, $p < 0.0001$)

Table 36 SO's and HW's performance in the Word and Nonword Repetition Test

(% correct)

	Words (N=120)	Nonwords (N=120)
HW	100	98
SO	99	86

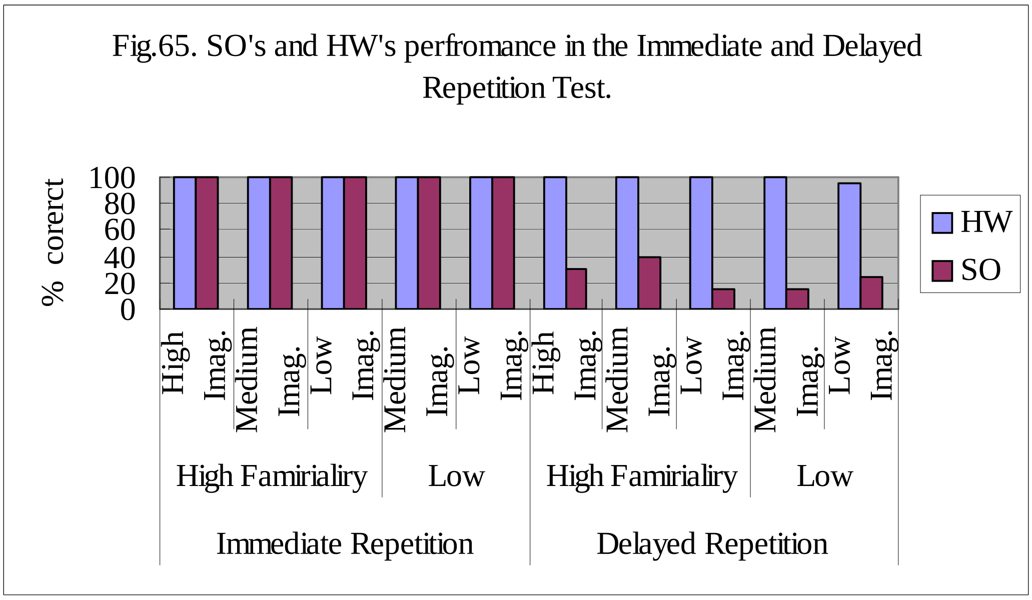
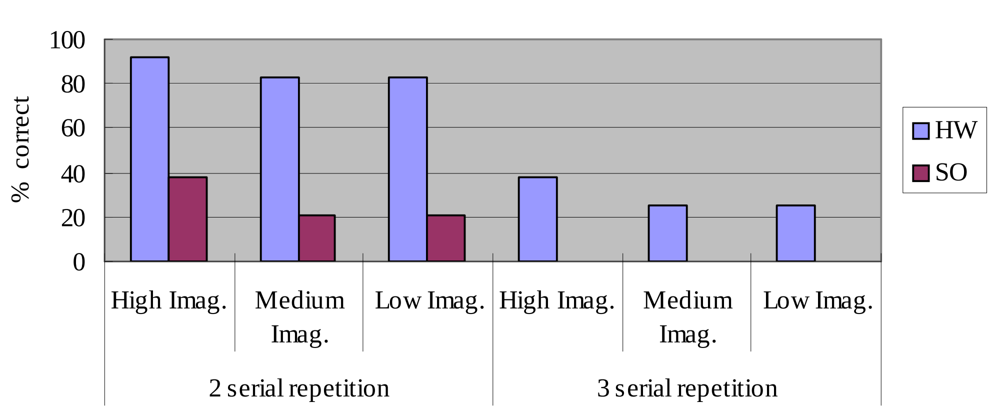


Figure 65 shows SO’s repetition performance under different conditions with a presentation of HW’s profile. SO’s immediate repetition of words was as good as HW’s. However, his delayed repetition was severely impaired which was in sharp contrast with HW's performance. There was no imageability effect in SO’s delayed repetition.

Figure 66 shows SO’s performance in the Serial Repetition Test. Serial repetition was extremely difficult for SO and he could not produce any correct responses in 3 serial repetitions. Though there was a numerical difference of SO’s serial repetition between high imageability words and medium/low imageability words, this was not statistically significant.

Fig.66. SO's and HW's performance in the Serial Repetition Test.



4) Summary of SO's phonological function

SO’s phonological ability was fairly well preserved, though SO showed a remarkable deterioration in more demanding phonological tasks which required more support from semantics (e.g. delayed repetition and serial repetition). SO also demonstrated a lexicality effect on immediate repetition. These results suggest that

SO’s phonology itself is weaker than that of HW due to SO’s severe semantic impairment.

7.3.3. Characteristics of SO's principal impairment

SO showed prominent semantic impairment together with fairly well preserved phonological function. SO's impairment pattern of the principal components was similar to HW's, but SO's semantic function had deteriorated more severely than that of HW. SO's phonological function was influenced by lexicality. For nonwords and more demanding tasks such as delayed/serial repetition SO’s phonological ability had deteriorated. These demonstrations in phonological tasks can be seen as a reflection of SO’s severe semantic impairment within an interactive cognitive system, where any phonological performances are the results of communication between phonology and semantics (e.g. Lambon Ralph & Patterson, 2005). In other words, SO's phonological function is not solid like HW’s because of SO's severe semantic impairment. This is a characteristic of SO's principal impairment.

7.4. The oral reading experiments for detecting surface dyslexia pattern

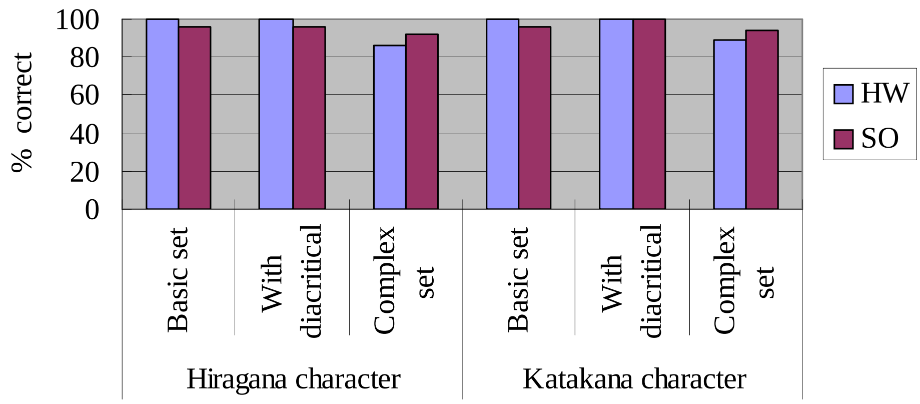
Since SO showed semantic impairment coupled with fairly well preserved phonological function, which is similar to that of HW who showed surface dyslexia, one can expect that SO would show a surface dyslexic pattern. This section presents the results of SO's oral reading performance which relate to the diagnosis of surface dyslexia.

7.4.1. Oral reading of nonwords

1) Single Kana characters

SO demonstrated well-preserved oral reading of single-character Kana, as did HW (Fig. 67). SO's accuracy for the full set for Hiragana characters and Katakana characters was well preserved (101/107, 94%; 103/107, 96%, respectively).

Fig. 67. SO's and HW's performance in single Kana character reaading.



2) Kana/Kanji nonwords

As shown in Table 37, SO’s oral reading of Katakana nonhomophonic nonwords was fairly good, but his oral reading of two-character Kanji nonwords (Fushimi et al., 1999) was severely impaired. This was radically different from

HW’s performance.

Table 37 SO's and HW's performance in nonword reading (% correct)

	Katakana nonwords (N=120)	Kanji nonnwords (N=120)
HW	93	87
SO	83	9

3) Summary of SO's oral reading of nonword strings

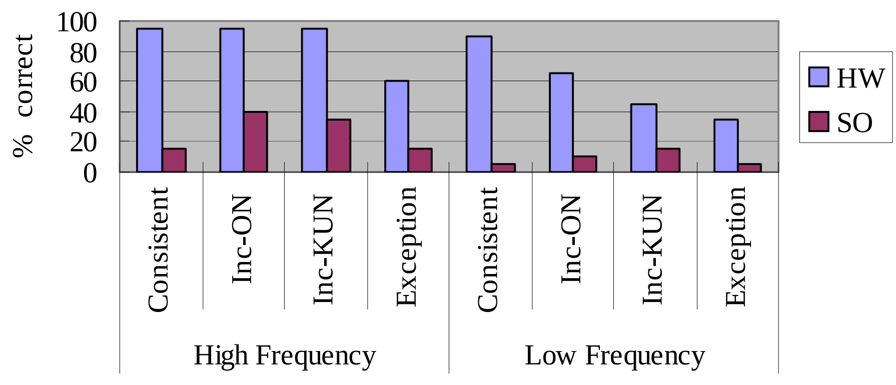
SO demonstrated good performance in oral reading of Kana characters (95%) and Kana nonhomophonic nonwords (83%). SO, however, showed great difficulty with reading aloud Kanji nonwords (9%).

7.4.2. Oral reading of Kanji words manipulated by consistency

1) The two-character Kanji words taken from the two published papers (Patterson et al., 1995; Fushimi et al., 1999)

Figure 68 shows SO’s oral reading performance for the 160 two-character Kanji words manipulated by consistency in Patterson et al. (1995) with a presentation of HW’s profile.

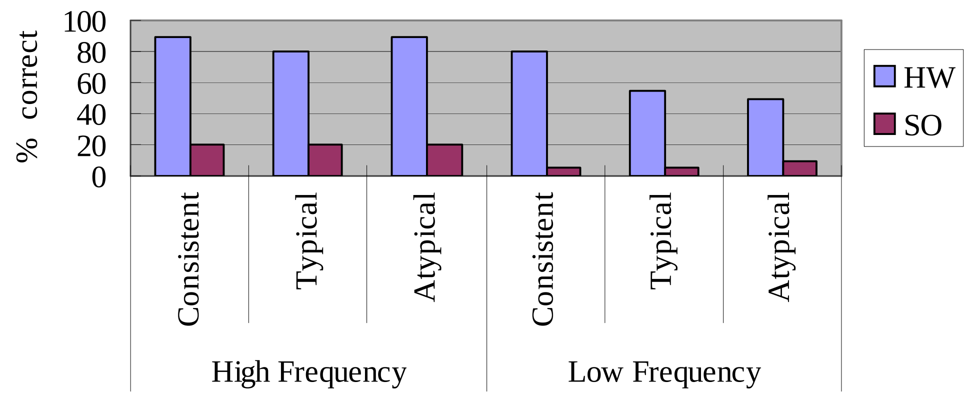
Fig. 68. SO's and HW's performance in the 160 Two-Character Kanji Word Reading Test (the stimuli taken from Patterson et al., 1995).



SO's performance was severely impaired and was modulated by frequency (high frequency words: 21/80, 26%; low frequency words: 7/80, 9%). But, a consistency effect was not observed in his oral reading performance.

Figure 69 presents SO's oral reading performance for the120 two-character Kanji words which were devised for examining the 'consistency effect' on normal Japanese readers (Fushimi et al., 1999), with a presentation of HW's profile. Again, there was no consistency effect on SO's oral reading performance and his performance was influenced by frequency (high frequency words: 12/60, 20%; low frequency words: 4/60, 7%).

Fig. 69. SO's and HW's performance in the 120 Two-Character Kanji Word Reading Test (the stimuli taken from Fushimi et al.,1999).



<u>Error analysis</u>

Table 38 and Table 39 show SO's error pattern in oral reading of the two-character Kanji words, which were created by Patterson et al. (1995) and Fushimi et al. (1999), respectively.

Table 38 Numbers of various error types by SO in the four consistency conditions of the 160 Two-Character Kanji Word Reading Test

	Consist.	Inc-ON	Inc-KUN	Exc	Total
Number of test items	40	40	40	40	160
LARC error	0	12	9	18	39
One character correct	9	10	7	5	31
Phonological error	2	1	0	0	3
Semantic error	1	0	0	2	3
Semantic/Visual error	1	0	3	1	5
Visual error	2	2	0	4	8
Unrelated	22	6	8	6	42
DK	0	0	0	1	1

Note. Consist.: consistent words; Inc-ON: Inconsistent-ON reading words; Inc-KUN: Inconsistent-KUN reading words; Exc.:exception words.

Table39 The proportion of error types in SO's performance in the four consistency conditions of the 120 Two-Character Kanji Word Reading Test

	High-frequency			Low-frequency		
		Inconsistent			Inconsistent	
	Consistent	Typical	Atypical	Consistent	Typical	Atypical
LARC	0.00	0.25	0.15	0.10	0.05	0.15
One character correct	0.25	0.20	0.20	0.15	0.05	0.20
Phonological	0.05	0.05	0.05	0.05	0.00	0.05
Semantic	0.00	0.05	0.05	0.05	0.00	0.00
Semantic/Visual	0.00	0.00	0.00	0.05	0.15	0.05
Visual	0.00	0.00	0.05	0.00	0.00	0.10
Unrelated	0.70	0.45	0.50	0.60	0.75	0.55

SO made LARC errors most frequently in oral reading of exception words devised by Patterson et al (1995), and in oral reading of atypical words devised by Fushimi et al (1999). However, the vast majority of SO’s errors were unrelated responses followed by ‘one character correct’ responses. These results suggest that SO's reading impairment for Kanji words was too severe for him to be able to produce the target pronunciation of two-character Kanji words.

In summary, SO’s Kanji word reading in both experiments was severely impaired and a consistency effect could not be observed. It seems that this relates to task difficulty. It is likely that oral reading of these Kanji words was too difficult for SO and therefore a consistency effect could not be detected. However, SO's LARC errors, which occurred most frequently in exception words and atypical words, belong to the characteristics of surface dyslexia. This indicate that SO's dyslexic pattern should be surface dyslexia.

2) The early-acquired two-character Kanji words (Fushimi, unpublished)

In order to detect a consistency effect on SO's oral reading performance, the Early Acquired Two-Character Kanji Word Reading Test (Fushimi, unpublished) was used. The characteristics of the stimuli words in this experiment are shown in Table 40-1.

Table 40-1 Characteristics of the stimuli materials (mean, ragne) of the Early Acquired Two-Character Kanji Word Reading Test, and examples of the stimuli

	Typical words (N=109)	Atypical words (N=109)
Moara (range)	3.6 (2-5)	3.6 (2-5)
Familiarity (range)	5.4 (4.3-6.7)	5.4 (4.1-6.6)
Frequency (range)	2.8 (0.8-4.8)	2.7 (0.0-5.0)
Examples Pronunciation Meaning	**国内** koku-nai *inland*	**風上** kaza-kami *windward*

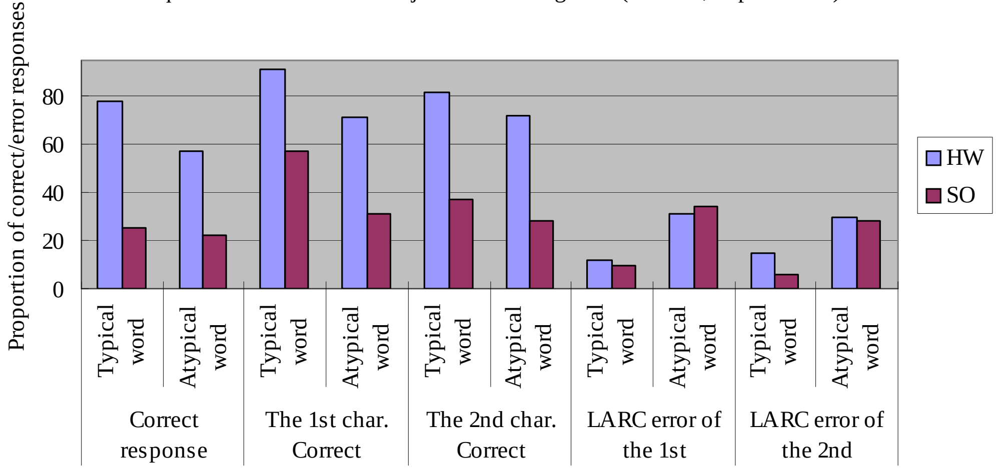
The constituent Kanji characters for the Kanji word stimuli were selected from Educational Kanji, which were prescribed by the Japanese Ministry of Education (see Chapter 3 or Glossary). This is because it was supposed that SO would be able to read high familiar and early-acquired Kanji words, in which there would be a higher possibility of observing a consistency effect. Consistency was statistically manipulated using the value of friends/orthographic neighbours (typical words vs. atypical words: 0.75 vs. 0.31); and the psycholinguistic properties of constituent Kanji characters were controlled by frequency, familiarity, age of acquisition and the number of strokes. Table 40-2 presents the characteristics of the first and second constituent Kanji characters in the stimuli of this test.

Table 40-2 Characteristics of the conctitunet Kanji characters (mean) of the Early Acquired Two-Character Kanji Word Reading Test

	Typical words		Atypical words	
	The first const. character	The second const. character	The first const. character	The second const. character
Consisntency	0.75	0.73	0.31	0.32
Familiarity	6.46	6.44	6.52	6.50
Frequency	5.40	5.30	5.48	5.50
Age of acquisition	1.92	1.94	1.92	1.94
Number of stroke	7.66	7.67	6.87	7.01

The left-hand part of Fig. 70 presents SO's and HW's oral reading performance for Kanji words in this experiment. Although HW showed a consistency effect in his accuracy of two-character Kanji word reading (typical word: 85/109, 78% vs. atypical word: 62/109, 57%, χ^2=11.05, p<0.001), SO did not show a consistency

Fig. 70. SO's and HW's accuracy, nd the proportion of LARC errors in the Early Acquired Two-Character Kanji Word Reading Test (Fushimi, unpublished).



effect (27/109, 25% vs. 24/109, 22%). Next, oral reading performance for each constituent Kanji character was examined in terms of a consistency effect.

As shown in the middle part of Fig. 70, SO's oral reading accuracy of each constituent character in typical words was better than that in atypical words (the first constituent character: 62/109, 57% > 34/109, 31%; the second constituent character: 40/109, 37% > 31/109, 28%). Statistical tests revealed a consistency effect on the first constituent Kanji character (χ^2 =14.59, $p = 0.0001$). The same pattern of consistency effect on oral reading of constituent Kanji characters was also observed in HW.

The proportion of SO's LARC errors for each constituent Kanji character in atypical words was higher that than in typical words (the first constituent character: 11/109, 10% < 37/109, 34%; the second constituent character: 6/109, 6% < 30/109, 28%). This was statistically significant in both constituent Kanji characters (χ^2 =18.06, $p < 0.0001$ for the first constituent characters; χ^2 =19.17, $p < 0.0001$ for the second constituent characters). Thus, SO's pattern for LARC errors was similar to HW's, as shown in the right-hand part of Fig. 70.

A simultaneous multiple logistic regression analysis on correct response for the first constituent Kanji character, with 9 variables - number of mora, word familiarity, word frequency, ON/KUN-Reading, character familiarity, character frequency, number of stroke, age of acquisition, and consistency for constituent Kanji character - revealed significant effects of consistency for the first constituent character (Wald = 11.902, $p < 0.001$), character familiarity for the second constituent character (Wald = 7.088, $p < 0.01$), character frequency for the first constituent character (Wald = 6.654, $p < 0.01$), the number of strokes (Wald = 5.876, $p < 0.02$), and age of acquisition (Wald = 5.876, $p < 0.02$) for the second Kanji character.

A simultaneous multiple logistic regression analysis on LARC errors for the first and second constituent character, with the same 9 predictors as in the previous analysis, revealed an inverse consistency effect of the constituent Kanji character (LARC errors of the first constituent character: Wald = 22.071, $p < 0.0001$; LARC errors of the second constituent character: Wald = 5.313, $p < 0.03$).

3) Summary of SO's oral reading of Kanji words manipulated by consistency

Although a consistency effect was not found in SO's oral reading performance for Kanji words (e.g. typical words vs. atypical words: 25% vs. 22%), SO demonstrated a consistency effect on oral reading of the first constituent Kanji character (typical words vs. atypical words: 57% > 31%).

7.4.3. Characteristics of SO's dyslexic pattern

1) The diagnosis of dyslexia type

SO’s consistency effect on Kanji word reading was detected by analysing the oral reading accuracy of single-constituent Kanji characters which were acquired early and had a high level of familiarity. The proportion of SO’s LARC errors for each constituent Kanji character in atypical words was significantly higher than that in typical words (typical words vs. atypical words: 10% < 34% for the first constituent character; 6% < 28% for the second constituent character). These characteristics fit surface dyslexia. Therefore, SO's dyslexic pattern can be treated as a variation of surface dyslexia. Since SO's oral reading accuracy was lower than HW's (e.g. typical words: 25% < 78%) and his oral reading of Kanji nonwords was impaired, unlike HW's (9% vs. 87%), it is reasonable to diagnose that SO showed a severe form of surface dyslexia in Japanese.

2) Comments about the surface dyslexic pattern observed in SO

SO's oral reading of Kanji words was more severely impaired than HW's and a consistency effect was not found in his oral reading accuracy for two-character Kanji words. However, a newly introduced analysis revealed that SO's oral reading of each constituent Kanji character for two-character Kanji words was governed by consistency, though a statistically significant consistency effect was only found in oral reading of the first constituent character. This result seems to arise from two things. Firstly, the value of consistency for the first constituent character is more accurate than that for the second constituent character. Since an initial phoneme of a pronunciation of the second character is occasionally changed by the 'phonotactic' voicing rule like 肝心 /kaN-ziN/ and 関心 /kaN-ʃiN/, Fushimi et al. (1999) counted them as different pronunciations of the second constituent character. This approach to 'a phonotactically altered pronunciation' might lead to a less accurate value of constituency for the second constituent character in two-character Kanji words. Secondly, the degree of phonological coherence from the first to the second constituent character would influence the correct pronunciation of the second constituent character in two-character Kanji words. This coherence would not differ between typical words and atypical words.

With regard to oral reading errors for Kanji words, SO showed a similar occurrence pattern of LARC errors to HW, but he produced many unrelated errors which was different from HW. This seems to reflect SO's severe semantic impairment. Meanwhile, SO's oral reading of Kanji nonwords was severely impaired. This contrasts with HW's well-preserved Kanji nonword reading. This could be explained by reduced phonological activation for each constituent Kanji character for Kanji nonwords due to severe semantic impairment; because morphographic Kanji characters (both free morpheme and bound morpheme) are connected with semantics and it can be supposed that semantic activation affects phonological activation for Kanji characters. So, these characteristics of SO's dyslexic pattern can be considered as a reflection of his severely impaired semantic function.

7.5. The oral reading experiments for examining semantic variables and lexicality

This section presents the results of SO's oral reading of Kanji/Kana strings manipulated by semantic variables and lexicality in order to clarify the characteristics of a severe form of Japanese surface dyslexia.

7.5.1. Oral reading of words manipulated by concreteness/imageability

Figure 71 shows SO's oral reading of Katakana character and single-character Kanji words, which were manipulated by concreteness, with a presentation of HW's profile. SO's Katakana word reading was preserved like HW's and there was no concreteness effect (concrete words: 56/60, 93%; abstract words: 57/60, 95%). In contrast, SO's Kanji word reading was disrupted and there was a concreteness effect (concrete words: 27/52, 52%; abstract words: 16/52, 31%; $\chi^2 = 4.79$, $p < 0.03$).

Fig. 71. SO's and HW's oral reading performance for Katakana and Kanji concrete/abstract words..

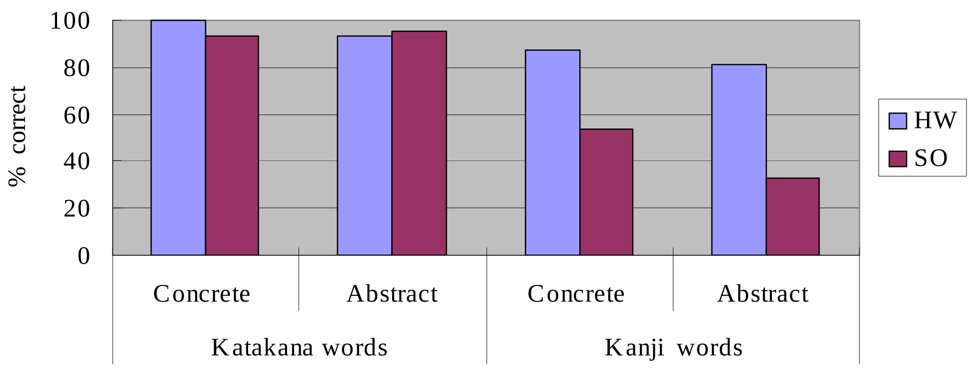


Figure 72 presents SO's oral reading performance in the Three Kinds of Word Reading Test, which were manipulated by imageability, with a presentation of HW's profile. Again, SO's Katakana word reading was preserved (high imageability words vs. low imageability words: 58/60, 97% vs. 59/60, 98%), whereas his Kanji word reading was strikingly impaired. SO showed a reading accuracy difference between single-character Kanji words and two-character Kanji words (39/120, 33% vs. 17/120, 14%: χ^2=11.27, $p < 0.001$), but he did not show an imageability effect on his oral reading of Kanji words.

Fig. 72. SO's and HW's oral reading performance in the Three Kinds of Word Reading Test.

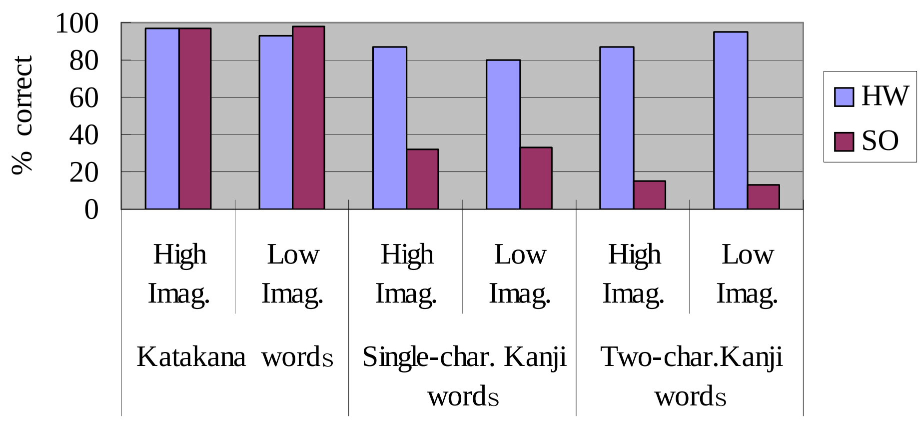


Fig. 73. SO's and HW's oral reading reading performance in the 100 Two-Character Kanji Word Test.

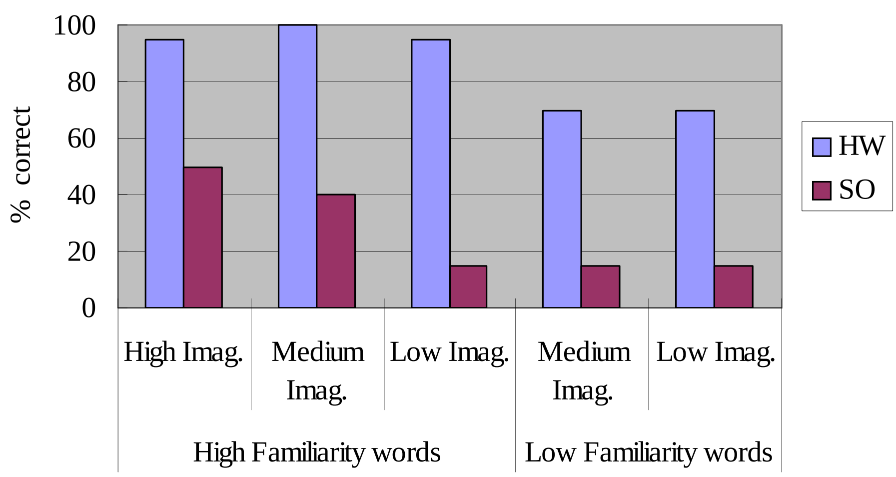


Figure 73 displays SO's performance in the 100 Two-Character Kanji Word Test, which were manipulated by familiarity and imageability, with a presentation of HW's profile. Like HW, SO showed a familiarity effect (high familiarity words vs. low familiarity words: 21/60, 35% vs. 6/40, 15%; χ^2 =4.87, $p < 0.03$). SO's reading accuracy of high familiarity words was modulated by imageability and an imageability effect was found (high imageability words vs. low imageability words: 10/20, 50% vs. 3/20,15%; χ^2 = 5.58, $p < 0.02$).

Error analysis

Table 41 **s**hows SO’s error pattern in oral reading of Katakana and Kanji words, manipulated by concreteness/imageability.

Table 41 The proportion of error types in SO's oral reading of Katakana/Kanji words manipulated in terms of concreteness and imageability

		Number of errors	Semantic	Circum.	Sem./Visual	Visual	Phono.W	Phono.NW	LARC	Unrel.W	Unrel.NW	DK/NR
Katakana word	Concrete	4	0.00	0.00	0.00	0.00	0.05	0.95	-	0.00	0.00	0.00
	Abstract	3	0.00	0.00	0.00	0.00	0.25	0.75	-	0.00	0.00	0.00
Katakana word	High Imag	2	0.00	0.00	0.00	0.00	0.00	1.00	-	0.00	0.00	0.00
	Low Imag.	1	0.00	0.00	0.00	0.00	0.00	1.00	-	0.00	0.00	0.00
1-character Kanji word	Concrete	53	0.38	0.11	0.02	0.02	0.00	0.02	0.00	0.32	0.13	0.00
	Abstract	36	0.36	0.00	0.00	0.06	0.00	0.06	0.08	0.19	0.22	0.03
1-character Kanji word	High Imag	63	0.24	0.10	0.03	0.06	0.03	0.00	0.00	0.43	0.11	0.00
	Low Imag.	54	0.07	0.00	0.09	0.00	0.04	0.02	0.06	0.59	0.09	0.04
2-character Kanji word	High Imag	77	0.03	0.01	0.04	0.00	0.08	0.03	0.23	0.40	0.18	0.00
	Low Imag.	78	0.00	0.01	0.03	0.00	0.08	0.06	0.05	0.44	0.33	0.00

Phono.W:phonologically similar word; Phono.NW:phonologically similar nonword; DK/NR: don't know or no response
Unrel.=unrelated; W: word; NW:nonword

In SO’s limited number of errors for Katakana word reading, all of his errors were in phonologically similar responses. In SO’s errors of Kanji word reading, semantically/phonologically unrelated errors were dominant. Semantic errors, however, occurred in Kanji words. LARC errors were made more frequently in two-character Kanji words than single-character Kanji words. SO's error pattern in the 100 Two-Character Kanji Word Test was exactly to the same as his error pattern in the two-character Kanji words manipulated by imageability.

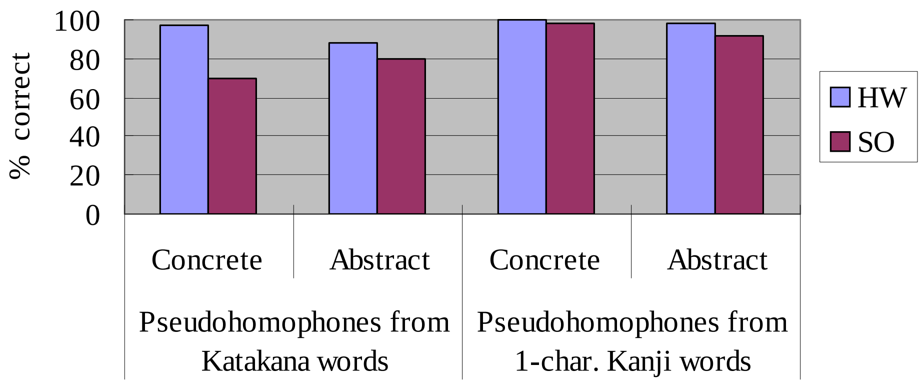
Summary

SO’s oral reading of Katakana words was well preserved (93-98%), whereas his Kanji word reading was remarkably impaired (15-54%). Familiarity affected SO's Kanji word reading (high familiarity words vs. low familiarity words: 35% vs.15%) and a concreteness/imageability also affected his Kanji word reading in several conditions (i.e. a concreteness effect on single-character Kanji words: 54% vs. 33%; an imageability effect on high familiarity words: 50% vs. 15%).

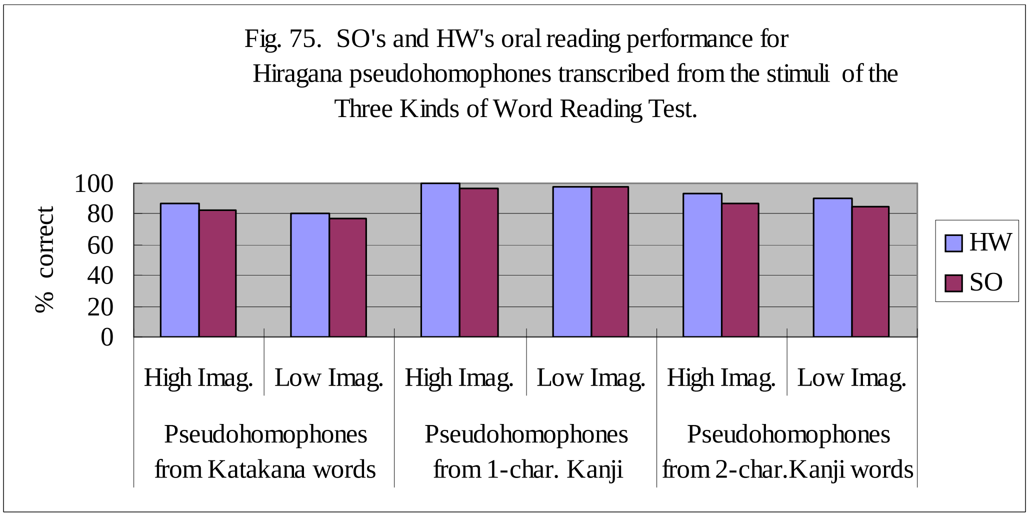
7.5.2. Oral reading of Kana/Kanji pseudohomophones

As shown in Fig. 74 and Fig. 75, SO’s oral reading of Hiragana pseudohomophones, which were transcribed from Katakana/Kanji words of the concrete/abstract word test and the Three Kinds of Word Reading Test, was as well preserved as HW’s.

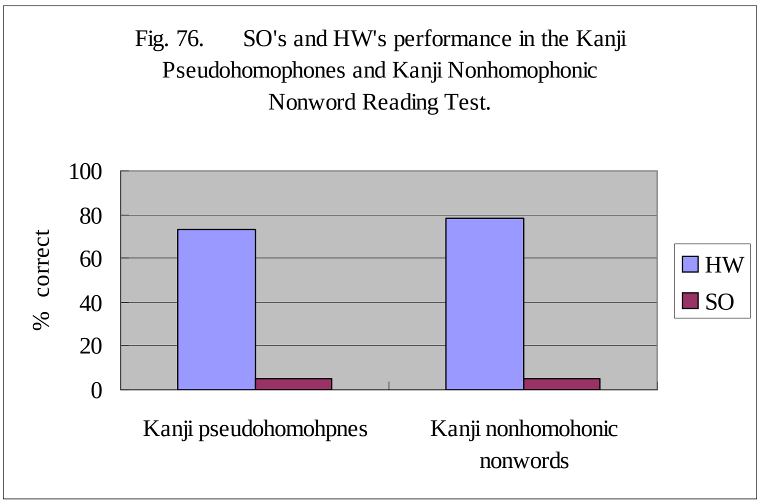
Fig. 74. SO's and HW's oral reading performance for Hiragana pseudohomophones transcribed from Katakana and Kanji concrete/abstract words.



SO showed fairly well preserved oral reading of Hiragana pseudohomophones, though his oral reading accuracy was lower than HW’s in all conditions, and in transcriptions from concrete Katakana words, in particular (70% < 97%). SO's oral reading accuracy of Kana pseudohomophones was modulated by the script type of its base words (Kanji words: 87-98%; Katakana words: 65-85%).



As shown in Fig. 76, SO showed great difficulty to read aloud both Kanji pseudohomophone and Kanji non-homophonic nonwords (5% for both). This was sharp contrast with HW's performance. There was no advantage of pseudohomophone reading over non-homophonic nonword reading.



Error analysis

Table 42 shows SO’s error pattern in oral reading of Hiragana pseudohomophones. SO’s dominant error type was phonologically similar to the target stimuli. Table 43 shows SO’s error pattern in oral reading of Kanji pseudohomophones and Kanji nonwords. SO produced mainly unrelated responses for Kanji nonword reading. This was different from HW's error pattern in which the vast majority of errors were phonologically similar. For SO, the proportion of phonologically similar errors in both types of Kanji nonwords was quite limited.

Table 42 The proportion of error types in SO's oral reading of Hiragana pseudohomophone transcribed from Katakana/Kanji words manipulated in terms of concreteness and imageability

		Number of errors	Semantic	Phono.W	Phono.NW	Unrelated W
Pseudo.from Katakana word	Concrete	18	0.00	0.00	1.00	0.00
	Abstract	12	0.00	0.08	0.92	0.00
	High Imag.	10	0.00	0.20	0.80	0.00
	Low Imag.	14	0.00	0.14	0.86	0.00
Pseudo.from 1 char.Kanji word	Concrete	1	0.00	1.00	0.00	0.00
	Abstract	4	0.00	0.50	0.50	0.00
	High Imag.	2	0.00	0.50	0.50	0.00
	Low Imag.	1	0.00	0.00	1.00	0.00
Pseudo.from 2 char.Kanji word	High Imag.	8	0.13	0.13	0.50	0.25
	Low Imag.	9	0.00	0.11	0.78	0.11

Pseudo.= pseudohomophones Imag.=imageability
Phono. W=phonologically related word char.=character
Phono.NW=phonologically related nonword
Unrelated W=unrelated word

Table 43 The proportion of error types in SO's oral reading of Kanji pseudohomophones and Kanji nonhomophonic nonwords

	Number of errors	Visual	Phonological	Unrelated
Kanji pseudohomophones	39	0.10	0.10	0.80
Kanji nonhomophonic nonwords	41	0.00	0.07	0.93

Summary

SO's oral reading of Kana pseudohomophones (65-98%) was preserved, but was modulated by the script type of its base words (Kanji words: 87-98%; Katakana words: 65-85%). In contrast, his oral reading of Kanji pseudohomophones (5%) was severely impaired as with Kanji nonhomophonic nonwords.

7.5.3. Comment about the influence of semantic variables and lexicality on SO's oral reading performance

SO's oral reading of Kanji words was modulated by concreteness (concrete words vs. abstract words: 54% > 33%) and imageability (high familiarity/high imageability words vs. high familiarity/low imageability words: 50% > 15%). This dyslexic pattern was different from HW's which did not show such semantic variables effects.

This appears to reflect SO's severe semantic impairment. In the case of HW, who had moderate semantic impairment, phonological activation is strong enough to be governed by character-sound consistency. However, in SO with severe semantic impairment, phonological activation is fragile and semantic variables affect his oral reading.

SO's oral reading of Kanji pseudohomophones (5%) was severely impaired and there was no pseudohomophone effect. This also might be explained by SO's severe semantic impairment. Since semantics could affect phonological activation of morphographic Kanji characters, severe semantic impairment would lead to abnormally reduced phonological activation of constituent Kanji characters for Kanji pseudohomophones and Kanji nonhomophonic nonwords, which consist of Kanji characters. Thus, phonological lexicality would not influence SO's oral reading performance of Kanji pseudohomophones.

On the other hand, SO's oral reading of Kana strings was preserved, there was no semantic variables effect on Kana word reading.

7.6. The analysis of SO's dyslexic pattern using the Kanji vs. Kana framework

7.6.1. The analysis of word reading using the Kanji vs. Kana framework

1) A comparison of oral reading accuracy of Kanji and Kana word reading

In SO's oral reading accuracy of Kanji/Kana words manipulated by concreteness/imageability, Kana word reading was better than Kanji word reading in all conditions (Kanji words vs. Kana words: 27/52, 52% vs. 56/60, 93% for concrete words: 28/120, 23% [single-character words: 19/60, 32%; two-character words: 9/60, 15%] vs. 58/60, 97% for high imageability words; 16/52, 31% vs. 57/60, 95% for abstract words; 28/120, 23% [single-character words: 20/60, 33%; two-character words: 8/60, 13%] vs. 59/60, 98% for low imageability words).). SO's oral reading accuracy of high frequency/consistent Kanji words (15% for Patterson et al.'s list; 20% for Fushimi et al's list) was considerably lower than his oral reading accuracy of Kana words (average of all Kana word stimuli: 97%).

7.6.2. The analysis of pseudohomophone reading using the Kanji vs. Kana framework

1) A comparison of oral reading accuracy of Kanji words and Hiragana pseudohomophones transcribed from Kanji words

SO's oral reading accuracy of Hiragana pseudohomophones transcribed from Kanji words was remarkably better than that of the base Kanji words (Kanji words vs. Hiragana pseudohomophones: 27/52, 52% vs. 51/52, 98% for concrete items; 28/120, 28% vs. 110/120, 92% for high imageability items; 16/52, 31% vs. 48/52, 92% for abstract items; 28/120, 23% vs. 110/120, 92% for low imageability items).

2) A comparison of oral reading accuracy of Katakana words and Hiragana pseudohomophones transcribed from Katakana words

SO's oral reading accuracy of Hiragana pseudohomophones transcribed from Katakana words was worse than that of the base Katakana words (Katakana words vs. Hiragana pseudohomophones: 56/60, 93% vs. 42/60, 70% for concrete items, $\chi^2 = 10.91$, $p = 0.001$; 57/60, 95% vs. 48/60, 80% for abstract items, $\chi^2 = 6.17$, $p < 0.02$; 58/60, 97% vs. 50/60, 83% for high imageability items, $\chi^2 = 5.93$, $p < 0.02$; 59/60, 98% vs. 46/60, 77% for low imageability words, $\chi^2 = 12.88$, $p < 0.001$). That is, SO showed an orthographic familiarity effect (or orthographic lexicality effect).

3) A comparison of oral reading accuracy of Kana pseudohomophones and Kanji pseudohomophones

SO's oral reading accuracy of Hiragana pseudohomophones transcribed form Kanji and Katakana words manipulated by concreteness/imageability (70-98%) was radically different from that of Kanji pseudohomophones (5%). SO's oral reading of Kana pseudohomophones (505/584, 86%) was worse than Kana words (230/240, 96%). Since SO's oral reading of Kanji pseudohomophones and Kanji nonhomophonic nonwords was nearly disrupted, lexicality effect was salient in his oral reading of Kanji strings.

7.6.3. The bi-scriptal influence observed in SO's oral reading performance

As with HW, SO's oral reading of Kana strings was better than of Kanji strings (e.g. Kanji words vs. Kana words: 29% vs. 96%). This difference is attributable to high 'pronunciation predictability' for Kana strings than for Kanji strings. In other words, SO's preserved oral reading of Kana strings can be considered as a part of a consistency effect. Thus, SO's different dyslexic pattern in Kana and Kanji strings is not a 'real' script-type effect.

7.6.4. Characteristics of a severe form of surface dyslexia as observed in SO

SO's dyslexic pattern was not identical to the typical surface dyslexia pattern in Japanese (i.e. a consistency effect on low frequency Kanji word reading and preserved Kanji nonword reading) which was demonstrated by HW in Study 1 in this thesis and in the recent cases of Japanese surface dyslexia (e.g. Fushimi et al., 2003). Unlike the findings relating to HW, the following characteristics were observed in SO's oral reading performance.

i) SO did not show a consistency effect on his oral reading of two-character Kanji words.

ii) SO showed prominent impairment of oral reading for Kanji pseudohomophones and Kanji nonhomophonic nonwords.

iii) Concreteness and imageability affected SO's oral reading of Kanji words.

iv) SO showed an orthographic familiarity (or orthographic lexicality) effect (i.e. words > pseudohomophones) on his oral reading of Kana strings.

However, SO's oral reading was basically governed by consistency, which is consonant with surface dyslexia. SO showed a consistency effect on his oral reading of the first constituent Kanji character and an inverse consistency effect on the proportion of LARC errors, both of which are defining characteristics of surface dyslexia. Moreover, SO's oral reading of Kana strings was well preserved, as with HW.

Thus, it appears that SO's dyslexia pattern, summarised above, manifests characteristics of a severe form of Japanese surface dyslexia.

7.7. The impact of severe semantic impairment on language performance

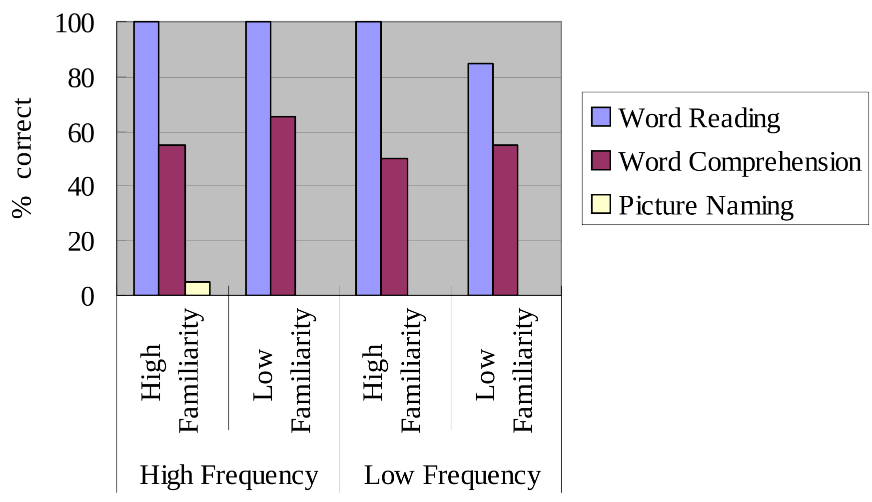
This section presents the results of SO's performance in the cross-domain tasks: written word comprehension, picture naming, and oral reading, and the cueing effect on both oral reading and picture naming. This exploration would give us further understanding about the impact of severe semantic impairment on language performances.

7.7.1. Cross-domain effect

1) Oral reading, written word comprehension, and picture naming for Katakana words

Figure 77 shows SO's performance in word reading, written word comprehension, and picture naming in the 80 Katakana Word Test.

Fig. 77. SO's performance in the cross-domain tasks for Katakana words.



SO demonstrated a striking cross-domain effect (oral reading > comprehension > picture naming). SO's Katakana word reading was not impaired except in the low frequency and low familiarity band (17/20, 85%), whereas his word comprehension was moderately impaired and his picture naming was nearly disrupted. SO could read Katakana words aloud without comprehension (35/80, 44%). Though his Katakana word reading was highly preserved like HW (77/80, 96% vs. 77/80, 96%), his Katakana word comprehension (45/80, 56%) and picture naming (1/80, 1%) was worse than HW's (72/80, 90% and 22/80, 28%, respectively). These findings suggest that severe semantic impairment prominently affected SO's comprehension of written words and his picture naming, but not his Katakana word reading.

Error analysis

In SO's written word comprehension semantic error was dominant (26/35, 74%), but he also made phonological errors (6/35, 17%) and unrelated error (3/35, 9%). Table 44 shows the proportion of SO's errors in the cross-domain tasks of oral reading and picture naming.

Table 44 The proportion of error types in SO's performance in the cross-domain tasks for Katakana words

		Number of Errors	Semantic	Circum.	Phono.W	Phono. NW.	Unrelated W.	Unrelated NW.	DK/NR
Oral reading	H Freq.	5	0.00	0.00	0.40	0.60	0.00	0.00	0.00
	L Freq.	5	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Picture naming	H Freq.	46	0.28	0.09	0.02	0.00	0.17	0.33	0.11
	L Freq.	45	0.22	0.11	0.00	0.00	0.29	0.20	0.18

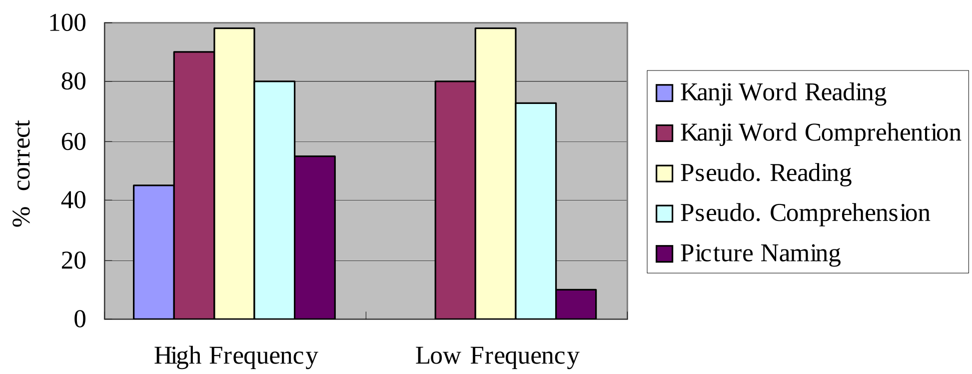
Note. Circum.= Circumlocution; Phono.=phonological; W.= words; NW.= nonwords; .
DK = don't know response; NR= no response.

SO's Katakana word reading errors were phonologically related nonwords or phonologically related words. Like HW, SO produced multiple responses in picture naming and word reading, but the difference between them was noticeable in the occurrence of circumlocutions (SO: 9/91, 10% vs. HW: 44/93, 47%). SO's main error types in picture naming were unrelated nonwords (24/91, 26%), unrelated words (21/91, 23%), and semantic errors (23/91, 25%).

2) Oral reading, written word comprehension, and picture naming for single-character Kanji words

In the case of the cross-domain tasks for the 80 single-character Kanji words, the order of SO's accuracy was Hiragana pseudohomophone reading > written Kanji word comprehension > Hiragana pseudohomophone comprehension > picture naming > Kanji word reading (Fig. 78).

Fig. 78. SO's performance in the cross-domain tasks for single-character Kanji words.



SO's comprehension for Hiragana pseudohomophones was less accurate than his Kanji word comprehension (high frequency words: 32/40, 80% < 36/40, 90%; low frequency words: 29/40, 73% < 32/40, 80%). SO's accuracy of Kanji word reading was relatively similar to his picture naming at a high frequency band (18/40, 45% and 22/40, 55%, respectively). Compared to HW's performance, SO showed substantial impairment in Kanji word reading (18/80, 23% vs. 44/80, 56%) and picture naming (25/80, 31% vs. 44/80, 55%). However, his Katakana pseudohomophone reading was highly preserved, as was HW's (78/80, 98% vs. 79/80, 99%) and his Kanji word comprehension was relatively preserved (68/80, 85% vs. 76/80, 95%). These results suggest that SO's severe semantic impairment affected his Kanji word reading and picture naming.

Error analysis

In comprehension of Kanji words, SO's dominant error was semantic (8/12, 67%), followed by phonological errors (3/12, 25%). SO produced a similar proportion of these errors in comprehension of Hiragana pseudohomophones transcribed from Kanji words (semantic error: 10/29, 53%;phonological error: 9/19, 47%). Table 45 presents SO's error pattern in the cross-domain tasks of oral reading of Kanji words and Hiragana pseudohomophones, and picture naming.

Table 45 The Proportion of error types in SO's performance in the cross-domain tasks for single-character Kanji words

		Number of Errors	Semantic	Circum.	Phono.W.	Phono.NW	Unrelated W.	Unrelated NW.	DK/NR
Kanji Reading	H Freq.	33	0.39	0.06	0.06	0.00	0.48	0.00	0.00
	L Freq.	56	0.21	0.13	0.02	0.00	0.39	0.16	0.09
Pseudo. Reading	H Freq.	4	0.00	0.00	1.00	0.00	0.00	0.33	0.00
	L Freq.	5	0.00	0.00	0.40	0.20	0.20	0.20	0.00
Picture Naming	H Freq.	38	0.62	0.08	0.13	0.00	0.13	0.03	0.00
	L Freq.	70	0.47	0.07	0.03	0.01	0.27	0.14	0.00

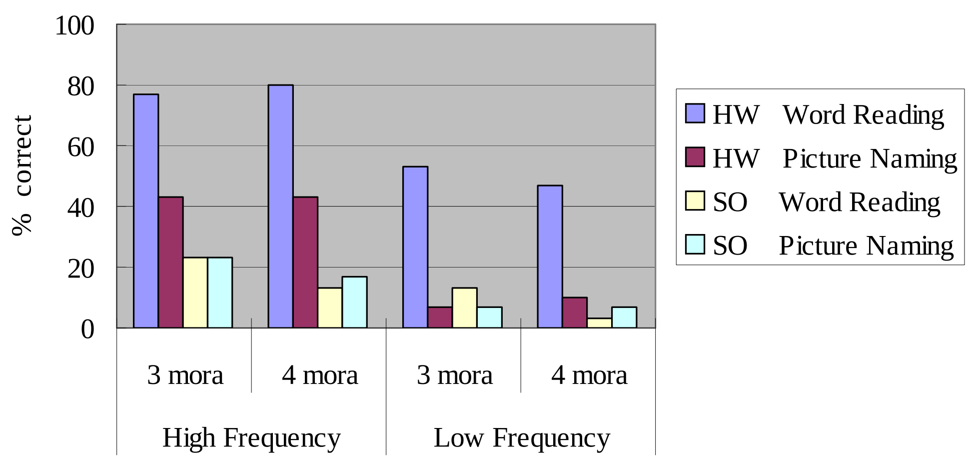
Note. Kanji Reading = Kanji character word reading; Pseudo. Reading = Hiragana pseudohomophone reading; Circum.= circumlocution; Phono.= phonological; W.= words; NW.= nonwords; DK = don't know response; NR= no response

In Kanji word reading, unrelated word response (47/89, 53%) was the dominant type of error, followed by semantic errors (25/89, 28%). In oral reading of Hiragana pseudohomophones, phonologically related word response (6/9, 67%) was the dominant error. In picture naming SO mainly made semantic errors (57/108, 53%), followed by unrelated word responses (24/108, 22%).

3) Oral reading and picture naming for two-character Kanji words manipulated by the number of mora and familiarity

As shown in Fig. 79, SO's accuracy in two-character Kanji word reading and picture naming was noticeably impaired and had deteriorated further than that shown in HW's performance. SO's performance in both word reading and picture naming was modulated by word familiarity (high frequency words vs. low frequency words: 11/60, 18% vs. 5/60, 8% for word reading: 12/60, 20% vs. 4/60, 7% for picture naming). SO's overall accuracy in both tasks was the same (16/120, 13%). That is, SO did not demonstrate superiority of word reading over picture naming in this test. This was clearly different from HW's performance which showed a striking advantage of word reading over picture naming (77/120, 64% > 31/120, 26%).

Fig. 79. SO's and HW's Kanji word reading and picture naming in the cross-domain test.



<u>Error analysis</u>

The error pattern for Kanji word reading was also different between SO and HW (Fig. 80). The proportion of unrelated errors (56/104, 54%) was the highest in SO's oral reading, followed by phonologically similar errors (22/104, 21%), whereas phonological errors (17/43, 40%) and LARC responses (16/43, 37%) were HW's dominant errors.

Fig.80. The proportion of eror types in SO's and HW's
Kanj word reading in the cross-doman test.

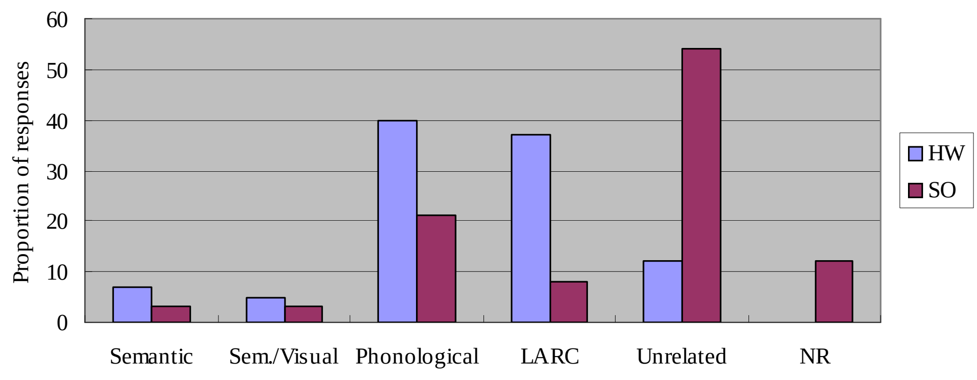
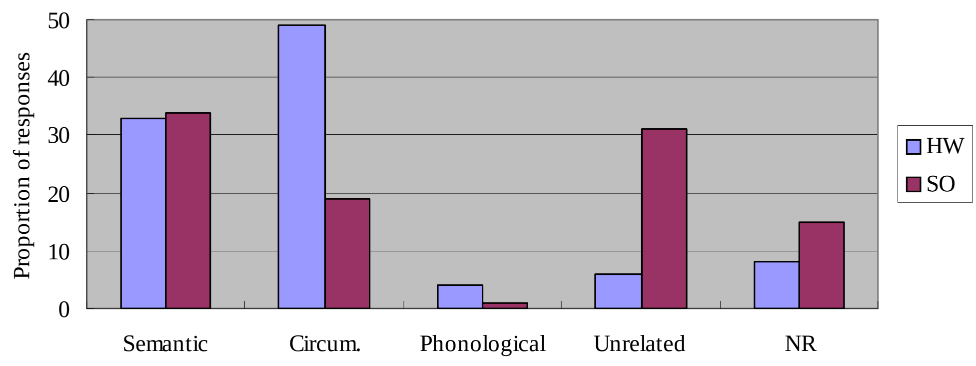


Fig. 81. The proportion of error types in SO's and HW's
picture naming in the cross-domain test.



As shown in Fig. 81, SO’s main error types in picture naming were semantic errors (35/104, 34%) and unrelated responses (32/104, 31%). Although the proportion of SO’s semantic errors was similar to HW’s, circumlocution was not frequently produced compared to HW (20/104, 19% vs. 44/89, 49%).

4) Summary and comment on SO's performances in the cross-domain tasks

SO’s performance in cross-domain tasks showed a modality effect which was modulated by the written stimuli’s script type. SO’s oral reading of Katakana words and Hiragana pseudohomophones, which were transcribed from Kanji words, was well preserved (96% and 98%, respectively) and his word comprehension for Kanji words (85%) was relatively preserved. However, SO's comprehension of Katakana words, and Hiragana pseudohomophones transcribed from Kanji words, was moderately impaired (57% and 76%, respectively). Furthermore, SO's Kanji word reading (23%) and his picture naming (1% for Katakana words; 31% for Kanji words) were severely impaired.

These results suggest that the sharp contrast in SO's accuracy in cross-domain tasks reflects the different degree of impact of semantic impairment. Since picture naming is mediated from semantic activation, semantic impairment directly affects this performance. Oral reading of Kanji words inherently requires semantic support due to the opaque relationship between orthography and phonology, and so this performance is strongly influenced by semantic impairment. Comprehension of written strings also requires semantic activation, and severe semantic deterioration has an impact on performance in this area. However, oral reading of transparent Kana strings showed great resistance to semantic impairment. Moreover, a high proportion of semantically and phonologically unrelated errors in SO's word reading and picture naming reflect severe semantic impairment.

7.7.2. The phonological cueing effect on oral reading and picture naming

Table 46 describes the phonological cueing effect on SO’s performance in both word reading and picture naming, and this is presented in the relation to the first error types in his response given without a cue.

The rate of facilitation after the initial mora cue was only 3% in both word reading and picture naming which was lower than HW's rate (28% for word reading, 17% for picture naming). SO's dominant response after the initial cue was no phonological overlapping, or no response (78/104, 75% for word reading; 56/104, 63% for picture naming), which was contrast with the findings for HW (16% for word reading, 19% for picture naming). Phonologically similar responses, which overlapped 2-mora to the target, were very limited (10/104, 9.6% for word reading, 8/104, 7.6% for picture naming).

Table 46 SO's performance in the Two-Character Kanji Word Reading and Picture Naming Test

		Error type in the first response						
Reading aloud	correct	sem	sv	phon	larc	unrel.	no resp.	total or mean
No. of items	16	3	3	22	8	56	12	104
Proportion to total errors	-	0.03	0.03	0.21	0.08	0.54	0.12	1.00
No. of items with successful first cue		0	0	1	0	2	0	3
proportion to No. of items	-	0.00	0.00	0.05	0.00	0.04	0.00	0.03
No. of items with successful cues		2	1	13	3	21	5	45
proportion to No. of items	-	0.67	0.33	0.59	0.38	0.38	0.42	0.43
Mean No. of morae of stimulus words	3.31	3.67	4.00	3.45	3.25	3.52	3.75	3.50
Mean uniqueness point of stimulus words	3.19	3.33	4.00	3.36	3.13	3.41	3.50	3.38
Mean No. of morae in successful cue	-	2.33	3.67	2.77	2.25	2.93	2.83	2.84
Mean of uniqueness point minus successful cue	-	1.00	0.33	0.59	0.88	0.48	0.67	0.57

		Error type in the first response					
Picturte naming	correct	sem	cirs.	phon	unrel.	no resp.	total or mean
No. of items	16	35	20	1	32	16	104
Proportion to total errors	-	0.34	0.19	0.01	0.31	0.15	1.00
No. of items with successful first cue		1	0	0	1	1	3
proportion to No. of items	-	0.03	0.00	0.00	0.03	0.06	0.03
No. of items with successful cues		19	6	0	11	5	41
proportion to No. of items	-	0.54	0.30	0.00	0.34	0.31	0.39
Mean No. of morae of stimulus words	3.44	3.51	3.45	4.00	3.50	3.56	3.50
Mean uniqueness point of stimulus words	3.38	3.49	3.20	4.00	3.34	3.38	3.38
Mean No. of morae in successful cue	-	2.97	3.15	4.00	3.09	3.13	3.08
Mean of uniqueness point minus successful cue	-	0.51	0.05	0.00	0.25	0.25	0.30

Note. sem: semantic; sv: semantic/visual; circ: circumlocution;
phon: phonological;unrel: unrelated; no resp.: no response.

The progressive cueing technique, also, did not do much to facilitate SO’s correct response in both word reading and picture naming, in which about 40% of the successful cueing effect was found. This proportion was half of HW’s successful responses (SO vs. HW: 43% vs. 79% for word reading, 39% vs.75% for picture naming). The mean number of morae for a successful cue for SO's word reading and picture naming was larger than HW’s (2.84 > 2.23 for word reading, 3.08 > 2.44 for picture naming). The error type most facilitated by progressive phonological cueing was the semantic error in both word reading (2/3, 67%) and picture naming (19/35, 54%). Many of the phonologically similar errors in his word reading were also facilitated by progressive phonological cueing (13/22, 59%).

7.7.3. Interpretations of the impact of severe semantic impairment observed in SO

SO's performance in the cross-domain tasks confirmed that severe semantic impairment did not affect Kana word reading but strongly affected Kanji word reading, and also revealed that severe semantic deterioration affected written word comprehension moderately and picture naming considerably. Thus, SO demonstrated superiority of Kana word reading over Kana written word comprehension, but superiority of Kanji word comprehension over Kanji word reading. Since SO's principal impairment was not phonological but semantic, phonological cueing was not so effective in facilitating his correct oral reading of Kanji words and picture naming. Since SO's semantic impairment was more severe than HW's, his rate of phonological cueing effect was lower than HW's.

SO's results suggests that i) the degree of impact of severe semantic impairment depends on the requirement of semantic contribution for task performance, and ii) Kana word reading has great resistance to severe semantic impairment.

7.8. Discussion

7.8.1. The conclusion of research question 1

Research question 1

"What is a severe type of Japanese surface dyslexia like?"

SO demonstrated i) better reading accuracy of the first constituent Kanji character for typical words than that for atypical words (i.e. a consistency effect), ii) an inverse consistency effect for the proportion of LARC errors (i.e. LARC errors occurred more frequently in atypical words than in typical words), though a unrelated response was SO’s dominant error type; iii) severely impaired oral reading of Kanji nonwords (both Kanji pseudohomophones and Kanji nonhomophonic nonwords); iv) concreteness/imageability in Kanji word reading; and v) orthographic lexicality effect on oral reading of Kana strings (i.e. Kana words > Kana pseudohomophones) .

SO did not show a consistency effect on oral reading of two-character Kanji words as a whole. This is because his Kanji word reading had deteriorated more severally than that of HW in Study 1. Thus, it was difficult to detect a consistency effect on SO's Kanji word reading with low reading accuracy. Despite this, both the consistency effect on SO's oral reading of the first constituent Kanji character, and the production of LARC errors fit the defining characteristics for surface dyslexia.

Concreteness/imageability and lexicality affected SO's oral reading of Kanji strings. These effects, which were not found in HW's oral reading performances, appear to arise from substantially deteriorated phonological activation for Kanji written stimuli. Therefore, it is rational to conclude that SO's dyslexic pattern is a severe form of Japanese surface dyslexia.

7.8.2. The conclusion of research question 2

Research question 2

"Is a severe type of Japanese surface dyslexia a Kanji script-specific reading disorder?"

SO's oral reading of Kana strings was better than that of Kanji strings. At first glance SO's dyslexic pattern appears to be similar to the classical cases of Japanese surface dyslexia (Sasanuma, 1980a, 1985) which showed impaired Kanji word reading with preserved oral reading of Kana pseudohomophones. However, SO demonstrated a consistency effect on his oral reading accuracy of the first constituent Kanji character, and he made LARC errors. These findings fit the defining characteristics of surface dyslexia, which suggests that SO's dyslexic pattern is basically governed by character-sound consistency. Thus, preserved oral reading of Kana strings is attributable to high 'pronunciation predictability' for Kana and can be considered as a part of a consistency effect.

Meanwhile, orthographic lexicality (or orthographic familiarity) and lexicality could explain SO's profoundly impaired oral reading of Kanji pseudohomophones and Kanji nonhomophonic nonwords. Due to SO's severe semantic impairment his phonological activation for Kanji characters is fragile, and semantic support becomes important for correct oral reading. Thus, Kanji words have an advantage over Kanji nonwords which have no meanings.

Given these considerations, SO's deteriorated oral reading of Kanji strings, coupled with preserved oral reading of Kana scripts, reflects psycholinguistic variables effects and is not a Kana script-dependent reading disorder. Therefore, **the answer to research question 2** is **"No"**.

7.8.3. The conclusion of research question 3

Research question 3

"Can the Japanese versions of the DRC model and the triangle model explain the co-occurrence of severe semantic impairment and a severe form of surface dyslexia in Japanese?"

The framework for addressing this research question was to verify the semantic impairment hypothesis based on the triangle model. SO demonstrated the co-occurrence of semantic impairment and a severe form of surface dyslexia. This seems to support the semantic impairment hypothesis, indicating a reliability of the triangle model. However, the key of this research question is whether the two models can explain the co-occurrence of severe semantic impairment and a severe form of surface dyslexic pattern. The explanations of SO's dyslexic pattern using the two models are shown below in.

<The interpretation using the Japanese version of the DRC model>

Since SO showed deteriorated oral reading of Kanji words and profound impairment of Kanji nonword reading, which was different from the results for HW and the recent surface dyslexia cases, SO's dyslexic pattern requires not only the damage of the lexical route but also the non-lexical route. This is because the DRC model assumes that correct oral reading of nonwords is only processed through the non-lexical route.

The Japanese version of the DRC model, however, needs a modification in order to explain following reading performance found in SO's:

i) oral reading of consistent Kanji words was severely impaired;

ii) oral reading of Kanji nonwords, whose constituent character has only one pronunciation, was substantially impaired;

iii) oral reading of Kana words and Kana nonwords was preserved.

This model, in which Kanji and Kana characters share the Character-Sound Rule system in the non-lexical route, cannot account for these dyslexia patterns. If one assumes the two non-lexical routes for Kanji and Kana, these characteristics of SO's reading performance can be explained by the damage to the Kanji non-lexical route coupled with the intact Kana non-lexical route. Thus, this modified Japanese version of the DRC model can explain the severe form of surface dyslexia demonstrated by SO, as damage to the lexical route and the non-lexical route for Kanji.

The other problem for interpretation of SO's surface dyslexic pattern, using the Japanese version of the DRC model, is that this model does not predict the co-occurrence between severe semantic impairment and a severe form of surface dyslexia (i.e. SO's dyslexic pattern). Since this model assumes independent reading routes, semantic impairment cannot affect the non-lexical route processing or the lexical-nonsemantic route processing. For this model, the co-occurrence between severe semantic impairment and a severe form of surface dyslexia is not causal but is accidental.

<The interpretation using the Japanese version of the triangle model>

In the triangle model, correct oral reading is the result of a joint contribution of the direct O→P computation and semantic support (O→S→P, or O→P⇔S). If the system has semantic impairment, reading aloud the written strings (which have lower character-sound consistency) is prone to error because correct oral reading of such types of words needs a semantic contribution. Semantic impairment, however, would not greatly affect reading aloud the written strings (which have high character-sound consistency) because the direct O→P computation is efficient enough for correct oral reading.

Taking these basic mechanisms, this model can predict that severe semantic impairment does not much affect oral reading of Kana strings which have transparent correspondences between a character and its phonological counterparts. Indeed, SO could read aloud Katakana words for the cross-domain task despite the fact that approximately half of them were not correctly understood. In the case of Kana pseudohomophones, orthographic unfamiliarity and the degree of phonological activation for the base words would affect the reading accuracy. So, it is predictable that severe semantic impairment leads to a more fragile status of phonological activation of the base words, and this affects the accuracy of Kana pseudohomophones. Indeed, SO's oral reading accuracy of Kana pseudohomophones was lower than HW's, though oral reading accuracy of Kana nonhomophonic nonwords was the same and well-preserved in the two cases.

More importantly, this model can predict that the degree of semantic impairment affects the oral reading performance of Kanji strings. In this model, severe semantic impairment would lead to a remarkably reduced phonological activation, based on the communication between Semantics and Phonology. Due to this, the Kanji words with higher familiarity, higher frequency and higher concreteness/imageability would have a more solid phonological activation, which might be sufficient for correct oral reading. In other words, consistency does not have a dominant influence on oral reading performance in the cases with severe semantic impairment. Thus, it becomes difficult to detect a consistency effect on oral reading accuracy for Kanji words as a whole. However, a consistency effect on oral reading of constituent characters for Kanji words would be detectable because severe semantic impairment forces subjects to use the direct O→P computation which is governed by character-sound consistency. SO's demonstration of a statistically significant consistency effect on his oral reading of the first constituent Kanji character fits this prediction. Furthermore, severe semantic impairment would explain SO's profound impairment of Kanji nonword reading. When the semantic system is severely impaired, phonological activation for single Kanji characters might be abnormally reduced due to the nature of morphographic Kanji. Thus, oral reading of both Kanji nonhomophonic nonwords and Kanji pseudohomophones should have deteriorated.

In conclusion, the Japanese version of the triangle model could explain SO's dyslexic pattern through the rationale that severe semantic impairment leads to a severe form of surface dyslexia.

Taking into account the above considerations, **the answer to research question 3** is **"No"** for the Japanese version of the DRC model, **but "Yes"** for the Japanese version of the triangle model.

7.9. The contribution of Study 2 to acquired dyslexia research

Firstly, Study 2 revealed a severe form of Japanese surface dyslexia by using psycholinguistically well-manipulated reading stimuli and a typical surface dyslexic pattern demonstrated by HW as a control data.

Secondly, Study 2 proposed a new method of analysis for detecting a consistency effect on Kanji word reading in severe cases of surface dyslexia.

Thirdly, Study 2 showed that the semantic impairment hypothesis could apply to the severe surface dyslexia pattern.

Fourthly, Study 2 clarified different interpretations of a severe form of surface dyslexia, using the Japanese versions of the DRC model and the triangle model.

Chapter 8

Study 3: A Case Study of ME

This chapter presents Study 3 which is a case study of ME who was suffering from a visuo-constructive deficit and right spatial neglect, as well as aphasia (see case report about ME in Chapter 5). ME also showed phonological impairment, for which YT's performance in Study 1 is used as control data. Study 3 focused on i) exploring the influence of a visuo-spatial deficit on phonological dyslexic performance in Japanese; and ii) examining whether the Japanese versions of the DRC model and the triangle model can explain impaired oral reading of Kana strings coupled with preserved oral reading of Kanji strings.

8.1. The research questions of Study 3 and the methodology used to explore them

Study 3 sets up the following three research questions which correspond to the three research questions of this thesis as explained in Chapter 4. In each section both the research questions of Study 3 and the methodology are shown.

8.1.1. Research question 1 of Study 3 and the methodology used to explore it

<u>Research question 1</u>

"What is Japanese phonological dyslexia with a visuo-spatial deficit like?”

Based on YT's demonstration, in Study 1, of co-occurrence of phonological impairment and deep/phonological dyslexia, one can predict that a patient who has phonological impairment would show deep/phonological dyslexia. The question is whether a patient who has phonological impairment coupled with a visuo-spatial cognitive deficit would show the modified oral reading pattern of deep/phonological dyslexia. Thus, ME's semantic and phonological function was evaluated, and compared to YT's performance as control data. Then, the oral reading experiments of i) Kana/Kanji nonwords, and ii) the two character Kanji words manipulated by consistency were conducted in order to capture the basic characteristics of ME's dyslexic pattern. Furthermore, the oral reading experiments of iii) Kana/Kanji words manipulated by concreteness/imageability, and iv) Kana/Kanji pseudohomophones were administrated in order to clarify ME's dyslexic pattern.

Since ME had a visuo-spatial cognitive deficit one could expect that word-length would affect his oral reading performance. Thus, ME's results of oral reading experiments were re-analysed in terms of word-length, and the new experiments for examining word-length effect were administered.

Through these investigations, the characteristics of ME's dyslexic pattern is revealed.

8.1.2. Research question 2 of Study 3 and the methodology used to explore it

Research question 2

"Is Japanese phonological dyslexia with a visuo-spatial deficit a Kana script-specific reading disorder?"

A classical deep dyslexia case, TO (Hayashi et al., 1985), with a suspected right homonymous hemianopia, showed superiority of Kanji word reading over Kana word reading. Since the oral reading stimuli used for TO were single- or two-character Kanji words and three- to six-character Kana words, TO's dyslexic pattern might not reflect the script-type effect but the word-length effect instead.

That is, clarifying ME's dyslexic pattern in terms of the script type effect and word-length effect is crucial for verifying TO's dyslexic pattern. Therefore, this exploration is important in the discussion of the unsolved issue relating to whether the Japanese dyslexic pattern is script-dependent or script-independent.

So, ME's results of the oral reading experiments for research question 1 were re-analysed not only by word-length but also by using the framework of Kanji strings vs. Kana strings. The following comparisons of reading accuracy were made: i) between Kanji words and Kana words; ii) between the two types of Hiragana pseudohomophone: one is transcriptions from Kanji words, and the other is transcriptions from Katakana words; iii) between Kana pseudohomophones and Kanji pseudohomophones; and iv) between Kana nonhomophonic nonwords and Kanji nonhomophonic nonwords. In addition to these re-analyses using the Kanji vs. Kana framework, the new oral reading experiments, manipulated by word-length and script-type, are essential for addressing this issue. These investigations provide a comprehensive picture of the influence of visuo-spatial deficit on oral reading performance in a Japanese dyslexic patient.

8.1.3. Research question 3 of Study 3 and the methodology used to explore it

Research question 3

"Can the Japanese versions of the DRC model and the triangle model explain a variation of phonological dyslexia with a visual-deficit?"

The phonological impairment hypothesis predicts that phonological impairment leads to phonological/deep dyslexia, but it does not include a prediction about the dyslexic pattern of the patients who have a phonological impairment and also a visuo-spatial cognitive deficit. If ME's dyslexic pattern is different from Japanese deep dyslexia demonstrated by YT and recent phonological dyslexia cases (e.g. Kato et al., 2004) with only phonological impairment, but if the basic nature of ME's dyslexic pattern belongs to deep/phonological dyslexia, this supports the phonological impairment hypothesis.

Thus, ME's semantic/phonological function and his oral reading performance were compared to YT's results in Study 1. Then, it was intended to explain ME's dyslexic pattern by using the two models.

8.2. The organisation of the data presentation

The results of ME's performance in the experimental tasks are presented with YT's results in the order of: 1) the evaluation of semantic phonological function; 2) the oral reading experiments for capturing the basic characteristics of acquired dyslexia; 3) the oral reading experiments for examining the influence of semantic variables and lexicality; and 4) the re-analysis of the results of 2) and 3), and then the oral reading experiments for examining word-length effect. Finally, the results of cross-domain tasks are presented.

The results of the oral reading experiments were divided into the three parts. The first part presents the results of a) oral reading of Kanji/Kana nonhomophonic nonwords, and b) oral reading of two-character Kanji words manipulated by consistency. This section focuses on detecting the basic characteristics of ME's dyslexic pattern.

The second part presents the results of a) oral reading of Kanji/Kana words manipulated by concreteness/imageability, and b) oral reading of Kanji/Kana pseudohomophones. This section focuses on clarifying semantic variables effects on ME's dyslexic pattern.

The third part presents the re-analysis of the oral reading data in order to examine both the script-type effect and the word-length effect, and also the results of the new oral reading experiments manipulated/controlled by word-length and the script-type. This section focuses on examining the impacts of ME's visuo-spatial deficit and phonological impairment on his oral reading performance.

8.3. The evaluation of semantic and phonological function

8.3.1. The evaluation of semantic function

1) Semantic knowledge, word comprehension, and picture naming

Figure 82 shows ME’s performance in the Pyramid and Palm Tree Test and the Tiger and Lion Test with a presentation of YT’s profile.

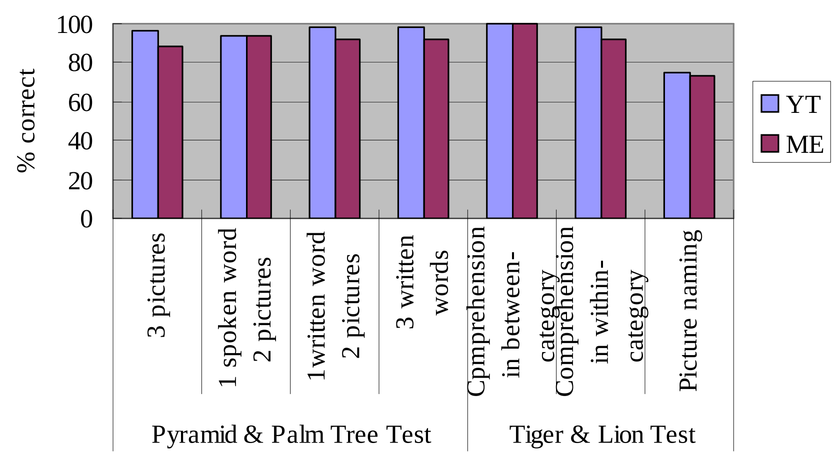


Fig.82. ME' and YT's performance in the Pyramid & Palm Tree Test and the Tiger & Lion Test.

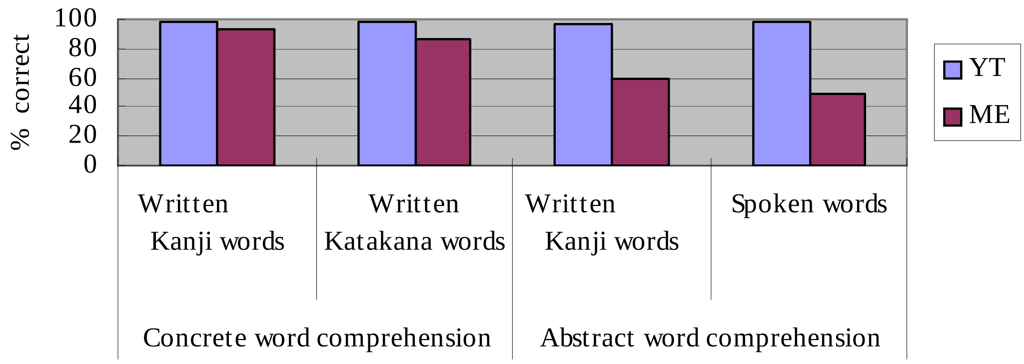
ME’s associative knowledge had not deteriorated and his spoken word comprehension was well preserved, with the same category (i.e. within-category) condition (55/60, 92%), which requires a more specific semantic activation for the target word. ME’s profile of semantic function showed a similar pattern to that of YT.

Although his accuracy was slightly lower than YT’s in many tasks, accuracy of picture naming for both patients was quite similar and showed moderate impairment (44/60, 73%).

2) Single-word comprehension and abstract knowledge

Figure 83 presents ME's performance in the Written Word Comprehension Test, which uses the same category condition, and the Abstract Word Recognition Test with a presentation of YT’s profile. ME’s written word comprehension of concrete Kanji words (39/42, 93%) and Katakana words (36/42, 86%) was preserved. However, his Katakana word comprehension was lower than YT’s (χ^2=11.01, $p < 0.001$). ME's abstract word comprehension for both the written form (Kanji words) and the spoken form was moderately impaired (27/45, 60%, 22/45, 49%, respectively).

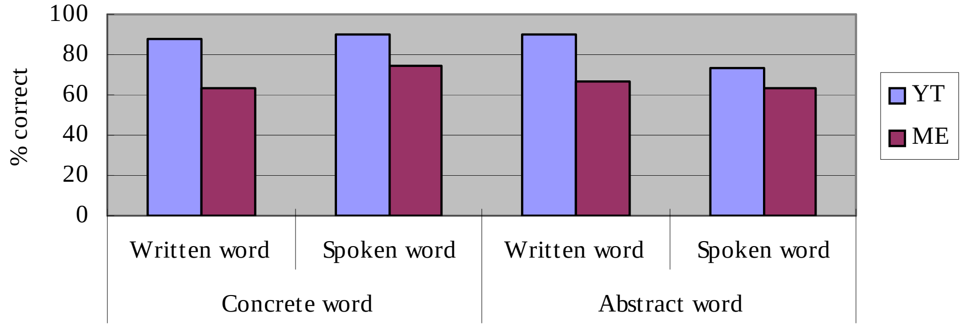
Fig. 83. ME's and YT's performance in the Written Word Comprehension Test and the Abstract Word Comprehension Test.



As shown in Fig. 84, ME's accuracy in the synonym judgment test was lower than YT’s in all conditions. ME did not show a concreteness effect on this judgment (concrete vs. abstract: 33/52, 63% vs. 35/52, 67% for written words; 39/52, 75% vs.

33/52, 63% for spoken words).

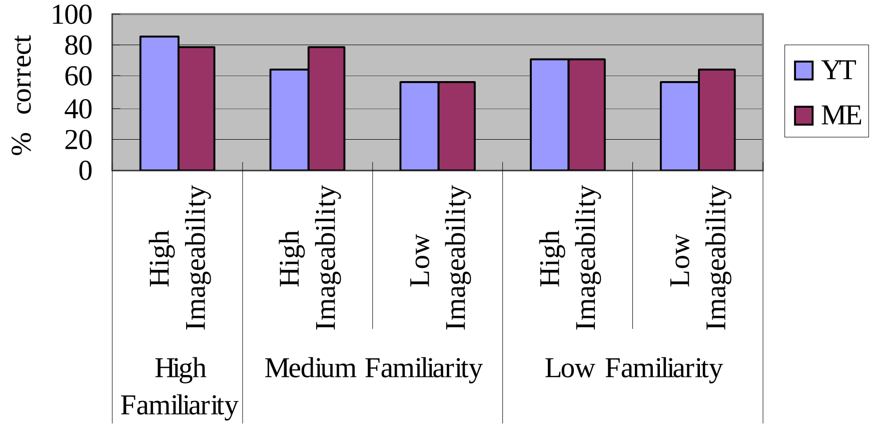
Fig. 84. ME's and YT's performance in the Single-Character Kanji Word Synonym Judgment Test.



3) 70 Picture Naming Test

Figure 85 presents ME's and YT's performance in the 70 picture naming test.

Fig. 85. ME's and YT's performance in the 70 Picture Naming Test.



Their accuracy was similar (ME: 70%, YT: 67%), and both cases did not show a statistically significant imageability effect, though there was a numerical difference by imageability.

4) Summary of ME's semantic function

ME showed preserved associative semantic knowledge and concrete word comprehension as did YT, but his abstract word comprehension was moderately impaired.

8.3.2. The evaluation of phonological function

1) Phonological discrimination and mora repetition

Table 47 shows the phonological discrimination and mora repetition performances of ME and YT. ME's phonological discrimination was slightly more impaired than YT's.

Table 47 ME's and YT's performance in phonological discrimination and mora repetetion

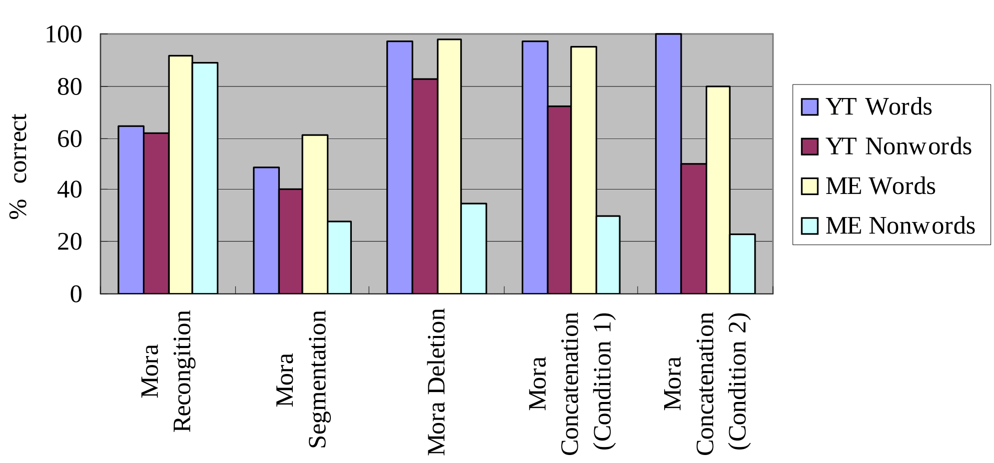
(% correct)

	Phoneme discrimination (N=52)	Single mora repetition (N=20)
ME	94	75
YT	100	100

2) Phonological manipulation

Figure 86 displays ME's performance in phonological manipulation tasks together with a presentation of YT's profile. ME had preserved mora recognition for both words (132/144, 92%) and nonwords (128/144, 89%) and this was superior to YT's performance (χ^2=32.89, $p < 0.0001$; χ^2=28.43, $p < 0.0001$, respectively). However, ME's mora segmentation was impaired in the same way as YT's, and showed a lexicality effect (words vs. nonwords: 44/72, 61% > 20/72, 28%; χ^2=16.20, $p < 0.001$). The lexicality effect was striking in ME's mora deletion (words vs. nonwords: 39/40, 98% > 14/40, 35%; χ^2=34.94, $p < 0.0001$) and mora concatenation (words vs. nonwords: 38/40, 95% > 12/40, 30% for condition 1, one mora per second presentation, χ^2=31.65, $p < 0.0001$; 32/40, 80% > 9/40, 23% for condition 2, one mora per second presentation followed by a continuous sequence of 2 morae, χ^2 =26.47, $p < 0.001$). This lexicality effect was more noticeable for ME than for YT.

Fig. 86. ME's and YT's performance in phonologicalmanipulation tasks.



3) Immediate repetition of words/nonwords, and delayed and serial repetition of words

Table 48 presents ME's performance in immediate repetition of 4-mora Katakana words and 4-mora nonwords, with a presentation of YT's profile.

Table 48 ME's and YT's performance in the Word and Nonword Repetition Test

(% correct)

	Words (N=120)	Nonwords (N=120)
ME	90.0	23.0
YT	97.5	65.0

While ME had preserved word repetition, his nonword repetition had deteriorated severely. This lexicality effect was more striking in ME than YT. In nonword repetition ME produced lexicalisation errors (8/92, 9%), though the proportion of these was lower for ME than for YT (9/42, 21%).

Figure 87 shows ME’s and YT’s performance in the Immediate and Delayed Repetition Test. ME’s immediate repetition was less accurate than that of YT - for low familiarity/low imageability words in particular (15/20, 75% < 20/20, 100%) - but ME’s and YT’s accuracy was similar in delayed repetition. The influence of imageability and frequency on ME's performance was not statistically significant. However, in the serial repetition shown in Fig.88 ME demonstrated an imageability effect, which was more remarkable than YT’s.

Fig. 87. ME's and YT's performance in the Immdeiate and Delayed Repetition Test.

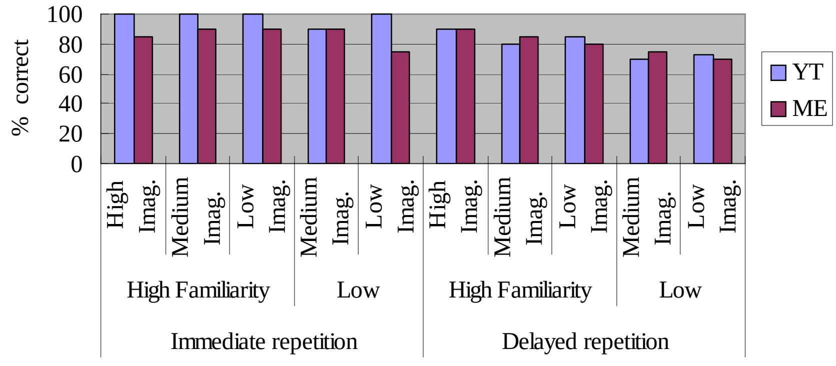
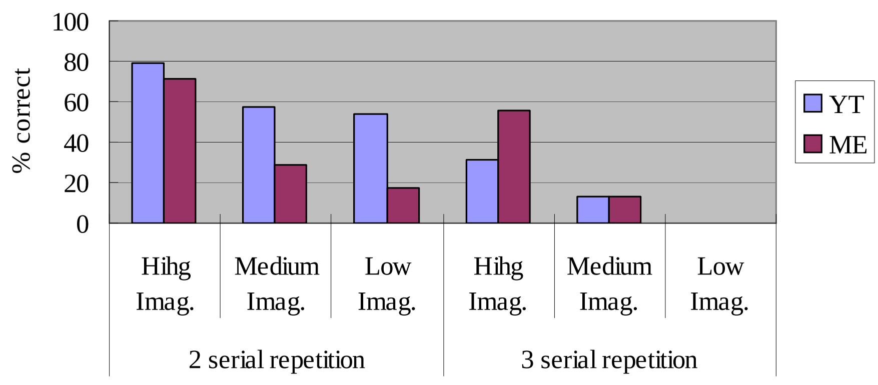


Fig. 88. ME's and YT's performance in the Serial Repetition Test.



4) Summary of ME's phonological function

ME showed a clear deficit in mora segmentation for both words and nonwords (61% and 28%). The lexicality effect on ME's phonological manipulation, such as mora deletion (98% > 35%) and mora concatenation (95% > 30%, and 80% > 23% in different condition), was more profound than in YT’s case. Imageability affected ME’s performance in serial repetition (i.e. a more demanding phonological task). That is, ME’s phonological function had deteriorated and was remarkably modulated by semantic variables.

8.3.3. Characteristics of ME's principal impairment

Though ME’s abstract word comprehension was moderately impaired, his semantic knowledge and single word comprehension was well preserved. In contrast, ME’s performance in the phonological tasks was impaired and was remarkably influenced by lexicality. This influence was more profound than in YT’s case. ME also showed an imageability effect on serial repetition. So, ME showed phonological impairment coupled with preserved semantic function

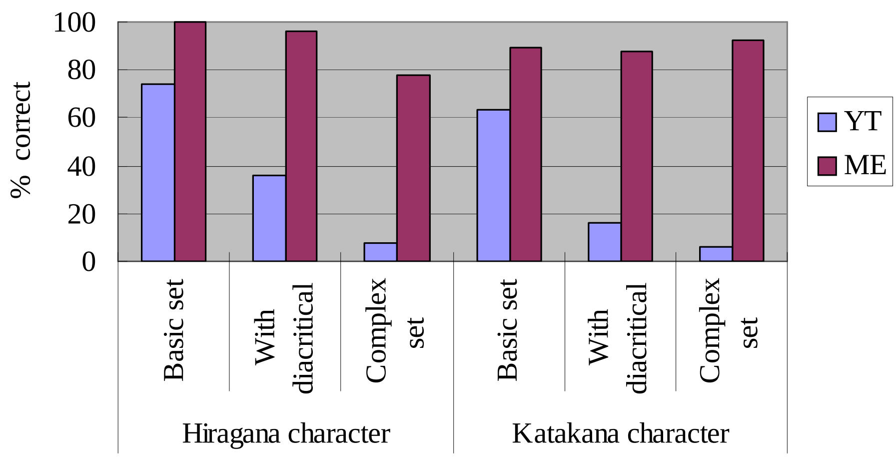
8.4. The oral reading experiments for capturing the basic characteristics of acquired dyslexia

8.4.1. Oral reading of nonwords

1) Single Kana characters

Figure 89 shows ME’s oral reading performance for single Kana characters, with the presentation of YT’s profiles. ME could read single Kana characters fairly well (full set: 98/107, 92% for Hiragana characters; 96/107, 90% for Katakana characters), which was radically different from YT's performance. ME's oral reading in a complex set for Hiragana characters was slightly deteriorated (28/36, 78%) , but this trend was not found for Katakana characters (33/36, 92%).

Fig. 89. ME's and YT's performance
in single Kana character reading.



2) Kana/Kanji nonwords

Figure 90 displays ME’s oral reading performance for nonhomophonic nonwords written in both Katakana and Kanji, with a presentation of YT’s profiles. With regard to Kanji nonhomophonic nonwords, which were devised by Fushimi et al.

(1999), the details of ME’s results are shown in Table 49.

Fig. 90. ME's and YT's performance in nonword reading.

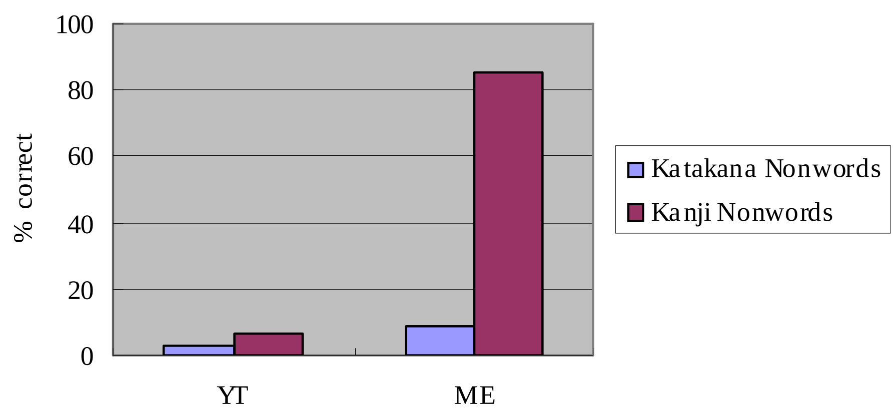


Table 49 ME's performance in two-character Kanji nonword reading

	High Frequency			High Frequency		
	Consistent	Biased	Ambiguous	Consistent	Biased	Ambiguous
Pronunciation correct in normal	0.92	0.93	0.88	0.92	0.83	0.85
Typical/correct in normal	0.99	0.81	0.41	1.00	0.78	0.39
ME's Correct response	0.90	0.85	0.80	0.90	0.80	0.85
ME's Typical/correct response	0.94	0.94	0.63	0.94	0.63	0.53

Normal Data: Fushimi et al. (1999).

ME's Kana nonword reading (8/120, 9%) had deteriorated severely, like YT’s, but his Kanji nonword reading (102/120, 85%) was well preserved with a similar accuracy level to normal control (average: 88%). That is, ME’s nonword reading was dissociated between Kana and Kanji script.

8.4.2. Oral reading of Kanji words manipulated by consistency

Table 50 and Table 51 show ME’s oral reading performance for the two lists of two-character Kanji words, which were devised for detecting a consistency effect by Patterson et al. (1995) and Fushimi et al. (1999). ME's oral reading of two-character

Kanji words was good, and he did not show any consistency effect on his reading performance in these tests.

Table 50 ME's accuracy in the 160 two-character Kanji Word Reading Test
(the simuli taken from devised by Patterson et al., 1995)
(% correct)

	Consistent	Inconsisntent-ON	Inconsistent-KUN	Exceptions
High frequency	100	85	85	95
Low frequency	95	95	80	85

Table 51 ME's accuracy in the 120 Two-Character Kanji Word Reading Test
(the simuli taken from devised by Fushimi et al., 1999)
(% correct)

	Consistent	Typical	Atypical
High Frequency	100	100	100
Low Frequency	95	100	95

8.4.3. The basic characteristics of ME's dyslexic pattern

ME showed oral reading difficulty of Kana nonwords, and did not show a consistency effect on Kanji word reading, and these findings were similar to those for YT. This suggests that ME did not demonstrate a surface dyslexic pattern. However, unlike YT, ME's oral reading of Kanji nonwords was preserved and his accuracy of Kanji word reading was radically better than that of YT. This suggests that ME did not demonstrate deep/phonological dyslexia for Kanji strings.

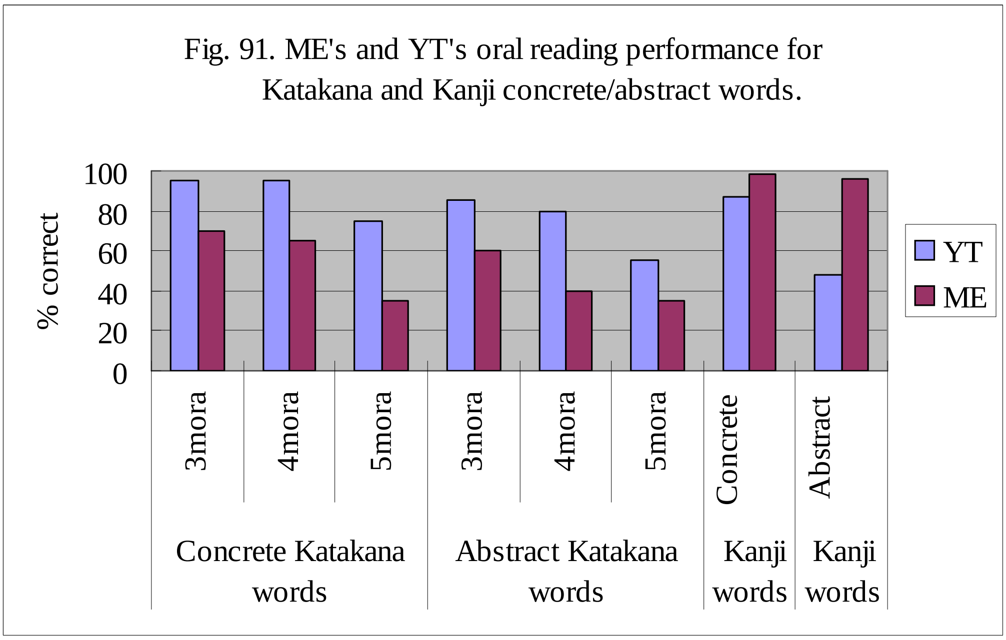
8.5. The oral reading experiments for clarifying ME's dyslexic pattern

Both deep dyslexia and phonological dyslexia show a lexicality effect, and some cases show a concreteness/imageability effect on word reading and superiority of pseudohomophone reading over nonhomophonic nonword reading. This section presents the results of oral reading experiments manipulated by semantic variables and pseudohomophones, in order to clarify ME's dyslexic pattern.

8.5.1. Oral reading of Kana/Kanji words manipulated in terms of concreteness/imageability

1) Kanji/Kana words manipulated in terms of concreteness

Figure 91 presents ME’s oral reading performance for concrete/abstract Katakana words and concrete/abstract Kanji words with a presentation of YT's performance.



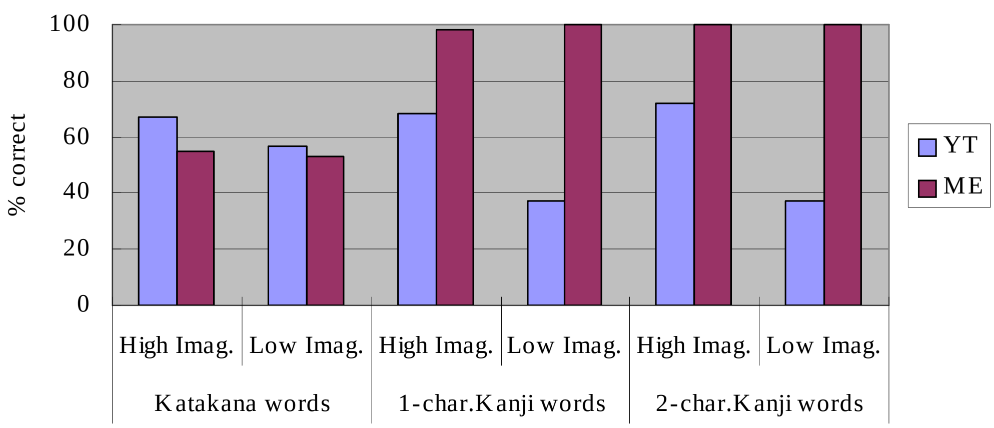
While ME’s Kanji word reading was extremely well preserved, ME’s Katakana word reading was impaired and modulated by word-length (i.e. number of mora) and concreteness (3 mora vs. 4 mora vs. 5 mora: 14/20, 70% > 13/20, 65% > 7/20, 35% for concrete words; 12/20, 60% > 8/20, 40% > 7/20, 35%). This dyslexic pattern was similar to YT's, but ME's oral reading accuracy was lower than YT and ME sometimes showed delayed responses with letter-by-letter reading.

A simultaneous multiple logistic regression analysis on correct Katakana word reading, with 5 independent variables (i.e. concreteness: concrete/abstract, word-length, familiarity, imageability, and word frequency) revealed significant effects of familiarity (Wald = 5.976, $p < 0.02$) and word-length (Wald = 5.078, $p < 0.03$).

2) Kanji/Kana words manipulated in terms of imageability

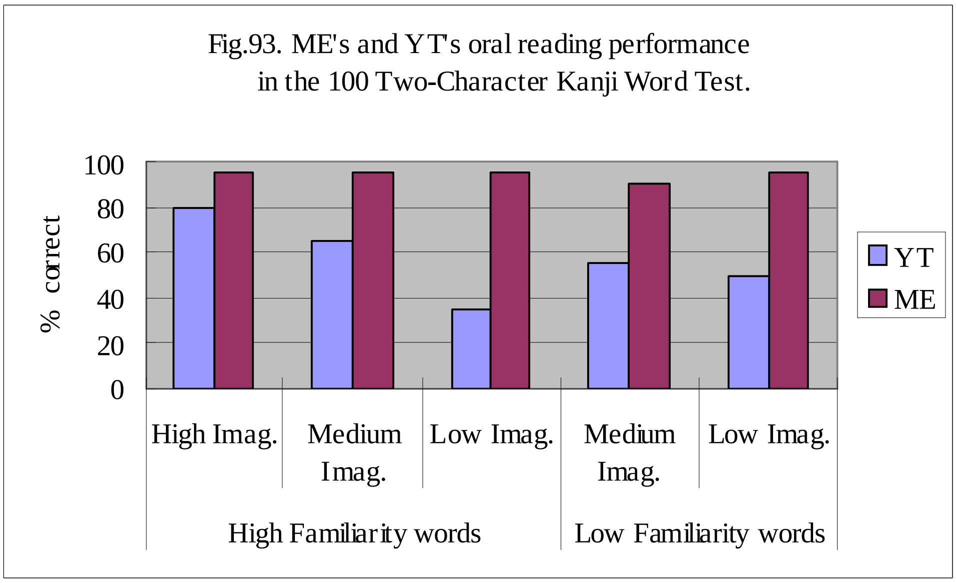
Figure 92 displays ME's performance in the Three Kinds of Word Reading Test with a presentation of YT's performance. Whereas ME showed moderate impairment of Katakana word reading in which there was no imageability effect (high imageability words: 33/60, 55%; low imageability words: 32/60, 53%), he showed well-preserved Kanji word reading. Letter-by-letter reading was sometimes observed in ME’s oral reading of Katakana words.

Fig. 92. ME's and YT's oral reading perforamance in the Three Kinds of Word Reading Test.



3) Oral reading of Kanji words manipulated by imageability and familiarity

As shown in Fig.93, ME showed preserved Kanji word reading, and it was not affected by imageability and familiarity.



8.5.2. Oral reading of Kana/Kanji pseudohomophones

1) Kana pseudohomophones

Figures 94, 95, and 96 show ME’s oral reading for Hiragana pseudohomophones transcribed from Katakana/Kanji words used for oral reading experiments in the previous section. ME showed considerable difficulty in reading aloud Hiragana pseudohomophones in which letter-by-letter reading was usually observed. Superiority of Katakana/Kanji word reading over Hiragana pseudohomophone reading was striking: Kanji concrete/abstract words vs. Hiragana pseudo-homophones (51/52, 98% > 30/52, 58% and 50/60, 96% > 19/52, 37%); Katakana concrete/abstract words vs. Hiragana pseudohomophones (34/60; 57% > 6/60, 10%, and 27/60, 45% > 8/60, 13%); and Kanji high/ low imageability words vs. Hiragana pseudohomophones (119/120, 99% > 80/120, 67% and 100% > 78/120, 65%).

Although concreteness of the base Kanji words affected ME's pseudohomophone reading (χ^2 =4.67, p < 0.04), imageability and familiarity of the base Katakana words did not affect his pseudohomophone reading. Rather, word-length appears to affect

Fig. 94. ME's and YT's oral reading performance for Hiragana pseudohomophones trasncribed from Katakana/Kanji words manipulated by concreteness.

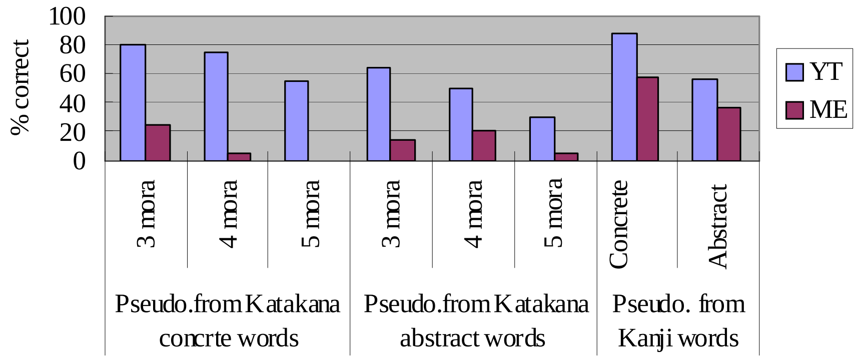


Fig. 95. ME's and YT's oral reading perforamnce for Hiragana pseudohomophones transcribed from the stimuli of the Three Kinds of Word Reading Test.

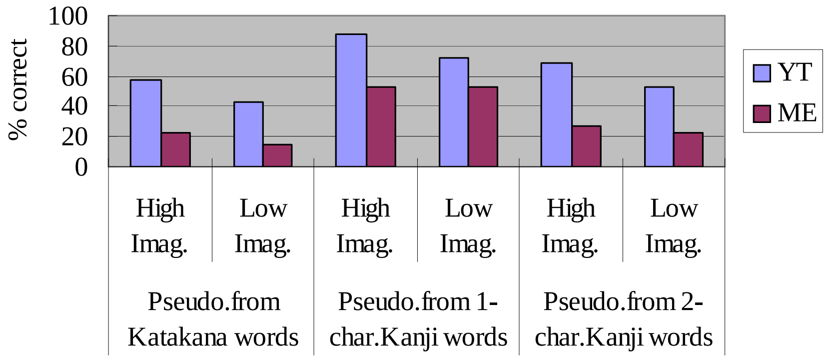
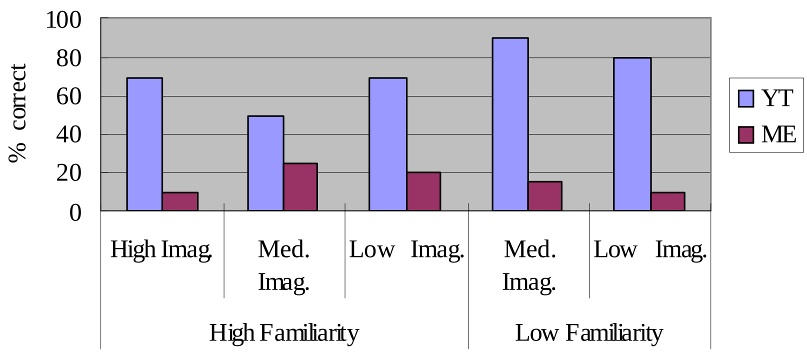


Fig. 96. ME's and YT's oral reading performance for Hiragana pseudohomophones transcribed from the stimuli of the 100 Two-Character Kanji Word Test.

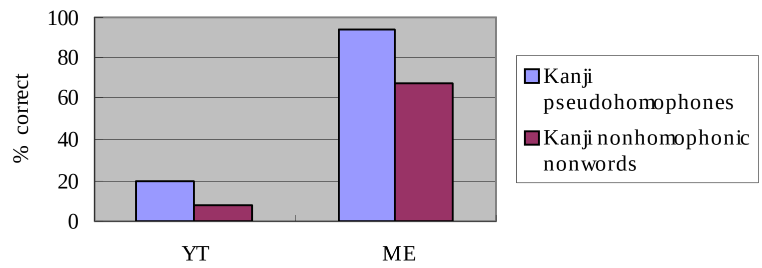


his oral reading performance for Kana pseudohomophones, as shown in Fig. 94. Indeed, ME's oral reading performance for pseudohomophones transcribed from single-Kanji words manipulated by imageability (64/120, 53%) was significantly better than that transcribed from both Katakana words and two-character Kanji words manipulated by imageability (30/120, 25% and 22/120, 18%, respectively). The average number of mora for these base words was 2.3 for single-character Kanji words, 3.2 for two-character Kanji words, and 3.9 for Katakana words.

2) Kanji pseudohomophones

As shown in Fig. 97, ME showed preserved oral reading of Kanji pseudohomophones (37/40, 93%) and Kanji nonhomophonic nonwords (27/40, 68%). There was a pseudohomophone effect (χ^2 =7.81, $p < 0.01$). Although YT showed a numerical difference of reading accuracy between Kanji pseudohomophones and Kanji nonhomophonic nonwords, ME's preserved Kanji nonword reading was radically different from the dyslexic pattern shown by YT.

Fig. 97. ME's and YT's oral reading performanc in the Kanji pseudohomophone and Kanji Nonhomophonic Nonword Reading Test.



8.5.3. ME's error pattern in oral reading of Katakana words and Hiragana pseudohomophones

Table 54-1 and Table 54-2 show ME's error pattern in oral reading of Katakana words and Hiragana pseudohomophones.

Table 52-1 The proportion of error type in ME's oral reading of Katakana words and Hiragana pseudohomophones transcribed from Katakana words

	Katakana wordas		Katakana words		Pseudo.of Katakana word s		Pseudo.of Katakana words	
	Concrete	Abstract	H. Imag.	L. Imag.	Concrete	Abstract	H. Imag.	L. Imag.
N. of errors	26	33	27	28	54	52	47	51
Pw	0.12	0.12	0.15	0.25	0.02	0.04	0.11	0.06
Pnw	0.08	0.09	0.07	0.07	0.09	0.19	0.06	0.08
Overlap	0.62	0.55	0.48	0.50	0.46	0.44	0.62	0.61
SV	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Uw	0.00	0.04	0.04	0.00	0.04	0.04	0.02	0.08
Unw	0.19	0.18	0.11	0.11	0.39	0.29	0.19	0.18
DK	0.00	0.00	0.15	0.04	0.00	0.00	0.00	0.00

Table 52-2 The proportion of error types in ME's oral reading of Hiragana pseudohomophones transcribed from Kanji words

	Types of base word for Hiragana pseudohomophone							
	1char. Kanji words		1char.Kanji words		2 char.Kanji words		2 char.Kanji words	
	Concrete	Abstract	H. Imag.	L. Imag.	H. Imag.	L. Imag.	H. Fam.	L.Fam.
N. of errors	22	33	28	28	44	46	49	35
Pw	0.59	0.44	0.32	0.25	0.11	0.20	0.10	0.14
Pnw	0.00	0.07	0.07	0.25	0.14	0.07	0.04	0.00
Overlap	0.23	0.16	0.25	0.32	0.36	0.43	0.59	0.60
SV	0.00	0.00	0.07	0.00	0.05	0.00	0.00	0.03
Uw	0.18	0.31	0.14	0.07	0.14	0.15	0.12	0.09
Unw	0.00	0.02	0.14	0.11	0.20	0.15	0.14	0.14

Pw:Phonologically similar word; Pnw:Phonologically similar nonword; SV: Semantically and visually related respons
Overlap: Overlapping the target mora; Uw: Unrelated word; Unw:Unrelated nonword
H:High; L:Low; Imag.:Imageability; Fam.:Familiarity.

The vast majority of ME's oral reading errors for Katakana words and Hiragana pseudohomophones were phonologically similar responses, which were categorised as follows:

a) phonologically similar words (Pw in the Table): words, which are only one mora different from the target words/the base words;

b) phonologically similar nonwords (Pnw): nonwords, which are only one mora different from the target words/the base words;

c) overlap: the response, which shares the mora of the target words/the base words, but where phonological similarity is less than in Pw or Pnw.

ME made overlap errors most frequently in oral reading of Katakana words (61/112, 54%), Hiragana pseudohomophones transcribed from Katakana words (108/204, 53%) and Hiragana pseudohomophones transcribed from two-character Kanji words (86/174, 49%). In oral reading of Hiragana pseudohomophones transcribed from single-character Kanji words, ME’s most frequent errors were phonologically similar words (40/111, 36%).

It is worth noting that ME made only one semantic error (ベスト /be-su-to/ *waistcoat*→ブラウス /bu-ra-u-su/ *blouse*) in oral reading of Katakana words (1/55, 2%).

8.5.4. Comments about ME's dyslexic pattern

ME's oral reading of Kana strings was strongly influenced by lexicality. For example, ME's reading accuracy of 3-mora/Katakana concrete words, Hiragana pseudohomophones transcribed from 3-mora/Katakana concrete words, and 4-mora nonhomophonic nonwords (in the previous section) was 70%, 25%, and 9% respectively. Only one semantic error was observed in ME's Katakana word reading. Concreteness/imageability did not affect ME's Katakana word reading. On the other hand, ME's oral reading of Kanji strings was well preserved, though a pseudohomophone effect (Kanji pseudohomophones vs. Kanji nonhomophonic nonwords: 93% > 68%) was detected, suggesting that phonological lexicality affected ME's oral reading of Kanji nonwords.

Therefore, ME's oral reading performance can be described as phonological dyslexia for Kana strings, coupled with preserved oral reading of Kanji strings. However, ME's oral reading of Kana strings was influenced by length of written stimuli, suggesting that preserved oral reading of Kanji strings might reflect a length effect. This is because word-length for oral reading stimuli of Kanji strings (two-character) is shorter than for Kana strings (from three- to five-character).

8.6. The analysis of the bi-scriptal influence and the length effect on ME's oral reading performance using the Kanji vs. Kana framework

This section presents the re-analysis of ME's oral reading performance in terms of script-type and word-length. In addition, this section presents ME's results in the new oral reading experiments, which manipulated or controlled word-length and used three types of words (i.e. Kanji words, Katakana words and Hiragana words).

8.6.1. The analysis of word reading using the Kanji vs. Kana word reading

1) A comparison of oral reading accuracy of Kanji and Kana word reading, by word-length

In ME's oral reading of Kanji words which were manipulated by concreteness/imageability word-length did not affect his oral reading accuracy (one-character Kanji words vs. two-character Kanji words: 118/120, 98% vs. 120/120, 100%). ME's oral reading accuracy of two-character Kanji words manipulated by consistency and frequency ranged from 80% to 100%. In contrast, word-length affected ME's oral reading of Kana words manipulated by concreteness/imageability. His oral reading accuracy for 5-mora (i.e. five-character) Katakana words (29/75, 39%) was lower than that for 3-mora Katakana words (47/78, 60%) and 4-mora Katakana words (50/87, 57%). These differences are statistically significant ($\chi^2 = 7.13$, $p < 0.01$, and $\chi^2 = 5.70$, $p < 0.02$, respectively).

8.6.2. The analysis of pseudohomophone reading using the Kanji vs. Kana framework

1) A comparison of Hiragana pseudohomophones transcribed from Kanji and Kana words, by character-length

Character-length affected ME's oral reading accuracy of Hiragana pseudohomophones. In oral reading of Hiragana pseudohomophones transcribed from Kanji words ME's accuracy for two-, three- and four-character Kana pseudohomophones was 56% (95/170), 32% (37/116), and 19% (11/58) respectively. In oral reading of Hiragana pseudohomophones transcribed form Katakana words, ME's accuracy for three-, four- and five-character Kana pseudohomophones was 18% (14/87), 17% (15/87), and 9% (7/75) respectively.

When oral reading accuracy was compared between three-character Hiragana pseudohomophones transcribed from Kanji and from Katakana words, ME's oral reading of Kana pseudohomophones transcribed from Kanji words was better than that from Katakana words (32% > 18%; $\chi^2=6.60$, $p < 0.02$). Although the reason for this difference in accuracy of 3-mora Kana pseudohomophones is not clear, it might be attributable to the different properties of the base words, and these pseudohomophone stimuli, in terms of 'script acceptability or script plausibility' (Amano & Kondo, 1999). This psycholinguistic variable refers to subjective agreement as a formal script for the target word. So, 'script acceptability or script plausibility' might be a specific variable for the Japanese language, in which Hiragana transcription is sometimes used in daily life when people do not know, or cannot remember constituent Kanji characters for Kanji words, leading to some words being written in both Kanji script and Hiragana script. That is, 'script acceptability or script plausibility' relates to orthographic familiarity or orthographic lexicality. Thus, script acceptability would be an important variable for ME's oral reading of Kana pseudohomophones.

Table 53 shows five properties (mean) of three kinds of base words for Hiragana pseudohomophones, and ‘script acceptability’ (mean) for Hiragana pseudohomophones, in which the base words were the oral reading stimuli in the Three Kinds of Word Reading Test.

Table 53 The five properties of the stimulus materials for the Three Kinds of Word Reading Test and script acceptability of their Hiragana pseudohomophones (mean)

	Katakana word		1-charac.Kanji word		2-charac.Kanji word	
	High Imag	Low Imag.	High Imag	Low Imag.	High Imag	Low Imag.
Imageability	6.44	4.71	6.70	5.50	6.62	4.80
Familiarity	6.03	6.00	6.07	5.98	6.07	6.07
Frequency	2.46	3.06	3.26	3.66	3.28	3.87
Mora	3.92	4.02	2.25	2.42	3.22	3.42
Script acceptability	4.98	4.96	4.87	4.90	4.95	4.94
Script acceptability of Hiragana pseudohomophones	1.24	1.25	3.45	3.27	2.82	2.58

Even though familiarity and imageability were controlled, frequency of Katakana words was lower than of Kanji words, and the number of mora for Katakana words was longer than for Kanji words. More importantly, the ‘script acceptability’ of Hiragana pseudohomophones was different, depending on the script-type of the base words. Hiragana pseudohomophones transcribed from Katakana words had the lowest ‘script acceptability’, whereas Hiragana pseudohomophones transcribed from single-character Kanji words had the highest ‘script acceptability’. So, it is plausible that higher frequency of the base Kanji words, and higher ‘script acceptability’ for Kana pseudohomophones transcribed from single-character Kanji words, led to different reading accuracy of Kana pseudohomophones depending on the script-type of the base words, even though word-length was matched.

2) A comparison of oral reading accuracy of Kana and Kanji pseudohomophones by character-length

Since Kanji pseudohomophones in this study consisted of 2 Kanji characters, two-character Kana pseudohomophones were used for a comparison of reading accuracy. ME's oral reading accuracy of Kanji pseudohomophones was 93%, whereas his reading accuracy of Kana pseudohomophones showed an average of 56% (95/170). So, oral reading of Kanji pseudohomophones was better than Kana pseudohomophones in ME, even though the length of reading stimuli was matched.

3) A comparison of oral reading accuracy of pseudohomophones and nonhomophonic nonwords by character-length

A comparison of ME's reading accuracy between four-character Kana pseudohomophones and four-character Kana nonhomophonic nonwords revealed a pseudohomophone effect (26/145, 18% > 11/120, 9%; $\chi^2 = 4.19$, $p < 0.05$). But, ME's oral reading accuracy of five-character Kana pseudohomophones (7/75, 9%) was the same as his oral reading of Kana nonhomophonic nonwords. That is, superiority of Kana pseudohomophone over Kana nonhomophonic nonwords was modulated by character-length. ME showed a pseudohomophone effect on Kanji strings (93% > 68%) which was mentioned in the previous section. However, one cannot examine character-length effect on the oral reading of Kanji strings because, in this study, both Kanji pseudohomophones and Kanji nonhomophonic nonwords consisted of 2 Kanji characters.

8.6.3. Oral reading experiments for examining word-length effect

1) Katakana words, Hiragana words and Kanji words manipulated by word-length

The Katakana, Hiragana and Kanji Word Reading Test (Fushimi, unpublished) was designed to examine the word-length effect on the three types of words: Katakana words, Hiragana words and Kanji words. As shown in Table 54, the stimuli were manipulated by word-length (i.e. number of characters) and controlled by familiarity. Each condition included 20 words and the total number of word stimuli was 360. Although word familiarity was controlled, word frequency of the three types of words was different: Kanji words had highest frequency, followed by Katakana words, and then Hiragana words.

Table54-1 Characteristics of the stimulus materials of the Katakana, Hiragana and Kanji Word Reading Test

	High Familiarity								
	Katakana word			Hiragana word			Kanji word		
No. of the stimuli	20	20	20	20	20	20	20	20	20
No. of character	3	4	5	3	4	5	1	2	3
Mora (*)	3.00	4.00	5.00	3.00	4.00	5.00	2.00	3.45	5.10
Familiarity (*)	6.36	6.33	6.24	6.32	6.29	5.99	6.37	6.29	6.17
Frequency (*)	2.81	2.71	2.54	1.95	1.75	1.17	3.78	3.27	2.80
Script acceptability (*)	4.90	4.94	4.98	4.40	4.33	4.30	4.95	4.94	4.94

	Low Familiarity								
	Katakana word			Hiragana word			Kanji word		
No. of the stimuli	20	20	20	20	20	20	20	20	20
No. of character	3	4	5	3	4	5	1	2	3
Mora (*)	3	4	5	3	4	5	2.05	3.70	5.15
Familiarity (*)	5.69	5.70	5.85	5.71	5.70	5.69	5.77	5.68	5.67
Frequency (*)	2.70	2.26	2.34	2.28	1.75	1.42	3.47	3.12	2.48
Script acceptability (*)	4.93	4.98	4.99	4.44	4.47	4.58	4.87	4.93	4.92

(*): mean

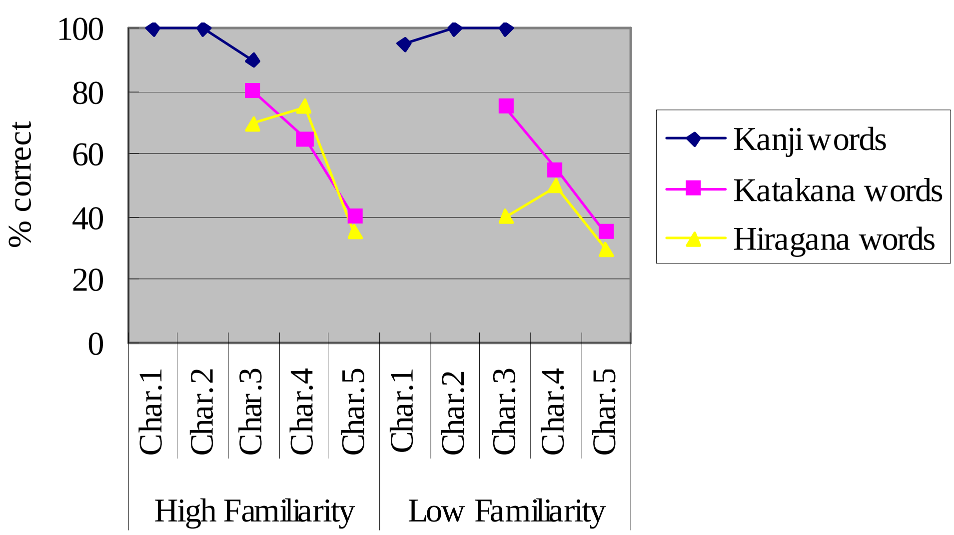
Table 54-2 Summary of the characteristics of the Katakana, Hiragana and Kanji Word Reading Test and examples of the stimuli

	High Familiarity			Low Familiarity		
	Katakana word	Hiragana word	Kanji word	Katakana word	Hiragana word	Kanji word
No. of character	4	4	2	4	4	2
Familiarity (*)	6.25	6.09	6.30	5.72	5.72	5.75
Frequency (*)	2.68	1.17	3.29	2.43	1.42	3.02
Script acceptability (*)	4.74	4.34	4.94	4.97	4.58	4.91
Examples Pronunciation Meaning	**ネクタイ** /ne-ku-ta-i/ *tie*	**ぬいぐるみ** /nu-i-gu-ru-mi/ *stuffed toy*	**真夜中** /ma-yo-na-ka/ *midnight*	**エレガンス** /e-re-ga-N-su/ *elegance*	**なごり** /na-go-ri/ *remains*	**水平線** /sui-hei-seN/ *horizonal line*

(*): mean

Figure 98 shows ME's results in this oral reading experiment. ME demonstrated a remarkable word-length effect on Katakana word reading (three-, four- and five-character words: 16/20, 80% > 13/20, 65% > 8/20, 40% for the high familiarity band; 15/20, 75% > 11/20, 55% > 7/20, 35% for the low familiarity band). ME's oral reading of Hiragana words showed a different pattern in which reading accuracy of 3-mora words was lower than for 4-mora words, but he showed a word-length effect between 4-mora words and 5-mora words (15/20, 75% > 7/20, 35% for high familiarity band; 10/20, 50% > 6/20, 30% for low familiarity band).

Fig. 98. ME's oral reading performance for the Katakana, Hiragana and Kanji Word Reading Test.



Note: Char. = character

In contrast, ME's Kanji word reading was not influenced by word-length and was well preserved (90-100%). It is worth noting that ME’s accuracy of oral reading for three-character Kanji words and three-character Katakana words was close at a high familiarity band (18/20, 90% and 16/20, 80%, respectively), indicating that word-length might be a factor in ME's superiority of Kanji word reading over Kana word reading. Word frequency might be another factor in this, because frequency of Kanji words is highest amongst the three types of words mentioned above (Kanji words, Hiragana words and Katakana words), as shown in Table 54-2.

2) 2-character Katakana words, Hiragana words, and Kanji words controlled by word-length, word familiarity and word frequency

Based on ME's results in the previous experiment, word-length, word familiarity and word frequency should be controlled in order to clarify ME's dyslexic pattern. The Two-Character Kana and Kanji Word Reading Test (Fushimi, unpublished) controlled these variables, and also controlled concreteness, orthographic neighbours and 'script acceptability'. As shown in Table 55, the stimuli consisted of the three sets of word lists.

Table 55 Characteristics of the stimuli materials of the Two-Character Kana and Kanji Word Reading Test and examples of the stimuli

	Set 1		Set2		Set3	
	Katakana word	Kanji word	Hiragana word	Kanji word	Katakana word	Kanji word
No. of the stimuli	20	20	20	20	20	20
No. of mora	2.00	3.15	2.00	2.00	2.00	2.00
Familiarity (mean)	6.38	6.35	5.68	5.70	5.92	5.84
Frequency (mean)	3.25	3.35	2.73	2.80	3.15	3.27
No. of phonological neighbors	37	27	50	42	26	33
No. of orthographic neighbors	12	114	69	71	14	93
Script acceptability (mean)	4.76	4.93	4.26	4.93	4.95	4.93
Examples Pronunciation Meaning	ダム /da-mu/ *dam*	手紙 /te-gami/ *letter*	ずれ /zu-re/ *gap*	居間 /i-ma/ *sitting room*	ベル /be-ru/ *bell*	画家 /ga-ka/ *painter*

Set1: Word list controlled by concreteness
Set 2: Word list controlled by the number of orthographic neighbors
Set3: Word list controlled by 'script acceptability'

Concreteness was controlled for Set 1, the number of orthographic neighbours was controlled for Set 2, and 'script acceptability' was controlled for Set 3. Each set comprised 20 words and the total number of stimuli was 120.

Table 56 shows ME's performance in these three sets. ME's oral reading accuracy for the three types of words was similar. However, he showed delayed reading responses for both Katakana and Hiragana words in which he read the target word more than 5 seconds after presentation of the stimuli, and showed letter-by-letter reading behaviour.

Table 56 ME's performance in the Two-Character Katakana and Kanji Word Reading Test

	Set 1		Set2		Set3	
	Katakana word	Kanji word	Hiragana word	Kanji word	Katakana word	Kanji word
Proportion of correct (%)	100	100	100	95	100	100
Proportion of delayed* response (%)	20	0	30	5	30	0

*Delayed response: over 5 seconds after stimlui presentation

8.6.4. Characteristics of phonological dyslexia pattern observed in ME

ME demonstrated a substantial difficulty in Katakana nonword reading (9%) and Hiragana pseudohomophone reading (9-56%), despite the fact that he could read single Kana characters fairly well (Hiragana characters: 92%; Katakana characters: 90%). ME's Kana word reading had also deteriorated (Katakana words: 35-80%; Hiragana words: 30-75%). The lexicality effect on ME's oral reading of Kana strings was strongly modulated by character length. ME's oral reading of five-character Kana words (30%) was similar to his oral reading of three-character Kana pseudohomophones (26%). Likewise, his oral reading of five-character Kana pseudohomophones (9%) was the same as his oral reading of four-character Kana nonhomophonic nonwords. Thus, ME's oral reading of Kana strings was governed by both lexicality and character length. He sometimes showed letter-by-letter reading in reading aloud Kana words, but always showed this 'sequential reading behaviour' in Kana nonword reading.

In contrast, ME demonstrated well-preserved oral reading of Kanji strings (Kanji words: 80-100%; Kanji pseudohomophones: 93%; Kanji nonhomophonic nonwords: 68%-85%). However, ME’s Kanji word reading superiority over Kana word reading disappeared when the stimuli were well controlled between Kanji words and Kana words in terms of word-length, word familiarity and word frequency. This seems to indicate that a different length of Kanji and Kana stimuli led to a discrepancy between oral reading of Kanji and Kana strings. Although the length of Kanji/Kana nonwords was matched, in a reading experiment, which was not completed due to his medical treatment, ME showed difficulty in Kana nonword reading. This indicates that ME would show a script-type effect on nonword reading. So, ME's better reading accuracy for Kanji strings than for Kana strings appears to be difficult to explain through a length effect only.

In sum, ME demonstrated a phonological dyslexic pattern in oral reading of Kana strings, in which his reading accuracy was strongly modulated by character-length and lexicality.

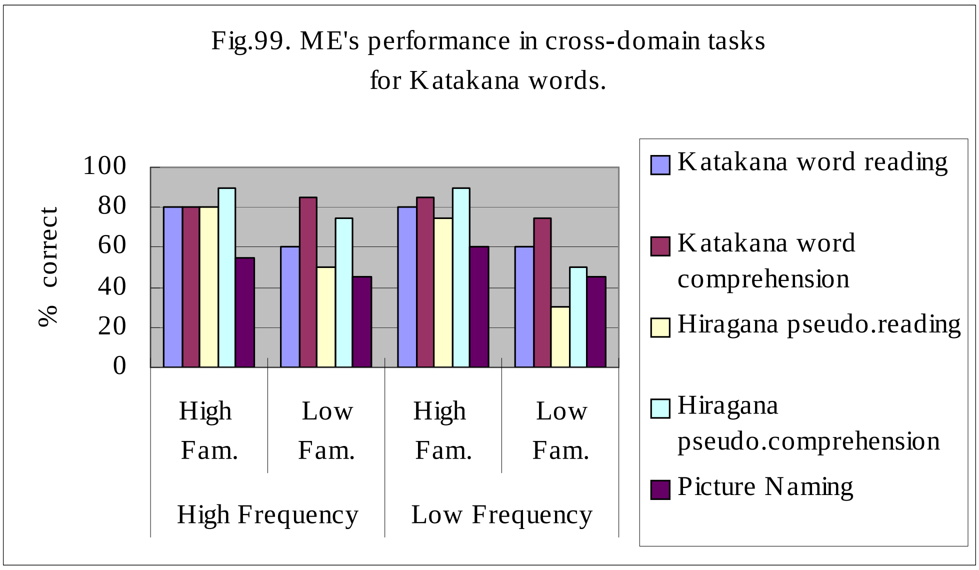
8.7. The impact of phonological impairment, coupled with visual deficit, on language performance

This section presents the results of ME’s cross-domain tasks - oral reading of words/pseudohomophones, written word/pseudohomophone comprehension, picture naming - and the cueing effect on both oral reading and picture naming. Since ME showed remarkable difficulty with reading aloud Kana pseudohomophones in the oral reading experiments, Kana pseudohomophones were also used as stimuli for the tasks of oral reading and written comprehension. This exploration would give us a further understanding of the impact of phonological impairment coupled with visual deficit on language performance.

8.7.1. Cross-domain effect

1) Oral reading, written word comprehension, and picture naming for Katakana words and their Hiragana pseudohomophones

Figure 99 shows ME's performance in word/pseudohomophone reading, written word/pseudohomophone comprehension, and picture naming in the 80 Katakana Word Test.

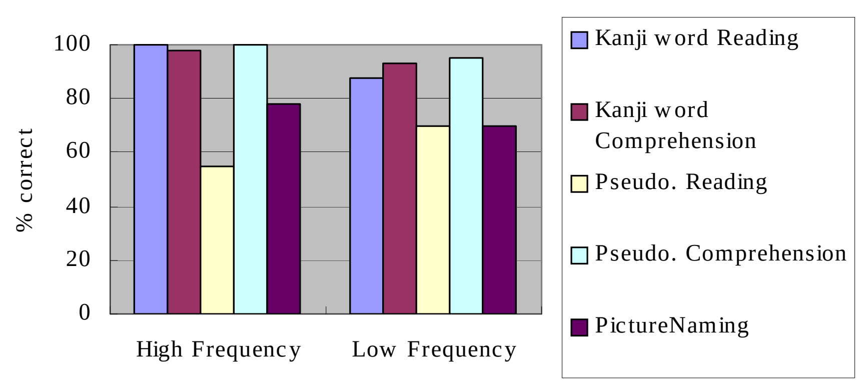


ME's cross-domain effect and lexicality effect were modulated by familiarity and frequency. In the high familiarity band oral reading and written comprehension for Katakana words and Hiragana pseudohomophones were relatively preserved, and picture naming was mildly impaired. In the high frequency/low familiarity band, ME showed a clear cross-domain effect (written comprehension for words > written comprehension for pseudohomophones > oral reading for words > oral reading for pseudohomophones > picture naming). In the low frequency/low familiarity band, ME's performance was more influenced by lexicality (written comprehension for words > oral reading for words > written comprehension for pseudohomophones > picture naming > oral reading for pseudohomophones). In this band ME's accuracy of Kana pseudohomophone reading/comprehension was strikingly impaired (6/20, 30% and 10/20, 50%, respectively).

2) Oral reading, written word comprehension and picture naming for single-character Kanji words and its Hiragana pseudohomophones

Figure 100 presents ME's performance in word/pseudohomophone reading, written word/pseudohomophone comprehension, and picture naming in the 80 Single-Character Kanji Word Test.

Fig. 100. ME's performance in cross-domain tasks for single-character Kanji words.

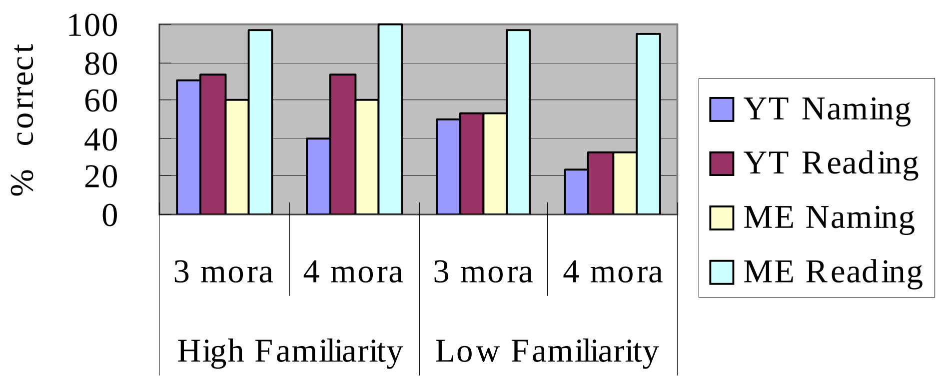


ME's oral reading accuracy of Kana pseudohomophones (50/80, 63%) was lower than that of picture naming (59/80, 74%), though this difference was not statistically significant. However, ME's Kanji word reading and written comprehension of Kanji words and Kana pseudohomophones was preserved.

3) Oral reading and picture naming for two-character Kanji words manipulated by the number of mora and familiarity

Figure 101 presents ME's performance in the Two-Character Kanji Word Reading and Picture Naming Test with the presentation of YT's profile.

Fig. 101. ME's and YT's performance in Kanji word reading and picture naming in the cross-domain test.



ME’s Kanji word reading was well preserved in all conditions. ME's picture naming was modulated by familiarity and word-length. In picture naming for high familiarity words ME did not show a word-length effect, but the accuracy of his picture naming for 4 mora words (10/30, 33%) was lower than that for 3-mora words (16/30, 53%) at the low familiarity band.

4) Error analysis

This section describes the error analysis of ME's performance in the three cross-domain tests: the 80 Katakana Word Test, the 80 Single-Character Kanji Word Test and the Two-Character Kanji Word Reading and Picture Naming Test.

In comprehension of written Katakana words the majority of ME's errors were semantic (10/15, 67%), whereas no response errors (9/19, 47%) and semantic errors (6/19, 32%) were his main error type in comprehension of Hiragana pseudohomophones transcribed from Katakana words. ME made very few errors in both comprehension of written Kanji words and Hiragana pseudohomophones transcribed from Kanji words, in which almost all errors were semantic (3/4 and 2/2, respectively).

Table 57 The proportion of error types in ME's oral reading of Katakana words and Hiragana pseudohomophones transcribed from Katakana/single-character Kanji words in the cross-doimain tasks

		N. of errors	Pw	Pnw	Overlap	Uw	Unw	NR
Katakana words	H Freq.	12	0.25	0.25	0.50	0.00	0.00	0.00
	L Freq.	12	0.17	0.08	0.50	0.25	0.00	0.00
Pseudo. from Katakana words	H Freq.	15	0.13	0.07	0.73	0.00	0.07	0.00
	L Freq.	19	0.00	0.05	0.53	0.26	0.16	0.00
Pseudo. from 1 char.Kanji words	H Freq.	17	0.47	0.12	0.24	0.18	0.00	0.00
	L Freq.	13	0.23	0.23	0.15	0.23	0.00	0.15

Pw:Phonologically similar word; Pnw:Phonologically similar nonword; NR: No Response
Overlap: Overlapping the target mora; Uw: Unrelated word; Unw:Unrelated nonword
H=High; L=Low; Freq.=Frequency; Pseudo.=Pseudohomophones

Table 57 shows ME's error pattern in oral reading, excluding Kanji word reading. His most frequent error in Katakana word reading and Hiragana pseudohomophones transcribed from Katakana words was overlap (12/24, 50% and 21/34, 62%, respectively) – i.e., where the mora of the target words/the base words are shared, but where phonological similarity is less than phonologically similar nonword (Pnw). In oral reading of Hiragana pseudohomophones transcribed from Kanji words ME's main error type was phonologically similar response to the target (Pw, Pnw) (14/30, 47%). ME made a few errors in Kanji word reading; in which phonological similar errors and semantic/visual errors were main error type (5/9 and 3/9, respectively). In picture naming the vast majority of ME's errors were semantic (95/118, 81%).

8.7.2. Phonological cueing effect on oral reading and picture naming

Table 58 describes the phonological cueing effect on ME's performance in the Two-Character Kanji Word Reading and Picture Naming Test. The results are presented in the relation to the first error types in ME's responses made without a cue.

Table 58 ME's performance in the Two-Character Kanji Word and Picture Naming Test

		Error type in the first response		
Reading aloud	correct	phon	no resp.	total or mean
No. of items	116	3	1	4
Proportion to total errors		0.75	0.25	1.00
No. of items with successful first cue		2	1	3
proportion to No. of items		0.67	1.00	0.75
No. of items with successful cues		2	1	3
proportion to No. of items		0.67	1.00	0.75
Mean No. of morae of stimulus words	3.50	3.33	4.00	3.50
Mean uniqueness point of stimulus words	3.37	2.67	3.00	3.35
Mean No. of morae in successful cue	-	0.67	1.00	0.75
Mean of uniqueness point minus successful cu	-	2.67	3.00	2.75

		Error type in the first response				
Picturte naming	correct	sem	cirs.	unrel.	no resp.	total or mean
No. of items	62	46	4	4	4	58
Proportion to total errors		0.79	0.07	0.07	0.07	1.00
No. of items with successful first cue	-	10	0	0	0	10
proportion to No. of items		0.22	0.00	0.00	0.00	0.17
No. of items with successful cues	-	31	4	1	2	38
proportion to No. of items		0.67	1.00	0.25	0.50	0.66
Mean No. of morae of stimulus words	3.45	3.54	3.75	3.50	3.50	3.50
Mean uniqueness point of stimulus words	3.37	3.41	3.50	3.00	3.25	3.38
Mean No. of morae in successful cue	-	2.28	2.50	3.25	3.00	2.41
Mean of uniqueness point minus successful cu	-	1.13	1.00	−0.25	0.25	0.97

Note. sem: semantic; circ: circumlocution; phon: phonological; unrel: unrelated; no resp.: no response.

ME made a few errors in Kanji word reading and most of them were facilitated by the initial mora cue (3/4, 75%). Meanwhile, the rate of facilitation for picture naming after the initial mora cue was only 17% (10/58), which was much lower than YT's rate (27/50, 54%). ME's dominant response after the initial cue was no response (38/48, 79%), and he also produced responses which were semantically related to the target (7/48, 15%), and also unrelated responses (3/48, 6%). The rate of facilitation of progressive phonological cueing for picture naming was 66% (38/59), which was lower than YT's rate (46/50, 92%).

These results suggest that ME's implicit phonological activation for picture naming was weaker than YT's.

8.7.3. Interpretations of the impact of phonological impairment, coupled with a visuo-spatial deficit, on language performance observed in ME

ME's performance in the cross-domain tasks confirmed that his oral reading of Kana pseudohomophones was modulated by the base word's familiarity and frequency. It was found that his accuracy of Hiragana pseudohomophone reading was lower than that of picture naming in the low familiarity/frequency band, though this difference was numerical. It appears that this phenomenon reflects the nature of ME's impairments. Usually, oral reading has a lower task-demand compared to picture naming which is derived from only Semantics. However, NE's accuracy of Hiragana pseudohomophones was similar to that of picture naming when the base Katakana words belong to high frequency band. ME's comprehension of Kana pseudohomophones was also modulated by the familiarity of the base words. These suggest that semantic activation from the base words affects ME's phonological activation for orthographically unfamiliar Kana strings.

8.8 Discussion

8.8.1. The conclusion of research question 1

Research question 1

"What is Japanese phonological dyslexia with a visuo-spatial deficit like?"

ME, with phonological impairment and also a visuo-spatial deficit, demonstrated the following dyslexic pattern.

i) Oral reading of Kana nonhomophonic nonwords was severely impaired, but oral reading of single Kana characters and Kanji nonhomophonic nonwords were well preserved.

ii) Oral reading of Kana strings showed a lexicality effect (i.e. words > pseudohomophones > nonhomophonic nonwords), but also character-length (i.e. number of characters) strongly affected oral reading of Kana strings.

iii) Oral reading of Kanji strings was well preserved and its accuracy was much higher than for oral reading of Kana strings. However, there was no difference in accuracy for oral reading of two-character Kanji words and two-character Kana words which were controlled by word-length, word frequency and word familiarity.

Thus, ME's oral reading of Kana strings was influenced by both lexicality and word-length. Meanwhile, ME's oral reading of Kanji words and Kanji pseudohomophones was preserved, and Kanji nonhomophonic nonword reading was quite good. This dyslexic pattern was distinct from Japanese phonological dyslexia, in which a lexicality effect can be observed in both Kana and Kanji strings, but there was no word length effect.

8.8.2. The conclusion of research question 2

Research question 2

"Is Japanese phonological dyslexia with a visuo-spatial deficit a Kana script-specific reading disorder?"

ME demonstrated script discrepancy in his oral reading performance. ME's dyslexic pattern can be described as phonological dyslexia for Kana strings, coupled with preserved oral reading of Kanji strings, so his dyslexic pattern appears to be a Kana script-specific reading disorder. However, ME's oral reading of two-character Kana and Kanji words, which were controlled by word familiarity and word frequency, was well preserved and there was no discrepancy between them. This suggests that ME's superiority of Kanji word reading over Kana word reading reflects a word-length effect. This suggests that the superiority of Kanji word reading over Kana word reading demonstrated by TO (Hayashi et al., 1985), a classical deep dyslexia case, who was tested using single- and two-character Kanji words and three- to six-character Kana words, does not show a script-type effect but, rather, reflects a word-length effect.

ME's oral reading of Kanji pseudohomophones was well preserved, and he could also read Kanji nonhomophonic nonwords fairly well. This was in radical contrast to his severely impaired oral reading of Kana pseudohomophones and Kana nonhomophonic nonwords. Although a reading experiment, which intended to compare 2-character Kanji/Kana nonwords, could not completed due to his medical treatment, ME showed difficulty to read Kana nonwords compared to Kanji nonwords. This suggests that a length effect cannot solely explain ME's preserved Kanji nonword reading.

Taking into account these considerations, **the answer to research question 2** is **partially "No", but partially "Yes"**. This is because the discrepancy in ME's oral reading performance between Kanji words and Kana words disappeared when word stimuli were controlled by word-length, word familiarity, and word frequency However, it appears to be difficult to explain his discrepancy between Kanji and Kana nonword reading by psycholinguistic variables' effects.

8.8.3. The conclusion of research question 3

Research question 3

"Can the Japanese versions of the DRC model and the triangle model explain a variation of phonological dyslexia with a visuo-spatial deficit?"

ME demonstrated a co-occurrence of phonological impairment and phonological dyslexia, though character-length (i.e. number of characters in the written stimuli) strongly affected his oral reading for Kana strings. Basically this fits the phonological impairment hypothesis. ME's visuo-spatial deficit would explain the word-length effect and letter-by-letter reading which were observed in his oral reading of Kana strings. Indeed, the co-occurrence of phonological dyslexia (or recovered deep dyslexia) and letter-by-letter reading has been reported in some papers (e.g. Buxbaum & Coslett, 1996). The question is why ME did not show a phonological dyslexic pattern for Kanji strings. Therefore, the main issue of this research question is whether the Japanese versions of the DRC model and the triangle model can explain ME's distinctive reading performance for Kanji and Kana strings.

<The interpretation using the Japanese version of the DRC model>

This model involves *Visual Feature Units*, which is directly related to visual processing. Although ME showed a visuo-spatial deficit, ME could recognise both Kanji and Kana script within a brief presentation (i.e. 1 second), which was described in ME's case report in Chapter 5 (see Table 6). So, Visual Feature Units seem to be preserved in ME and his visuo-spatial deficit appears to lead to inefficient computation of *Letter Units* in this model. An abnormally reduced activation of Letter Units, in which shorter strings can be recognised more rapidly than longer strings, led to a length effect and a compensatory letter-by-letter reading strategy. This is because reduced input would still produce a partial activation in subsequent levels of the cascaded processing system. This is a primary characteristic of ME's oral reading performance. Indeed, ME could read single Kana characters very well, but his oral reading of Kana strings had deteriorated.

If one uses the additional assumptions proposed by Studies 1 and 2 (i.e. the greater efficiency of the lexical-semantic route for Kanji words than for Kana words, and the two non-lexical routes for Kanji and Kana), ME's dyslexia pattern can be explained as follows:

i) the damage to the non-lexical route for Kana led to ME's marked impairment of Kana nonword reading;

ii) the preserved lexical routes led to ME's superiority of Kana word reading over Kana nonword reading;

iii) the interaction between the Orthographic Output Lexicon and the Phoneme System led to a Kana pseudohomophone effect (pseudohomophones > nonhomophonic nonwords);

iv) the interaction between Letter Units and the Orthographic Input Lexicon, and between the Orthographic Input Lexicon and the semantic system (which is more efficient for Kanji words than Kana words), led to preserved Kanji word reading despite ME's visuo-spatial deficit.

v) the intact non-lexical route for Kanji led to preserved Kanji nonword reading.

Therefore, ME's dyslexia pattern can be interpreted as i) the damage to the non-lexical route for Kana; and ii) inefficient computation of Letter Units due to ME's visuo-spatial deficit.

However, there are two problems with this interpretation. Firstly, this model cannot explain why the non-lexical route for Kana is selectively impaired in a patient with phonological impairment and a visuo-spatial deficit, and also why the non-lexical routes for both Kanji and Kana are impaired in the patients with only phonological impairment (i.e. patients with Japanese phonological dyslexia demonstrated by recent cases). Secondly, it might not be appropriate that ME's dyslexic pattern is treated as a variation of phonological dyslexia, because the different loci of impairment would suggest a different dyslexia type within the framework of the DRC model.

<The interpretation using the Japanese version of the triangle model>

Within the framework of the triangle model an abnormally reduced activation of Orthography, due to ME's visuo-spatial deficit, is the primary source of ME's dyslexia pattern. When visual input is reduced the interaction between Orthography and Phonology/Semantics (O⇔P and O⇔S) reinforces the orthographic activation. In this parallel processing, morphographic Kanji characters - which have a connection with Semantics - can receive semantic feedback, but phonographic Kana characters - which have no connection with Semantics - cannot have semantic support. This difference between Kanji and Kana characters would lead to a different degree of activation for Kanji characters and Kana characters in the domain of Orthography. In other words, morphographic Kanji advantage for recognition of written strings has a resistance against a visuo-spatial deficit and leads to sufficient orthographic activation of Kanji characters for oral reading of both words and nonwords. This is crucial to ME's distinctive reading performance for Kanji and Kana strings. Meanwhile, ME's phonological impairment leads to an increased reliance on semantic procedure which is more efficient for Kanji strings than Kana strings. Thus, these conditions of processing lead to preserved oral reading of Kanji strings within the interactive communication between Orthography, Semantics and Phonology in this model.

In the case of reading aloud of Kana strings, an abnormally reduced orthographic activation for Kana characters and phonological impairment would lead to inefficient computation for longer strings than for shorter strings (i.e. a word-length effect) and a compensatory letter-by-letter reading strategy for oral reading of Kana strings. Moreover, increased reliance on semantic procedure, due to phonological impairment, leads to efficient computation for written strings with higher lexicality and inefficient computation for written strings with lower lexicality (i.e. a lexicality effect). So, oral reading of Kana strings is governed by both lexicality and word-length.

Taking the above together, the different degree of orthographic activation for Kanji and Kana characters and phonological impairment would lead to a different oral reading pattern for Kanji and Kana strings. In other words, using this interactive model, ME's dyslexia pattern can be explained through a joint contribution of both a visuo-spatial deficit and phonological impairment.

In conclusion, **the answer to research question 3 is "No"** for the Japanese version of the DRC model, **but "Yes"** for the Japanese version of the triangle model. This is because the Japanese version of the DRC model needs additional assumptions in order to explain ME's dyslexia pattern. This model also cannot explain why phonological impairment with a visuo-spatial deficit leads to impairment of the non-lexical route for Kana. Thus, the Japanese version of the DRC model is not good enough to providing a coherent explanation of a variation of phonological dyslexia with a visuo-spatial deficit. On the other hand, the Japanese version of the triangle model can explain how a visuo-spatial deficit and phonological impairment together affect oral reading performance, and can interpret ME's dyslexia pattern without any additional assumptions.

8.9. The contribution of Study 3 to acquired dyslexia research

Firstly, Study 3 revealed that a variation of the Japanese phonological dyslexic pattern emerged from phonological impairment and a visuo-spatial deficit (i.e. a visuo-constructive deficit and right spatial neglect in ME) using psycholinguistically well-manipulated/controlled reading stimuli.

Secondly, Study 3 revealed that ME's superiority of Kanji word reading over Kana word reading could be mainly attributed to a word-length effect, verifying that the Kana script-specific dyslexic pattern reported by TO (Hayashi et al., 1985), a classical deep dyslexia case with a suspected right homonymous hemianopia, would not manifest script-type effect but reflect word-length effect.

Thirdly, Study 3 confirmed that the Japanese version of the DRC model needs the additional assumptions proposed by Studies 1 and 2 (different efficacy of the lexical semantic route and the different non-lexical route, respectively, depending on the script type,) in order to explain the dyslexia pattern demonstrated by a patient with both phonological impairment and a visuo-spatial deficit.

Chapter 9

General Discussion

This study was conducted with the aim of i) exploring acquired dyslexia patterns in the Japanese language, which has the 'bi-script' writing system, and ii) proposing a reading model, which can explain Japanese dyslexia patterns. Traditionally, Japanese dyslexia research has been conducted using a 'bi-script' paradigm (i.e. Kanji vs. Kana), and has supposed that reading processing for Kanji and Kana would be different, thus resulting in the view that Japanese dyslexia is script-dependent (e.g. Sasanuma, 1980a). The data for psycholinguistic variables effects on oral reading of both Kanji and Kana strings was not available until recent research, because classical case studies did not manipulate equally the property of Kanji and Kana reading stimuli. This makes it difficult to examine whether the reading models developed using English - an alphabetical 'mono-script' writing system (i.e. the DRC model and the triangle model) - can apply to Japanese acquired dyslexia. This study therefore posed three research questions: 1) do Japanese dyslexic patients show the same effects of psycholinguistic variables as observed in English dyslexic patients?; 2) do Japanese dyslexic patients show any script-dependent effects?; and 3) can the Japanese versions of the DRC model and the triangle model explain Japanese acquired dyslexia patterns?

This final chapter is organised in the following order:

i) A summary of results for the three research questions, and concluding points;

ii) The empirical implications for acquired dyslexia in Japanese and other orthographies;

iii) The theoretical implications for a theory of reading;

iv) Recommendation for future research.

9.1. Summary of the results and conclusions for the three research questions

9.1.1. Summary of the results and conclusion for Research Question 1

a. The Research Question 1

"Do Japanese dyslexic patients show the same effects of psycholinguistic variables as observed in English dyslexic patients?"

b. Summary of the results of examining psycholinguistic variables effects

Table 59-1 summarises the effects of psycholinguistic variables observed in the three types of acquired dyslexia in English, based on the literature review in Chapter 2. Table 59-2 summarises the effects of psycholinguistic variables observed in the four subjects.

YT and HW showed the same variables effects used for diagnosis of deep/phonological dyslexia and surface dyslexia in English, respectively. YT's oral reading performance for both Kanji and Kana strings was governed by the degree of lexicality (i.e. concrete/high imageability words > abstract/low imageability words > pseudohomophones > nonhomophonic nonwords). Lexicalisation errors were YT's main error type for oral reading of Kana/Kanji nonhomophonic nonwords (60% and 51%, respectively). However, YT's error pattern in word reading was different, depending on script-type (i.e. prominent occurrence of semantic errors in Kanji word reading vs. dominant occurrence of visual errors and very rare occurrence of semantic errors in Kana word reading) and she showed a greater concreteness/imageability effect on Kanji word reading compared to Kana word reading. Character-length (i.e. the number of constituent characters of the written stimulus) also affected YT's oral reading accuracy of Kana words and Kana pseudohomophones. Meanwhile, HW's oral reading performance was governed by character-sound consistency. HW made LARC errors with an inverse consistency effect.

Table 59-1 The psycholinguistic variables effects in English acquired dyslexia

	Deep dyslexia	Phonological dyslexia	Surface dyslexia
Impairment of nonword reading	＋	＋	－
Pseudohomophone effect	±	±	－
Concreteness/ Imageability effect	＋	±	－
Consistency effect	－	－	＋
Main error type of word reading	Semantic error (with co-occurrence of visual error)	Visual error	LARC error
Main error type of nonhomophonic nonword reading	lexicalisation	Visual error lexicalisation	－

Table 59-2 Summary of the four cases' dyslexic patterns in terms of psycholinguistic variables effects

	Script type	YT	HW	SO	ME
Impairment of nonword reading	Kanji	+	－	+	－
	Kana	+	－	－	+
Pseudohomophone effect	Kanji	+	－	－	－
	Kana	+	－	－	+
Concreteness/Imageability effect on word reading	Kanji	+	－	－	－
	Kana	+	－	－	－
Consistency effect	Kanji	－	+	+	－
Main error type of word reading	Kanji	semantic error	LARC error	LARC error	－
	Kana	visual error	－	－	visual error
Main error type of nonhomophonic nonword reading	Kanji	lexicalisation	－	unrelated error	－
	Kana	lexicalisation	－	－	visual error

+: impairment
－: lack of impairment

Like HW, SO showed defining characteristics of surface dyslexia (i.e. a consistency effect and LARC errors), but his oral reading accuracy for Kanji words was much lower than HW's. SO's oral reading of Kanji nonwords was impaired, unlike that of English surface dyslexia cases. SO's oral reading performance was also influenced by familiarity and concreteness.

ME demonstrated a lexicality effect and made visual (i.e. phonological) errors in reading aloud Kana strings, as in English phonological dyslexia. ME also showed the effect of character-length (i.e. number of characters). Although ME's oral reading performance for Kana strings was similar to YT's performance, the following are different from the findings relating to YT: i) a stronger effect of character-length; and ii) no lexicalisation errors in Kana nonword reading.

c. Conclusion of Research Question 1

The answer to Research Question 1 is basically 'Yes', but the manifestation of Japanese acquired dyslexia was not totally identical to English acquired dyslexia, due to the bi-scriptal influence.

9.1.2. Summary of the results and conclusion for Research Question 2

a. The Research Question 2:

" Do Japanese dyslexic patients show any script-dependent effects?"

b. Summary of the results of examining the Kanji vs. Kana discrepancy

Table 60 summarises the oral reading performance of the four cases in terms of the degree of impairment using the Kanji vs. Kana framework.

YT's oral reading accuracy did not show a discrepancy between Kanji and Kana word reading. She also did not show the superiority of Kanji word reading over Kana pseudohomophone reading which had been reported in classical deep dyslexia in Japanese (Sasanuma, 1980a, 1985, and 1986). The oral reading accuracy of Kana pseudohomophones was better than that of Kanji pseudohomophones (e.g.

3-character Kana pseudohomophones: 80% in transcriptions from concrete words, and 65% in transcriptions from abstract words; 2-character Kanji pseudohomophones: 20%). However, this difference seems to reflect the difference in orthographic lexicality between Kanji and Kana pseudohomophones. This is because Kana pseudohomophones are sometimes used in daily written Japanese, but Kanji pseudohomophones, consisting of morphographic Kanji, are seldom or never used.

Table 60 Summary of the four cases' dyslexic patterns in terms of the degree of impairment using the Kanji vs. Kana framework

Script type	Type of written strings	YT	HW	SO	ME
Kanji	Words	+	+	++	-
	Pseudohomophones	+++	-	++++	-
	Nonhomophonic nonwords	++++	-	++++	-
Kana	Words	+	-	-	- 〜 ++
	Pseudohomophones	+ 〜 ++	-	-	++ 〜 +++
	Nonhomophonic nonwords	++++	-	-	++++

+: impairment
- : lack of impairment

While HW's Kanji word reading was impaired, his oral reading of Kana strings was preserved (words: 90-100%; pseudohomophones: 80-100%; nonhomophonic nonwords: 93%). This discrepancy can be explained by a much higher pronunciation predictability for Kana than for Kanji. That is, preserved oral reading of Kana strings can be considered as a part of a consistency effect. Indeed, HW's oral reading accuracy of consistent Kanji words (89%) was similar to his average accuracy for Kana word reading (94%).

SO's oral reading of Kana strings was preserved (words: 80-100%; pseudohomophones: 77-98%; nonhomophonic nonwords: 93%), whereas he showed impairment of Kanji word reading and great difficulty in Kanji nonword reading. Since SO demonstrated a consistency effect on reading aloud the first constituent Kanji characters in two-character Kanji words, script discrepancy in SO's word reading can be interpreted as a part of a consistency effect. However, script discrepancy in SO's nonword reading cannot be explained by different character-sound consistency, because it was so difficult for him to read Kanji nonwords whose constituent Kanji character has a single pronunciation (i.e. consistent).

ME, who had a visuo-spatial deficit, showed well-preserved oral reading of Kanji strings, whereas his oral reading of Kana strings had deteriorated. ME's word reading was strongly influenced by character-length. When the word-length, word familiarity and word frequency of the reading stimuli were controlled, the script discrepancy in ME's word reading had disappeared. Thus, superiority of Kanji word reading over Kana word reading observed in ME was attributable to a length effect. However, it appears that the length effect cannot be the sole reason for the script discrepancy in ME's nonword reading. In a nonword reading experiment using length matched stimuli - which was not completed due to ME's medical treatment - ME showed difficulty in reading Kana nonwords but preserved Kanji nonword reading.

c. Conclusion of Research Question 2

The difference in reading accuracy between Kanji and Kana strings (i.e. words, pseudohomophones, and nonhomophonic nonwords) observed in YT and HW can be explained by the effect of psycholinguistic variables. However, the script dissociation in oral reading performance observed in SO and ME, cannot be explained completely by the effect of psycholinguistic variables. These results together suggest that Japanese acquired dyslexia is not totally independent of script type. Thus, the answer to Research Question 2 is "Yes".

9.1.3. Summary of the results and conclusion for Research Question 3

a. The Research Question 3

"Can the Japanese versions of the DRC model and the triangle model explain Japanese acquired dyslexia patterns?"

b. Summary of the results of experiments and interpretations

1) Relationships between dyslexia pattern and the principal impairment in the four cases

If one uses the diagnostic criteria of acquired dyslexia in English, the four subjects can be described as follows:

i) YT demonstrated deep dyslexia for Kanji, and phonological dyslexia for Kana;

ii) HW demonstrated surface dyslexia;

iii) SO showed a variation of surface dyslexia;

iv) ME showed phonological dyslexia for Kana.

Various kinds of phonological and semantic tasks revealed the nature of the principal impairment in the four cases. YT and ME (who was suffering from a visuo-constructive deficit and right spatial neglect) showed phonological impairment. Both YT and ME showed difficulty with mora segmentation (words vs. nonwords: 50% vs. 40%, and 61% vs. 28%, respectively) and mora concatenation with a prominent lexicality effect (words vs. nonwords: 100% vs. 50% and 80% vs. 23%, respectively). A lexicality effect on phonological manipulation tasks is consistent with the results of most phonological dyslexia cases (e.g. Patterson & Marcel, 1992;

Patterson, et al., 1996; Maekawa, et al., 1999; Mizuta, et al., 1992; Sasanuma, et al., 1996; Farah, et al., 1996; Maekawa, et al., 1999). Moreover, both YT and ME showed a lexicality effect on repetition (words vs. nonwords: 98% > 65%, and 90% > 23%, respectively). This is consistent with the results of deep dyslexia patients (Buchanan, et al., 1994; 1995; Patterson & Marcel, 1977; Southwood & Chatterjee, 1999). Meanwhile, HW and SO showed semantic impairment. Both HW and SO showed difficulty in understanding the meaning of single words in the within-category condition (e.g. the target word 'lion' is presented with tiger, horse, bear, giraffe, dog), compared to single words in the between-category condition (e.g. the target word 'lion' is presented with piano, glass, bus, apple, hands) (within-category vs. between-category: 100% vs. 78%, and 97% vs. 63%, respectively). HW's and SO's picture naming for low imageability words had deteriorated severally (28% and 7%, respectively), compared to YT's and ME's performance (57% and 61%, respectively), thus suggesting a remarkably reduced semantic activation for low imageability words.

Moreover, it might be worth noting that YT's lesion (the sub-cortex and the cortex of the left-superior-temporal lobe and the left-parietal lobe) and ME's lesion (the left-parieto-occipital lobe) are consistent with the lesion site (the left fronto-temporo-parietal region) in the past cases with deep dyslexia and phonological dyslexia (Lambon Ralph and Graham, 2000). YT's lesion also fits with the fact that the lesion for deep dyslexia cases is “typically larger, encompassing at least the perisylvian area and often extending to include much of the left hemisphere” (p.142, Lambon Ralph and Graham, 2000). ME's lesion included the occipital lobe and this is correspondent with his visuo-spatial deficit. Meanwhile, HW's lesion (the left-inferior-temporal lobe) and SO's lesion (the left-temporal lobe) are consistent with the lesion for patients with semantic dementia (atrophy of the anterior, inferior temporal lobes) who showed this co-occurrence (e.g. Hodges, et al., 1992; Snowden, et al., 1989).

Therefore, YT and ME demonstrated the co-occurrence of phonological impairment and deep/phonological dyslexia, and HW and SO demonstrated the co-occurrence of semantic impairment and surface dyslexia. These findings support both the phonological impairment hypotheses (Patterson & Lambon Ralph, 1999) and semantic impairment hypothesis (Patterson & Hodges, 1992; Graham et al., 1994; Patterson & Lambon Ralph, 1999), which are based on the triangle model.

2) The interpretations of the dyslexia patterns of the four cases, using the two cognitive models

<The interpretations, using the Japanese version of the DRC model>

Interpretation of YT's dyslexic pattern

YT's dyslexic pattern can be explained as a severe impairment of the non-lexical route and a mild impairment of the lexical routes, resulting in an increased dependency on the lexical routes. Since semantic activation is stronger for high rather than low concreteness/imageability words, a concreteness/imageability effect emerges from the processing of the lexical-semantic route. Since pseudohomophones, which share phonological representations with real words, can activate lexical items, a pseudohomophone effect (i.e. pseudohomophones > nonhomophonic nonwords) emerges from the processing of the lexical-nonsemantic route. The co-occurrence of semantic and visual errors in YT’s word reading can be interpreted as impairment of the Phoneme System, which connected with both the lexical routes and the non-lexical route.

The Japanese version of the DRC model, however, needed an additional assumption that the lexical-semantic route is more efficient for Kanji words than for Kana words in order to explain the bi-scriptal influence on YT's dyslexic pattern: i) a different error pattern, and ii) a different degree of concreteness/imageability effect in word reading.

Interpretation of HW’s dyslexia pattern

HW's surface dyslexia pattern can be interpreted as a selective impairment of the lexical routes. Since the Character-Sound Rule System governs the non-lexical route oral reading of written strings, which have consistent character-sound correspondence, is preserved, but oral reading of written strings with inconsistent character-sound correspondence is impaired. So, HW showed preserved oral reading of Kana strings and consistent Kanji words, but deteriorated oral reading of inconsistent Kanji words (inconsistent-atypical Kanji words in particular). LARC errors, which are incorrect pronunciation for the target words but appropriate pronunciation for orthographic neighbours, emerged from increased activation of orthographic neighbours by the damage to the lexical routes. Since LARC is not a fault in the pronunciation of nonwords, HW's Kanji nonword reading was preserved.

Interpretation of SO’s dyslexic pattern

A consistency effect on SO's oral reading of the first constituent Kanji characters in two-character Kanji words, an inverse consistency effect of LARC errors, and marked impairment of Kanji word reading, can be explained as severe impairment of the lexical route. However, SO's impairment of Kanji nonwords, whose constituent Kanji character had only one pronunciation, requires an additional assumption that there are the two non-lexical routes for Kanji and Kana. In this way, SO's oral reading performance can be explained as severe damage to the lexical routes and severe damage to the non-lexical route for Kanji. Taking this interpretation, the source of SO's oral reading disorder differs from surface dyslexia which emerged from a selective impairment of the lexical routes.

Interpretation of ME’s dyslexia pattern

Since ME's figure recognition is preserved, as evaluated by the same-different judgment task for Kanji/Kana characters with one-second presentation (see Table 6, ME's case report in Chapter 5, p.257), the *Visual Feature Unit* was intact for him. Instead, it is likely that ME's visuo-spatial deficit affected *Letter Units*. So, an abnormally reduced activation of orthographic representation in Letter Units would lead to greater difficulty of oral reading of longer strings than of shorter strings (i.e. length effect). Script discrepancy in ME's word reading could be explained by a length effect.

In order to interpret the striking difficulty with Kana nonword reading coupled with preserved Kanji nonword reading, this model needs the additional assumption that there are the two non-lexical routes for Kanji and Kana. Impairment of the non-lexical route for Kana and a severely reduced activation of Letter Units can explain ME’s difficulty with Kana nonword reading, with a compensatory letter-by-letter reading strategy. The preserved lexical routes can explain the lexicality effect on oral reading of Kana strings (Kana words > Kana pseudohomophones > Kana nonhomophonic nonwords).

Meanwhile, the greater efficiency of the lexical-semantic route for Kanji words than for Kana words - which is the assumption used for interpreting YT's dyslexia pattern, and the unimpaired non-lexical route for Kanji- which is based on the additional assumption described above, can explain the preserved oral reading of Kanji strings, despite ME's visuo-spatial deficit. This is because the interaction between the Orthographic Input Lexicon and the Semantic System, in which Kanji words have a considerable advantage over Kana words, would lead to a more efficient activation for Kanji strings at Letter Unit through the interaction between Orthographic Input Lexicon and Letter Unit.

<The interpretations, using the Japanese version of the triangle model>

Interpretation of YT's dyslexic pattern

YT’s phonological impairment led to an exaggerated reliance on semantic procedure (O→S→P computation) for oral reading, resulting in effects of semantic variables (concreteness/imageability, and lexicality) on her reading performance. Since the direct O→P computation for Kanji is less efficient than for Kana due to the varying degree of character-sound consistency, the connection weight between Orthography and Semantics became stronger for Kanji than for Kana, through learning. This resulted in the more efficient semantic procedure (O→S→P) for Kanji than for Kana. Both this advantage of the semantic procedure for Kanji words and increased reliance on the semantic procedure can, together, explain the prominent occurrence of semantic errors and a greater concreteness/ imageability effect for Kanji word reading. Meanwhile, the superiority of the direct computation over semantic procedure (O→S→P) for Kana remains despite of increased reliance on the semantic procedure, resulting in the frequent occurrence of visual (i.e. phonological) errors for Kana word reading.

Interpretation of HW’s dyslexia pattern

HW’s semantic impairment led to an exaggerated reliance on the direct procedure (O→P) for oral reading, resulting in a consistency effect on Kanji word reading. Since efficiency of the direct computation depends on character-sound consistency (or pronunciation predictability), HW's reading accuracy of inconsistent Kanji words became significantly lower than for consistent Kanji words, but his oral reading for transparent Kana strings and consistent Kanji words was preserved. An inverse consistency effect of the occurrence of LARC errors emerged from insufficient semantic support - this cannot inhibit appropriate pronunciation(s) for orthographic neighbours but can produce wrong pronunciation for the target words. HW's preserved Kanji nonword reading can be explained by a functional O→P computation.

<u>Interpretation of SO's dyslexia pattern</u>

SO's profound semantic impairment led to substantially reduced communication between Semantics and Phonology (S⇔P) and between Semantics and Orthography (S⇔O). This forced the deterioration of O→P computation, resulting in severe impairment of Kanji word reading and Kanji nonword reading. Meanwhile, increased reliance on the direct O→P computation, due to semantic impairment, led to a consistency effect on SO's oral reading of the first constituent Kanji character and an inverse consistency effect of LARC errors which are the same mechanisms as for HW's dyslexia pattern. Since an O→P computation for highly transparent Kana strings has great resistance to semantic impairment, SO's oral reading of Kana words/Kana nonwords was preserved.

<u>Interpretation of ME's dyslexia pattern</u>

ME's dyslexia pattern can be interpreted through a joint influence of both visuo-spatial deficit and phonological impairment. ME's visuo-spatial deficit led to an abnormally reduced activation of Orthography. Then, the interactions between Orthography and Semantics (O⇔S) reinforced the orthographic activation, in which a more efficient O⇔S interaction for morphographic Kanji than for phonographic

Kana resulted in higher orthographic activation for Kanji strings. ME's preserved oral reading of Kanji strings is explained by this advantage. Although there is the interaction between Orthography and Phonology, this communication is less efficient for reinforcing the orthographic activation because of the impairment of Phonology. The reduced orthographic activation for Kana strings and phonological impairment together led to a less efficient computation for longer strings than for shorter strings (i.e. length effect) with a compensatory letter-by-letter reading strategy. Degraded O→P computation and support from preserved Semantics (O→P ⇔ S, O→S→P) led to a lexicality effect (words > pseudohomophones > nonhomophonic nonwords). Since greatly reduced orthographic activation for Kana strings is a primary source of ME's dyslexia pattern lexicalisation errors cannot occur in Kana nonword reading. So, visual errors became the predominant error type of ME's oral reading of Kana strings.

Table 61 summarises the explanations for the four cases' dyslexia patterns, using the Japanese versions of the DRC model and the triangle model.

Table 61 Summary of the explanations for the four cases' acquired dyslexic patterns in Japanese using the two cognitive models

	YT	**HW**	**SO**	**ME**
The Japanese version of the DRC model	Lexical routes +	Lexical routes +	Lexical routes +++	Lexical routes −
	Non-lexical route +++	Non-lexical route −	Non-lexical route for Kanji +++ for Kana −	Non-lexical route* for Kanji − for Kana +++
*Additional assumption	The greater efficiency of the lexical-semantic route for Kanji (1)		The two non-lexical R. for Kanji and Kana (2)	(1) and (2)
The Japanese version of the triangle model	Phonological imp. ↓ Exaggerated reliance of O→S→P	Semantic imp. ↓ Increased reliance of O→P	Semantic imp. ↓ Increased reliance of O→P	Visuo-spatial deficit + Phonological imp. ↓ Exaggerated reliance of O→S→P

+: impairment imp.=impairment
−: lack of impairment R.=routes

c. Conclusion of Research Question 3

The Japanese version of the DRC model cannot explain YT's, SO's and ME's dyslexia patterns. This model needed additional assumptions, which related to the lexical-semantic route and the non-lexical route. Meanwhile, the Japanese version of the triangle model can explain the four cases' dyslexia patterns. Importantly, all four subjects demonstrated the co-occurrence between phonological/semantic impairment and deep/phonological and surface dyslexia, respectively. These results are consonant with the phonological/semantic impairment hypothesis, suggesting that the triangle model is reliable in terms predicting power. This is because the DRC model cannot forecast these associations.

9.1.4. Concluding points arising from the outcomes of this study

Table 62 summarises the findings of this study.

Table 62 Summary of the findings in this study

Subject	The primary impairment	The effect of psycholinguistic variables		The script-dependent characteristics	The needs of modification	
		Kanji	Kana		DRC model	Triangle model
YT	Phonological	Lexicality effect * Concreteness/ imageability effect	Lexicality effect * Concreteness/ imageability effect	Different error pattern in word reading A larger concreteness/ imageability effect	+	−
HW	Semantic	Consistency effect	−	−	−	−
SO	Semantic	Consistency effect	−	Script discrepancy in nonword reading (Kanji < Kana)	+	−
ME	Phonological + Visual	−	Lexicality effect * Length-effect	Script discrepancy in nonword reading (Kanji > Kana)	+	−

* Lexicality effect : words > pseudohomophones > nonhomophonic nonwords

The study addressed the issue of whether acquired dyslexia patterns in Japanese - which has the distinctive bi-scripts (morphographic Kanji and phonographic Kana) - are dependent on script-type. For this, the study analysed the reading performance of the four Japanese dyslexia patients by distinguishing between the psycholinguistic variables effect and the script-type effect on both Kanji and Kana strings. YT first demonstrated a 'script-independent' deep dyslexia pattern which is governed by lexicality (concrete/high imageability words > abstract/ low imageability words > pseudohomophones > nonhomophonic nonwords). HW also manifested 'script-independent' surface dyslexia which is governed by consistency (consistent words > inconsistent-typical words > inconsistent-atypical words), as recent case studies have shown. Although all four cases showed the same effects of psycholinguistic variables as observed in English acquired dyslexia three of them also showed script-dependent characteristics which cannot be explained by psycholinguistic variables. That is, Japanese acquired dyslexia patterns are not dependent on script-type, and are also not totally independent of script-type. The double dissociation between Kanji and Kana demonstrated by SO and ME (see. Table 60) is a clear manifestation of bi-scriptal influence. SO showed a surface dyslexia pattern in Kanji word reading, with substantial difficulty in Kanji nonword reading. ME, who had a visuo-spatial deficit, showed a phonological dyslexia pattern with a length-effect only for oral reading of Kana strings. YT demonstrated a striking script-dependent error pattern in her word reading and a greater concreteness/imageability effect on Kanji word reading than Kana word reading. If one uses the diagnostic criteria for English acquired dyslexia, YT's dyslexic pattern can be described as deep dyslexia for Kanji and phonological dyslexia for Kana.

Another key issue of this study was whether the two reading models (the DRC model and the triangle model), which have been developed using English orthography, could explain Japanese acquired dyslexia patterns. This thesis proposed a possible Japanese version of the DRC model (Fig. 20), which was a direct translation of the DRC model (Coltheart et al., 2001) without assuming the bi-scriptal influence on processing. In order to explain YT's, SO's and ME's dyslexia patterns, this model needed additional assumptions: i) the different efficiency of the lexical-semantic route depending on script type, and ii) the two non-lexical routes for Kanji and Kana. The dominant occurrence of semantic errors in Kanji word reading but very much more rare occurrence of semantic errors in Kana word reading required the assumption of a more efficient computation of the lexical semantic route for Kanji than for Kana. ME's preserved Kanji word reading also needed this assumption. The double dissociation between Kanji and Kana nonword reading in SO and ME required two independent non-lexical routes, depending on script type. The former assumption is inevitable, because the character level's connection between morphographic Kanji and semantics cannot be encoded in the functional architecture of the DRC model. The latter assumption means that morphographic Kanji characters and phonographic Kana characters have different rules for the translation of a sub-word level. This seems to be reasonable, because it is likely that orthographic sub-word constituents for Kanji and Kana are distinctive.

In the case of the Japanese version of the triangle model (Fushimi et al., 2000), which is also a direct application of the triangle model (Plaut et al., 1996), a distinguishable influence of morphographic Kanji and phonographic Kana on reading processing can be encoded as different weighted connections in bi-directional interactions between Orthography, Phonology and Semantics. Therefore, this model did not need to be modified in order to explain the script-dependent characteristics demonstrated by the three subjects of this study. The direct computation (O→P) is more efficient for Kana (i.e. a strong weighted connection) than for Kanji due to the transparent relationship between a Kana character and its phonological counterpart. The semantic procedure (O→S→P) for Kanji would continue to be learned due to the less efficient computation of the phonological procedure (O→P) which resulted in a more efficient computation of the semantic procedure for Kanji than for Kana. However, the explicit assumption about the processing efficiency (i.e. that the O→S→P computation for Kanji is more efficient, and the direct O→P computation for Kana is highly efficient) might be useful for interpreting Japanese acquired dyslexia patterns more easily.

A topical issue of reading models is whether the DRC model (Coltheart et al., 2001) is more reliable than the triangle model (Plaut et al, 1996; Harm & Seidenberg, 2004), and vice versa. As part of theoretical motivation, this study verified the phonological impairment hypothesis (Patterson and Lambon Ralph, 1999), which postulates the causal relationship between phonological impairment and deep/phonological dyslexia, and the semantic impairment hypothesis (Patterson & Hodges, 1992; Graham et al., 1994; Patterson and Lambon Ralph, 1999) which postulates the causal relationship between semantic impairment and surface dyslexia.

YT and ME demonstrated the co-occurrence of phonological impairment and deep/phonological dyslexia. Theoretically, findings in relation to YT are very important, because the phonological impairment hypothesis was first extended to deep dyslexia in acquired dyslexia research. Meanwhile, HW and SO showed the co-occurrence between semantic impairment and surface dyslexia, and also demonstrated that the degree of semantic impairment affects the manifestation of surface dyslexia patterns in Japanese. Since the causal relationship between semantic impairment and surface dyslexia has mainly been reported in patients with semantic dementia (e.g. Hodges et al., 1992), the findings in relation to HW and SO, whose etiology was herpes simplex virus encephalitis, are meaningful. This suggests that the semantic impairment hypothesis is applicable to different etiologies.

These results, which were consistent with the phonological/semantic impairment hypothesis, support the triangle model's view of reading processing, because the DRC model cannot predict these associations.

9.2. The empirical implications for acquired dyslexia in Japanese and other orthographies

9.2.1. The empirical implications for Japanese acquired dyslexia

One of the crucial outcomes of this study was that Japanese dyslexia patients showed the same effects of psycholinguistic variables for categorising English dyslexia types (i.e. deep/phonological dyslexia, and surface dyslexia), and also manifested script-dependent characteristics in their reading disorder. This section presents the predictions about the 'Japanese version' of deep/phonological dyslexia, surface dyslexia, and the possible dyslexia patterns in the patients with visuo-spatial deficits.

1) Deep/phonological dyslexia pattern in Japanese

The co-occurrence between phonological impairment and deep dyslexia, demonstrated by YT and the co-occurrence of phonological impairment and phonological dyslexia, observed by both classical case studies and recent case studies of phonological dyslexia (see. 3.3.1. -2 and 3.3.2. -2 in this thesis) are consistent with the phonological impairment hypothesis (Patterson & Lambon Ralph, 1999). These facts suggest that deep dyslexia and phonological dyslexia share the common cause. In other words, they are not independent dyslexia types, and deep dyslexia can be considered as a severe form of phonological dyslexia. The following comparison between deep and phonological dyslexia supports this notion.

The performance showed by Case K (Kato, et al., 2004), who demonstrated 'script-independent' phonological dyslexia, is comparable with YT's performance. This is because Case K was evaluated with a similar experimental framework and using well manipulated reading stimuli, including Fushimi et al. (1999)'s Kanji words/nonwords. In the phonological tasks, YT's performance was worse than Case K's performance (YT vs. Case K: mora recognition - 65% vs. 92%; mora segmentation - 50% vs. 96%; nonword repetition- 65% vs. 81%). In oral reading tasks, YT's accuracy was lower than Case K's (YT vs. Case K: Kanji words - 48% vs. 98%; Kana words - 71%, which is average accuracy of Kana words manipulated by concreteness/imageability, vs. 90%; Kana pseudohomophones: 64%, which is average accuracy of Hiragana pseudohomophones transcribed from Katakana/Kanji words, vs. 88%; Kanji nonwords - 7% vs. 45%; Kana nonwords - 3% vs. 57%; single Kana character - 43% vs. 96%). That is, YT's phonological impairment was more severe than Case K's and YT's reading performance was worse than Case K's. Although the two cases' reading accuracy was different their reading performance was governed by lexicality (i.e. words > pseudohomophones > nonhomophonic nonwords). Therefore, it is quite logical to conclude that there is a clear association between the degree of phonological impairment and the severity of reading performance, which is governed by lexicality. This is consistent with the prediction of the phonological impairment hypothesis. Indeed, the phonological ability of other phonological dyslexia cases (e.g. TY; Sasanuma et al., 1996; HN: Mori & Nakamura, 2003) was also better than YT's.

Based on the phonological impairment hypothesis, how can the dyslexic pattern in the patients who show more severe phonological impairment than YT's be predicted? Profound impairment of Phonology in the triangle model, which is the theoretical source of the phonological impairment hypothesis, would lead to a remarkable deterioration of the direct O→P computation and a considerable reliance on the semantic procedure (O→S→P) which is more efficient for Kanji than for Kana. These functional states would result in a marked impairment of reading aloud Kana strings but relatively preserved Kanji word reading. This is consonant with the dyslexia pattern reported by classical deep dyslexia (e.g. YH: Sasanuma, 1979, 1980a; SN: Sasanuma, 1980b, 1986). Although the phonological ability of classical deep dyslexia cases was not reported, their substantial difficulty with Kana nonword reading (YH- 0%; SN- 10%) indicates that they had severe phonological impairment. So, this dyslexia pattern can be treated as the most severe form of phonological dyslexia in Japanese.

If one uses the diagnostic criteria of English acquired dyslexia, recent cases of phonological dyslexia, YT's dyslexia pattern which was interpreted as a Japanese version of deep dyslexia in this study, and classical deep dyslexia are described as i) phonological dyslexia for Kana and Kanji, ii) phonological dyslexia for Kana and deep dyslexia for Kanji, and iii) marked reading impairment of Kana strings, in which the lexicality effect (words > nonwords) is not statistically significant, and deep dyslexia for Kanji, respectively. However, these three forms of reading disorder in Japanese can be accounted for as a variation of the same type of dyslexia, which was caused by the different degree of phonological impairment. Fig. 102 depicts this notion.

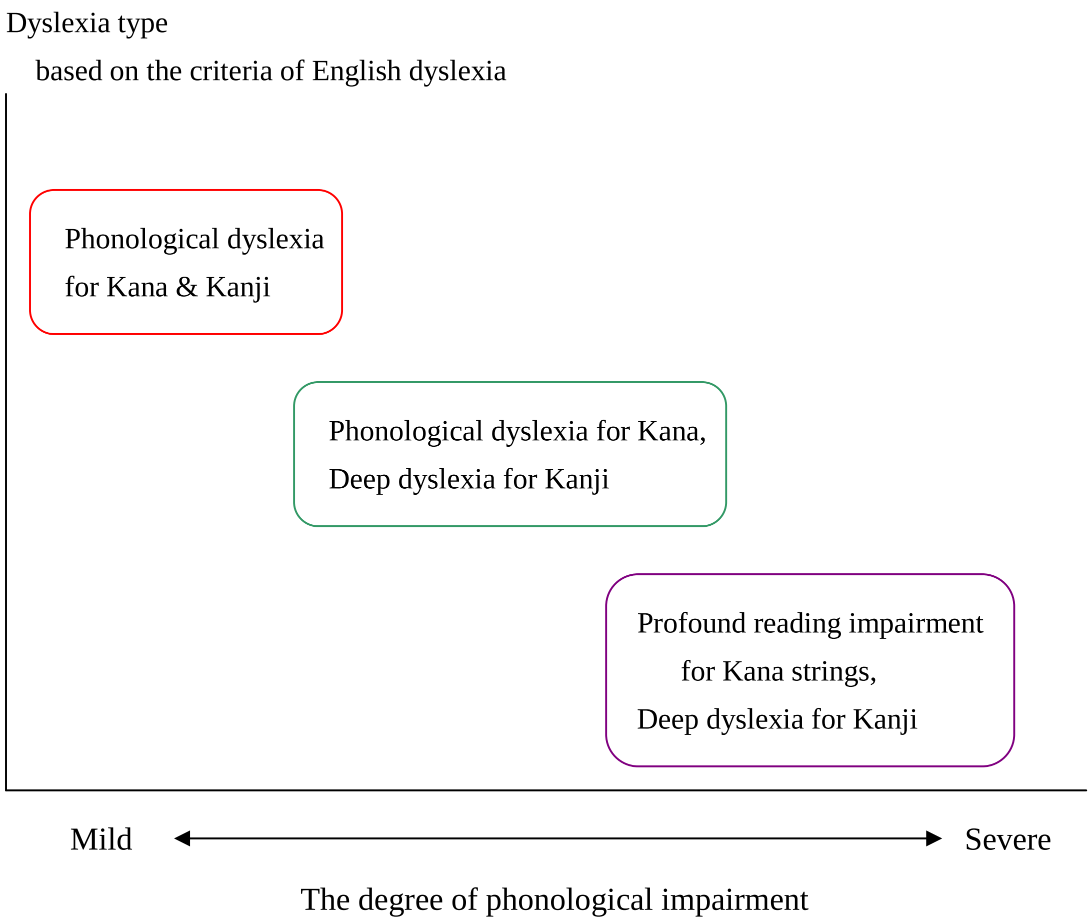


Fig. 102. A prediction for deep/phonological dyslexia in Japanese

Fig. 102 represents a prediction about deep/phonological dyslexia in Japanese, based on the outcome of this study.

2) Surface dyslexia

HW demonstrated the co-occurrence between semantic impairment and 'script-independent' surface dyslexia as observed in recent case studies for semantic dementia in Japanese (e.g. Fushimi et al., 2003). SO, whose semantic impairment was more severe than HW's, demonstrated the co-occurrence between severe semantic impairment and a severe form of surface dyslexia, in which i) a consistency effect on the first constituent character in the two-character Kanji word reading, and ii) a marked deterioration of Kanji nonword reading were observed. These demonstrations are consonant with the semantic impairment hypothesis (Patterson & Hodges, 1992; Graham et al., 1994; Patterson & Lambon Ralph, 1999), and also suggest that the degree of semantic impairment affects the manifestation of surface dyslexia in Japanese.

Given these facts, one can predict that a mild impairment of Semantics in the triangle model, which is the theoretical source of the semantic impairment hypothesis, would lead to less accurate oral reading of atypical Kanji words coupled with LARC errors, though a consistency effect is not statistically significant. This dyslexia pattern can be treated as a very mild form of surface dyslexia in Japanese. Meanwhile, classical surface dyslexia cases can be considered as a severe form of Japanese surface dyslexia. This is because they showed a remarkable deterioration of Kanji word reading (4% in KK, Sasanuma, 1979, 1980, and 1986; 10% in SU, Sasanuma, 1985 and 1986; 24% in Case 7, Sasanuma, 1980b) coupled with well-preserved oral reading for Kana strings as observed in SO (c.f. SO's reading accuracy for Kanji words ranged from 13% to 54%). Since reading aloud transparent Kana string has great resistance to semantic impairment, Japanese surface dyslexia inherently forces the manifestation of script dissociation. Profound semantic impairment, however, might lead to mild reading impairment for Kana strings. In the triangle model, the profound damage of Semantics would lead to a severely reduced activation of Phonology and Orthography, resulting in a remarkable deterioration of the direct O→P computation, even for Kana strings.

Fig. 103 depicts the association between the degree of semantic impairment and distinguishable surface dyslexia pattern in Japanese. This diagram represents a prediction about Japanese surface dyslexia based on the outcome of this study.

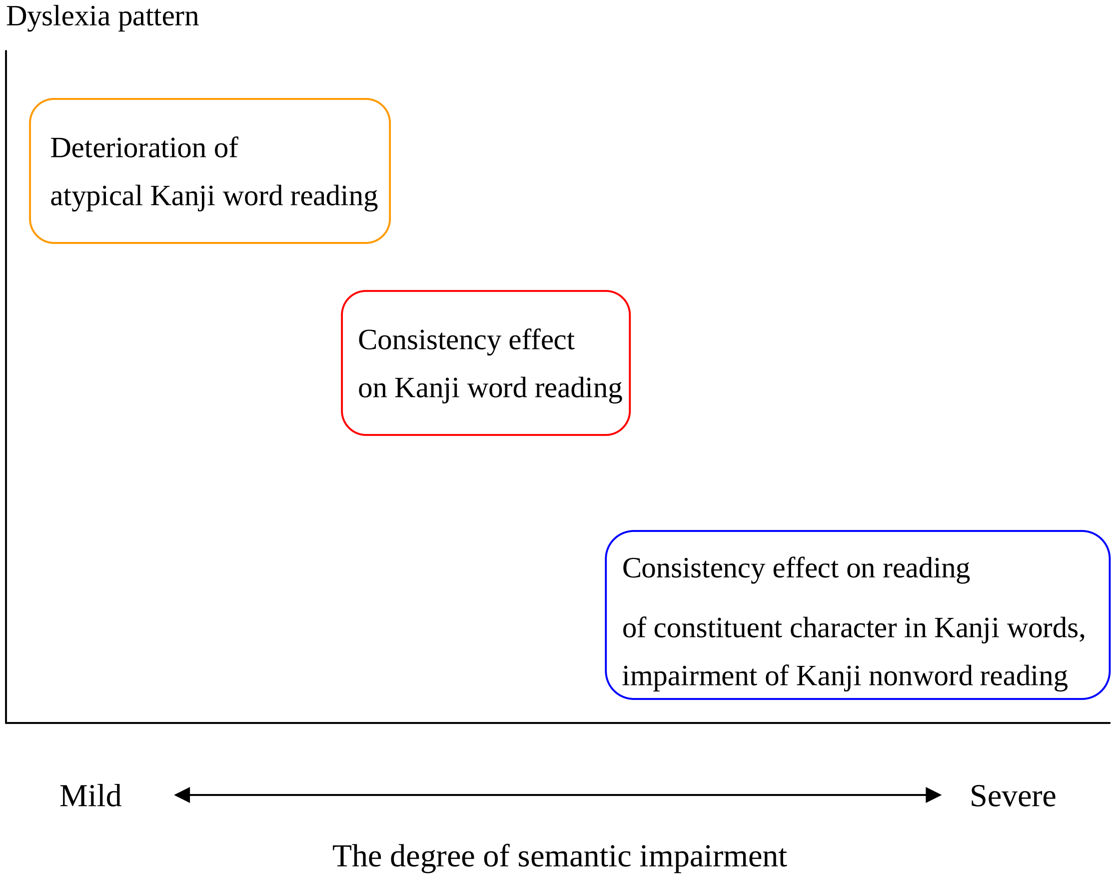


Fig. 103. A prediction for surface dyslexia in Japanese

3) The influence of visuo-spatial deficit on acquired dyslexia patterns

Recognition of written strings is an indispensable process for oral reading. Based on the triangle model the reading process is viewed as an interaction between visual and language processes (Lambon Ralph & Patterson, 2005). The vast majority of letter-by-letter reading cases showed speed/efficacy deficits in single-letter identification (Behrmann, Plaut and Nelson (1998). ME, who was suffering from right spatial neglect and a visuo-constructive deficit, showed fairly good performance in a same/different judgement task for both Kanji and Kana with a 1-second presentation. For YM, who showed visual agnosia, the same task was too difficult and he demonstrated profound impairment in Kanji character discrimination, even in a two-second presentation, coupled with preserved Kana character discrimination (Sato, 1998). While YM showed great difficulty in reading aloud Kanji words - even single-character words, ME did not show impairment of oral reading of Kana strings. Both patients showed letter-by-letter reading for Kana strings. These facts appear to indicate that the visual complexity effect would vary depending on the characteristics of the visuo-spatial deficit. On the basis of this notion, one might presuppose the influence of the damaged visual processing on reading aloud Japanese written strings as follows: i) if character identification were mainly influenced by visual complexity, superiority of oral reading of Kana strings over Kanji strings might be observed due to the different visual complexity of the two scripts (mean number of strokes: Kanji - 9.4 vs. Kana - 2.3);

ii) if character identification were not significantly influenced by visual complexity, the length of the stimulus would strongly affect reading aloud of both Kanji and Kana strings in terms of speed/efficacy. Some of such cases might show superiority of Kanji word reading over Kana word reading, due to the advantage of morphographic Kanji character recognition by the communication between Orthography and Semantics.

In the case of a combination of visual processing impairment and phonological/semantic impairment, one might presuppose the following three dyslexia patterns, based on the triangle model.

i) The patients, who have phonological impairment and show a visual complexity effect on character identification, would show a severe reading impairment for Kanji strings, and deteriorated reading aloud of Kana strings with a manner of letter-by-letter reading. It is likely that the advantage of Kana in terms of visual complexity would be kept even the reliance on the semantic procedure is increased due to phonological impairment.

ii) The patients who have semantic impairment and show a visual complexity effect on character identification, would show relatively preserved oral reading of Kana strings but would demonstrate considerable difficulty in reading aloud Kanji strings. This is because such patients would have a disadvantage with Kanji in terms of visual complexity and consistency.

iii) The patients, who have phonological impairment with degraded visual processing, would show a marked and greater difficulty of reading aloud Kana strings than Kanji strings, as observed in ME. It is likely that the disadvantage of longer strings, and a less accurate O→P computation due to phonological impairment, would lead to deterioration of reading aloud Kana strings, whereas a considerably greater reliance on the O→S→P computation due to phonological impairment would lead to the advantage of morphographic Kanji. Severely impaired oral reading of Kana strings, coupled with relatively preserved Kanji word reading as demonstrated by TO (Hayashi et al., 1985) (who was a suspected right homonymous hemianopia), might fit this dyslexia pattern. Since TO was tested using 1-2 character Kanji words and 3- to 6-character Kana words, marked reading impairment of Kana word reading can be considered as a word-length effect.

vi) The patients who have semantic impairment with degraded visual processing would show reading impairment for Kanji strings, coupled with preserved oral reading of Kana strings. A more efficient O→P computation for Kana and a greater reliance on the direct O→P computation due to semantic impairment would lead to this script dissociation.

These are very basic predictions. If a patient with visuo-spatial deficit shows both semantic and phonological impairment the degree of impairment and the interactive communication between Orthography, Phonology and Semantics would determine the dyslexia pattern.

9.2.2. The empirical implications for other orthographies

Among different languages in the world there is a considerable diversity in the way in which spoken language is represented in written form. However, the degree of correspondence between the written and spoken forms is a fundamental difference. This difference has been referred to as *'orthographic depth'* (Liberman, Liberman, Mattingly, & Shankweiler, 1980). An orthography in which print-sound correspondence is consistent is orthographically shallow. An orthography in which print-sound correspondence is inconsistent is orthographically deep. For instance, Kana and Serbo-Croatian have a shallow orthography, whereas Kanji and English have a deep orthography. Since pronunciation predictability directly reflects 'orthographic depth', translation from shallow orthography to phonology is highly efficient but translation from deep orthography to phonology is less efficient. Fig. 104 describes this point.

Kana **Kanji**
Serbo-Croatian Chinese
Italian French
Spanish German English

Shallow ← 'Orthographic depth' → Deep
High ← Pronunciation predictability → Low
More efficient ← Translation orthography to phonology → Less efficient

Fig. 104. The fundamental nature of different orthographies.

It is therefore possible to predict an acquired dyslexia pattern for shallow/deep orthographies based on Japanese dyslexia patients' oral reading performance for Kana/Kanji strings, respectively. This view is consonant with the point made by Marshall (1976) who wrote that "within the ‘'two-script’' system of Japanese writing, we seem to have an analogue of the ‘'two languages and two script's situation’" (p.123).

1) An acquired dyslexia pattern for shallow orthography

Shallow orthographies, which have entirely consistent correspondence between orthography and phonology, would hardly manifest a surface dyslexia pattern. If shallow orthographies have any property, which affects predictability, they will manifest a surface dyslexia pattern. For instance, Iribarren et al. (1996) reported a Spanish neurological patient with fluent aphasia, ITA, who could read words and nonwords correctly but made accent errors. That is, written words with a graphic accent symbol (´), representing a highly lexicalised stress pattern in spoken Spanish, were read as unstressed words. They treated these errors as regularisation errors and argued that a Spanish version of surface dyslexia, such as ITA, could be detected by using a special test to evaluate the stressed pattern of reading.

The occurrence of semantic errors would not be frequent and visual errors would be dominant in word reading. In other words, in shallow orthographies the occurrence of deep dyslexia is lower than that of phonological dyslexia. Indeed, Ardila (19919) reported that 41 Spanish-speaking aphasic patients did not produce semantic paralexias, and Ferreres and Miravalles (1995) pointed out that 68 Spanish-speaking aphasics with a reading disorder made only a limited number of semantic paralexias. Although Ruiz et al. (1994) reported that Spanish neurological patients, ON and MG, produced semantic errors (23% and 15%, respectively), their rate of semantic errors was lower than that found in Chinese neurological patients with deep dyslexia, whose average rate was 45.4% ranging from 24% to 57% (Yin & Butterworth, 1992). Furthermore, it is worth noting the reading performance by an Arabic/French bilingual patient, ZT, with deep dyslexia (Béland & Mimouni, 2001). ZT showed a deep dyslexia pattern in both languages, but the semantic error rate was lower in Arabic (i.e. shallow orthography) than in French (i.e. deep orthography). These empirical data are consonant with the prediction.

2) An acquired dyslexia pattern for deep orthography

The dyslexia patterns for Kanji strings observed in the cases of this study and Japanese literature were categorised as three types of acquired dyslexia in English. So, one can predict that deep orthographies would manifest surface dyslexia, phonological dyslexia, and deep dyslexia, regardless of whether they have alphabetical or non-alphabetical scripts.

In the case of logographic Chinese, in which print-sound consistency can be defined as whether the phonology of words corresponds to their phonetic radicals, surface dyslexia and deep dyslexia have been reported (Weekes & Chen, 1999; Yin & Butterworth, 1992; Yin, 1991). LARC errors in Chinese are a pronunciation inappropriate to the target irregular character but appropriate to other characters containing the same phonetic component (e.g. 眠/main/ *sleep* →民/min/ *people*, 祈/qi/ *pray*→斤/jin/ *weight*: Weekes & Chen, 1999). This error pattern is comparable to the 'Kanji-unit reading' in oral reading of single-character Kanji words (e.g. 箱/ha-ko/ *box*→竹/ta-ke/ *bamboo*, 相/sou/ On-reading of this kanji character, *phase*; 枕/ma-ku-ra/ *pillow*→木/ki/ *tree*) observed in SH, a Japanese patient with semantic dementia, SH (Sato, 1996). This type of error might be characterised as ‘lexical decomposition’ due to the reduction of semantic support. SO, who showed severe semantic impairment in this study, also produced this type of error in single-character Kanji word reading. A similar reading error was described in relation to Japanese patients with Alzheimer’s dementia (Sasanuma, et al., 1992). Since a single-character represents a word in the vast majority of Chinese written words, such Chinese words are equivalent to single-character Kanji words.

9.3. The theoretical implication arising from the outcome of this study

This study explored how Japanese orthography influences acquired dyslexia pattern. The outcome of this exploration is theoretically important because it suggests which aspects of reading are universal and which are orthographic-specific. This section presents i) the implications for the source of acquired dyslexia, which is related to a universal aspect of reading, ii) the implications for the origin of script discrepancy in Japanese acquired dyslexia, which is related to the orthographic-specific aspect of reading, and iii) the implications for a reading theory of Japanese orthography.

9.3.1. The source of acquired dyslexia

The phonological and semantic impairment hypothesis, based on the triangle model, presumes that phonological impairment is a source of deep/phonological dyslexia, and semantic impairment is a source of surface dyslexia. With the exception of deep dyslexia, there is ample evidence for these associations in the literature, as reviewed in Chapters 2 and 3. The results of all four Japanese subjects in this study also showed these associations. YT's evidence strongly supports the phonological impairment hypothesis because YT, who had phonological impairment but preserved semantic ability, showed deep dyslexia for Kanji and phonological dyslexia for Kana. This clearly suggests that deep dyslexia and phonological dyslexia share a common cause. ME who had phonological impairment but preserved semantic ability also showed the co-occurrence between phonological impairment and phonological dyslexia. HW and SO demonstrated that the degree of semantic impairment affected the surface dyslexia pattern in Japanese. This suggests that there is a causal relationship between semantic impairment and surface dyslexia. These demonstrations by Japanese dyslexic patients, and many observations of the association between phonological impairment and phonological dyslexia and between semantic impairment and surface dyslexia in the literature, together suggest that an underlying mechanism of acquired dyslexia would be universal. Beyond different languages, phonological/semantic impairment would lead to an increased reliance on a semantic/phonological procedure, respectively, for oral reading, resulting in a lexicality-governed dyslexia pattern in the former case and a print-sound consistency-governed dyslexia pattern in the latter.

However, cases have been reported with semantic impairment without surface dyslexia (WLP: Schwartz, Saffran, & Marin, 1980; DRN: Cipolotti & Warrington, 1995; DC: Lambon Ralph, Ellis, & Franklin, 1995; EW: Gerhand, 2001; EM: Blazely, Coltheart, & Casey, 2005). Furthermore, there are the reported cases that have shownd phonological dyslexia in the absence of phonological impairment (LB: Derouesné & Beauvois, 1985; RR: Bisiacchi, Cipolotti, & Denes, 1989; RG: Caccappolo-van Vliet, Mizzo, & Stern, 2004a, MO & IB: Caccappolo-van Vliet et al., 2004b). These exceptions pose a serious problem for the semantic and phonological hypothesis. However, this does not mean that the triangle model, which is the theoretical base for the two hypotheses, cannot provide an account for these exceptional cases' reading performance.

Since the triangle model offers the view that "language mechanism is inherently a learning device" (Plaut, 1999, p.340) and that unit connections are learned gradually through experience, it is plausible that weighted connections that encode the long-term knowledge of the system differ, depending on the individuals' experience. In other words, a different reading experience leads to a different statistical structure of the reading system. Indeed, Plaut (1997) presented the simulation that can account for oral reading performance by both DRN, who was a biological scientist with a high degree of education, and DC, who attended school until the age of 14, by manipulating the strength of external input to phonology and weight decay. This simulation showed that individual difference of weighted connections in the pre-morbid system could affect the manifestation of reading disorder. In this way, there is the possibility of accounting for phonological dyslexia without phonological impairment, though that is a post hoc interpretation.

On the other hand, the DRC model can explain oral reading performance in these exceptional cases. This is because the DRC model assumes the lexical non-semantic route, which is not connected to the semantic system, and the GPC rule in the non-lexical route, which is serial processing. If such route and rule are intact, neither semantic impairment (i.e. the damage of the semantic system) nor phonological impairment (i.e. the damage of the phoneme system) affects oral reading performance in this model. Therefore, the proponents of the DRC model emphasise that the data from exceptional cases pose a serious difficulty for the triangle model.

Coltheart (2006, p.107) has argued that "studies of both forms of acquired dyslexia have yield data that are inconsistent with models developed within the triangle model framework but have not yielded any data that are inconsistent with the DRC model.". If one just considers the data from surface dyslexia and phonological dyslexia, Coltheart's point seems to be reasonable.

The fact is that the modellers of the DRC model themselves give up attempts i) to interpret the co-occurrence between semantic impairment and surface dyslexia, and the co-occurrence between phonological impairment and deep/phonological dyslexia at a cognitive level; and ii) to explain deep dyslexia patterns, declaring that "the explanation of any symptom of deep dyslexia is outside the scope of the DRC." (Coltheart et al., 2001, p.246). Instead, they present biological explanations for these two issues. According to their argument, the association between impairment of the principal components and dyslexia patterns arises from an anatomical proximity of these functions in the brain, and deep dyslexia pattern occurs in the right hemisphere. This is a serious theoretical crisis, because any reliable reading theories are required to provide a coherent account of the phenomena shown by the vast majority of acquired dyslexia cases, and any types of reading disorder.

Why are the proponents of the DRC model keen to ignore deep dyslexia? This seems to be deeply rooted in the framework of this model. Although the DRC model is a computational model, model architecture - which consists of discrete components - is specified by the modeller. Each component (or "module" in traditional information-processing models) is assigned a specific function or type of representation (e.g. Orthographic Output Lexicon) in this model. In other words, the modeller defines function as ascribed to individual components. So, the creators of the DRC model postulate that oral reading of written strings is processed in the lexical route (for computation of the whole word level) and the non-lexical route (for computation of the sub-word level). Although nonwords activate orthographic neighbours in the Orthographic Input Lexicon in the current version of the DRC model (i.e. nonwords are processed in the lexical non-semantic route), only the non-lexical route can produce correct oral reading of nonwords. Given this framework, double dissociations between two classes of stimuli (i.e. exception words and nonwords) within a single task (i.e. oral reading) in surface dyslexia and phonological dyslexia are clearly explained by this model as the damage caused by two functionally independent processing routes. The demonstration of these two types of acquired dyslexia is strong evidence for the DRC model. Therefore, the creators of this model need to ignore deep dyslexia to achieve a logical adjustment, because deep the dyslexia pattern does not fit double dissociation logic.

However, the logic that double dissociations imply two or more functionally independent sub-systems (e.g. Shallice, 1988) is circular reasoning, as pointed out by Van Orden et al. (2001). This is because each component is defined as a functionally dissociable sub-system. So, it is not entirely clear whether the double dissociation observed in surface and phonological dyslexia supports the DRC model's reliability. Furthermore, the assumption of the two reading routes fails to reduce acquired dyslexia patterns to any causal component. Since the two reading routes consist of multiple components, the damage to a specific component does not always imply a specific pattern of reading disorder. For instance, the damage to the phoneme system, which is involved in the two reading routes, would lead to reading difficulty with any types of written stimuli. The damage to the semantic system will not produce reading difficulty solely for exception words, because the intact lexical non-semantic route can read all types of words. Therefore, the DRC model cannot interpret the co-occurrence of semantic/phonological impairment and surface/phonological dyslexia, respectively. This appears to be the reason why the proponents of the DRC model use a biological account for these phenomena.

Coltheart (2006, p.105) argued that "exceptions to the rule that semantic impairment is always accompanied by surface dyslexia" and "exceptions to the rule that phonological dyslexia is always accompanied by phonological impairment" are problematic for the triangle model account of the two types of acquired dyslexia. He criticised Fushimi et al. (2003)'s defense of the triangle model, which gave priority to hundreds of association data over a small number of dissociation data. The point is that Coltheart appears to confuse the relationship between reading models and reading theories. As Martin, Laine, and Harley (2002) wrote, "models are not theories themselves" (p.377). Both semantic and phonological impairment hypothesis are predictions about acquired dyslexia, based on the triangle model, and they are not "the rule" of the triangle model. The data that does not match the two hypotheses poses an insufficiency for these working hypotheses (i.e. a theory), but does not directly falsify the triangle model itself. In this context YT's data is theoretically very important, because YT first demonstrated the co-occurrence of phonological impairment and deep dyslexia, and also showed co-occurrence of deep dyslexia and phonological dyslexia, suggesting that they are not independent dyslexia types. Since YT showed preserved semantic ability, YT's semantic errors, which frequently occurred in Kanji word reading, cannot be attributable to a semantic deficit. So, substantially reduced activation of phonology, which cannot inhibit semantic neighbourhoods, can be considered as the cause of YT's semantic errors. A remarkable script discrepancy as to the occurrence of semantic errors in word reading suggested that a different efficacy of O→P computation would determine the occurrence of semantic errors. Therefore, YT's data fit the phonological impairment hypothesis and support the triangle model. In contrast, YT's data is seriously problematic for the DRC model, because it is difficult for the DRC model to provide a coherent account of the co-occurrence of deep/phonological dyslexia.

Given the results of this study and the fact that the vast majority of patients with semantic impairment are surface dyslexics, and the vast majority of patients with phonological dyslexia exhibit phonological impairment, the semantic and phonological impairment hypotheses seem to be a useful working theory as a base for evaluating acquired dyslexia patterns in different languages. Thus, it is reasonable to conclude that the source of acquired dyslexia would basically be the damage to semantic function or phonological function. In other words, acquired dyslexic patterns would fundamentally reflect the characteristics of a spoken language disorder, implying that i) written language and spoken language are interrelated, and ii) the mechanisms that underline acquired dyslexia are common to different orthographies. The second point indirectly suggests that the basic processing mechanism of oral reading is common to skilled readers of different orthographies (i.e. the universal aspect of reading).

9.3.2. The origin of script discrepancy in Japanese acquired dyslexia : A proposal for the Different Efficiency Hypothesis of Japanese Scripts

In classical case studies of Japanese acquired dyslexia the striking demonstration of double dissociations between Kanji and Kana (e.g. Sasanuma, 1980a, 1985) has been treated as evidence for different reading routes for Kanji and Kana, using 'double dissociations logic' (e.g. Shallice, 1988). This study revealed that this interpretation (that functionally dissociable reading routes for Kanji and Kana led to double dissociations in acquired dyslexia patterns) is not correct. This is partly because the models, which have different reading routes for the two scripts, could not properly explain Japanese acquired dyslexia patterns in recent cases (see. 3.4. in this thesis). This is mainly because the script discrepancy demonstrated by Japanese dyslexic patients in this study was accounted for by assuming a script-dependent differential efficiency of the same two procedures, not by assuming script-specific reading processes.

In this study, the bi-scriptal influence, which cannot be explained by psycholinguistic variables effects, was observed in three cases. Superficially, SO and ME demonstrated clear double dissociations between Kanji and Kana in oral reading of written strings. YT showed script discrepancy in terms of error patterns and the degree of a concreteness/imageability effect on word reading. If one postulates script-dependent differential efficiency of reading processing these script-related effects can be explained without assuming a different reading procedure for Kanji and Kana. The assumption was that i) the phonological procedure (O→P computation in the triangle model, and the non-lexical route in the DRC model) is more efficient for phonographic Kana, and ii) the semantic procedure (O→S→P computation in the triangle model, and the lexical-semantic route in the DRC model) is more efficient for morphographic Kanji. The reasoning of this assumption is based on the different psycholinguistic characteristics of Kanji and Kana characters. Since Kana characters have a consistent character-sound correspondence, the direct phonological procedure is more efficient for Kana characters than for Kanji characters which have a various degree of character-sound consistency. While the morphographic Kanji character has a link between orthography and semantics, the phonographic Kana character does not have such a link. It is likely that this difference, together with the less efficient operation of the phonological procedure for Kana, would lead to a greater reliance on a semantic procedure for Kanji, resulting in the more efficient operation of a semantic procedure for Kanji than for Kana.

The outcome of this study strongly suggests that this assumption will be necessary in order to account properly for Japanese acquired dyslexia patterns. So this study calls this assumption *The Differential Efficiency Hypothesis of Japanese Scripts,* and proposes this hypothesis for understanding oral reading performance by both intact and brain-damaged individuals. The point of this hypothesis is that the nature of the Japanese scripts produces a differential processing efficiency in the two reading procedures and this is used to explain reading mechanisms in English. This hypothesised functional nature is similar to Marshall (1976)'s view. He wrote, "two (at least) strategies can be applied to a single script (English) but that these same two strategies are differentially utilised in Japanese" (p.122).

This hypothesis predicts that the nature of different orthographies, which have a different degree of print-sound consistency and represent different linguistic levels (phoneme, syllable, and morpheme), would affect the efficiency of different reading procedures. It is worth noting that cross-orthography research (Kats & Feldman, 1983; Frost, Katz, and Bentin, 1987; Katz and Frost, 1992) suggested that 'the orthographic depth' affected the degree of lexical involvement in word naming by normal subjects. Katz and Frost (1992, p.71) proposed that "differences in orthographic depth leads to processing differences in naming and lexical decision" (*the Orthographic Depth Hypothesis*). In their view, processing in the lexical-nonsemantic route predominates in a deep orthography like English, and processing in the non-lexical route predominates in a shallow orthography such as Serbo-Croatian. It is not entirely clear why they excluded an assumption about the efficiency of the lexical-semantic route. This may be related to the dual-route model's view in which the lexical-semantic route is not thought to play much of a role in word reading. This hypothesis, however, presents the notion that the degree of print-sound consistency leads to differing efficiency of distinctive reading procedures. This is in line with the prediction based on the Differential Efficiency Hypothesis of Japanese Scripts.

In sum, script discrepancy in Japanese acquired dyslexia is inherent in the Japanese bi-scriptal writing system. The different nature of Kanji and Kana, in terms of both character-sound correspondence and representational level (morphogram vs. phonogram), can be thought of as the origin of script discrepancy in oral reading performance by Japanese dyslexia patients.

9.3.3. Possible workings of Japanese versions of the DRC model and the Triangle model

Based on the outcome of this study, this section presents possible workings of Japanese version of the two models, which are currently influential for interpreting oral reading performance in both skilled readers and dyslexic people.

1) The modified Japanese version of the DRC model

Fig. 105 depicts the modified Japanese version of the DRC model. This model is different from a Japanese version of the DRC model (see. Fig.20 in this thesis) in relation to the two different non-lexical reading routes for Kanji and Kana, and the degree of processing efficiency in the lexical semantic route, and this reflects the

Differential Efficiency Hypothesis of Japanese Scripts.

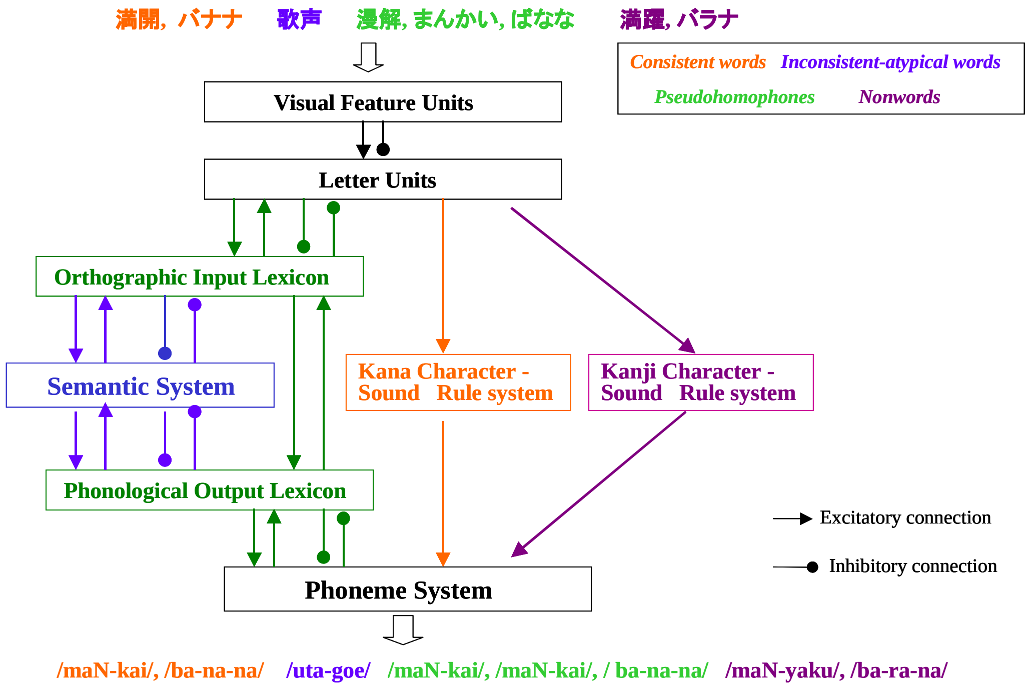


Fig. 105. The modified Japanese version of the DRC model.

<u>The non-lexical route</u>

The creators of the DRC model specified a functional architecture for the oral reading of written alphabetic strings in English. One of the core assumptions of this model is that direct translation from orthography to phonology is processed at sub-word level (in the non-lexical route) and whole-word level (in the lexical-nonsemantic route). The non-lexical route translates a letter string into a phoneme string by using GPC rules. The recent version of the DRC model (Coltheart et al., 2001) defined a set of context-dependent GPC rules and the order of rule selection - "multi rules (rules with more than two-letter graphemes), then context-sensitive rules, then two-letter grapheme rules, then the one letter to multiple phonology rule (the letter x) and finally single-letter rules" (p.217).

Thus, it is crucial to define Character-Sound Correspondence (CSC) rules in the two independent non-lexical routes for Kanji and Kana in the modified Japanese version of the DRC model. Although the pronunciation of Kana characters is totally predictable, there are two-character compounds corresponding to CjV mora (e.g. きゅ, キュ - /kju/; みゃ, ミャ - /mja/). The CSC rules for Kana characters consists of i) two-character rules, which delete the vowel of the first Kana character in the two-Kana character context; and ii) single-character rules, in which single a Kana character is translated into C or CV (e.g. お, オ - /o/; ね, ネ - /ne/; ぞ, ゾ - /zo/).

For defining the CSC rules for Kanji, one needs to take notice of the distinction between regularity and consistency in English written words. Regularity is defined according to grapheme-phoneme correspondences (GPC) and consistency is defined according to the pronunciation of word body neighbours. So, it is possible to find both regular inconsistent words like BEAD, which have many irregular neighbours (e.g. head, bread, stead) and irregular consistent words like BIND. Table 63 summarises the results of applying 'regularity' and 'consistency' to Kanji words. In the case of Kanji, print-sound correspondences are 'one-to-one' or 'one-to-many'. So, regular Kanji words can be defined as the words in which each constituent character has only one pronunciation. In this way quasi-regular Kanji words are those in which each constituent character has multiple pronunciations, and irregular Kanji words are those in which the phonology of words does not reflect each constituent character's pronunciation, known as 'Jukuji KUN' (see. p.130-131 in this thesis).

Table 63 The categorisation of Kanji words
in terms of 'regularity' and 'consistency' and its relationship

Regularity' based categorisation	CSC (Character-Sound Correspondence)	Consistency' based categorisation	The degree of consistency
Regular words	One-to-One	Consistent words	Identical pronunciation across O. neighbours
Quasi-regular words	One-to-Many	Inconsistent-typical words	Typical pronunciation across O. neighbours
		Inconsistent-atypical words	Atypical pronunciation across O. neighbours
Irregular words	No correspondence	Exception words	Exceptional pronunciation across O. neighbours

O. = orthographic

Meanwhile, the concept of 'consistency' involves statistical perspective. Consistent words are those in which each constituent character has an identical pronunciation across the orthographic neighbours. Consistent-typical words and inconsistent-atypical words are those in which each constituent character has a typical/identical pronunciation across the orthographic neighbours. Exception words, like 'Jukuji KUN', are those in which the phonology of words is exceptional across orthographic neighbours. As shown in Table 63, the concept of 'regularity' cannot distinguish between inconsistent-typical words and inconsistent-atypical words. Bearing in mind this difference, and context-sensitive selection for the pronunciation of Kanji words, a set of CSC rules for Kanji is considered as follows:

i) regular rules, in which constituent Kanji characters are translated into a corresponding single pronunciation in any context (i.e. single-character words, multiple-character words, and nonwords);

ii) 'position and frequency'-sensitive rules, in which each constituent a Kanji character that has multiple pronunciations is firstly translated into the most frequent corresponding pronunciation among the orthographic neighbours that share the same Kanji character at the same position (e.g. 手紙-手段; 靴下-上下), and then is translated into a less frequent corresponding pronunciation among the orthographic neighbours;

iii) context-sensitive rules, in which each constituent Kanji character that has multiple pronunciations is determined by the intra-word context (e.g. 神経/ʃiN-kei/ vs. 風神/fu：-ziN/).

The order of rule selection is: regular rules, 'position and frequency'-sensitive rules, and then context-sensitive rules. Therefore, the non-lexical route for Kanji can read regular words and quasi-regular words. 'Position and frequency'-sensitive rules can offer to distinguish inconsistent-typical words and inconsistent-atypical words. This reading route can also read Kanji nonwords by applying 'regular rules' or 'position and frequency'-sensitive rules.

The lexical-nonsemantic route

This reading route generates the pronunciation of written words by using the direct translation from orthography to phonology at whole-word level. So, in this process Kanji words and Kana words share the same operation. Moreover, both regular Kanji words and irregular Kanji words are processed in the same manner. Nonwords can activate orthographic neighbours in the Orthographic Input Lexicon, but this reading route cannot read nonwords correctly. This is the same assumption as the original DRC model. Therefore, the lexical-nonsemantic route can only read Kanji words and Kana words.

The lexical-semantic route

This reading route must be redefined based on the Differential Efficiency Hypothesis for Japanese Script. So, efficiency of the lexical-semantic route for Kanji words is higher than that for Kana words because of the highly efficient interaction between the Orthographic Input Lexicon and the semantic system for Kanji words. This reading route can read both Kanji words and Kana words with a different degree of efficiency.

2) The Japanese version of the triangle model

The Japanese version of the triangle model (Fushimi et al., 2000a, c) did not need to be modified in order to explain oral reading performance by all four subjects of this study. This is because the triangle model is a connectionist model, in which the operation of the system is governed by weighted connections that are learned through experience. In other words, the long-term knowledge is distributed in the network and functional specialisation in the processes of the network is learned. For instance, the weighted connection between Orthography and Phonology for consistent Kanji words and Kana words is strong enough to generate a target's pronunciation, whereas this link for Kanji inconsistent-atypical words is less strong and needs semantic support (O→P⇔S, or O→S→P). Given these characteristics, a marked difference of pronunciation predictability between Kanji and Kana characters and a difference of the representational level (morphographic Kanji vs. phonographic Kana) are encoded in the network as differentially weighted connections. However, the following explicit assumptions seem to be useful in order to interpret Japanese acquired dyslexia patterns more easily by using the Japanese version of the triangle model:

i) the O→P computation is more efficient for Kana than for Kanji.

ii) the O→S→P computation is more efficient for Kanji than for Kana.

These are applications of the Differential Efficiency Hypothesis of Japanese Scripts to the triangle model. Indeed, Ijuin, Fushimi, and Tatsumi (2003) simulated the script type effect on word reading and successfully showed a more efficient O→S computation for Kanji words than for Kana words.

Moreover, it might be better to explicitly assume the relationship between the peripheral visual system and Orthography in the triangle network. This has arisen from the interpretation of ME’s oral reading performance where both phonological impairment and visuo-spatial deficit were evident. While the DRC model includes Visual Feature Units, the triangle model (Plaut et al., 1996; Harm & Seidenberg, 2004) does not involve visual feature analysis of written strings in its diagram. The problem is that the relationship between the degree or quality of a generalised visual impairment, and the severity of a reading disorder in terms of time/efficiency and accuracy, is not well known. It appears to be reasonable to suppose that a generalised visual impairment, in which recognition of non-orthographic stimuli is impaired, would lead to pure alexia (Behrmann, Nelson, & Sekuler, 1998; Farah & Wallace, 1991). Indeed, out of 57 published cases of letter-by-letter reading, 50 patients showed deficits of single-letter identification in terms of speed/efficiency (Behrmann et al., 1998). ME's results appear to indicate that word recognition would be differently influenced by visual complexity and length of stimuli, depending on the characteristics of the visuo-spatial deficit. More peripheral aspects of visual deficit might directly relate to a visual complexity effect, whereas a degraded deficit might more closely related a length-effect. More importantly, ME's results suggest an interaction between visual and language processes. That is, visual processing is deeply connected to reading processing. So, it might be necessary for the Japanese version of the triangle model to include this view, which is depicted in Fig. 106 and referred to in the modified Japanese version of the triangle model.

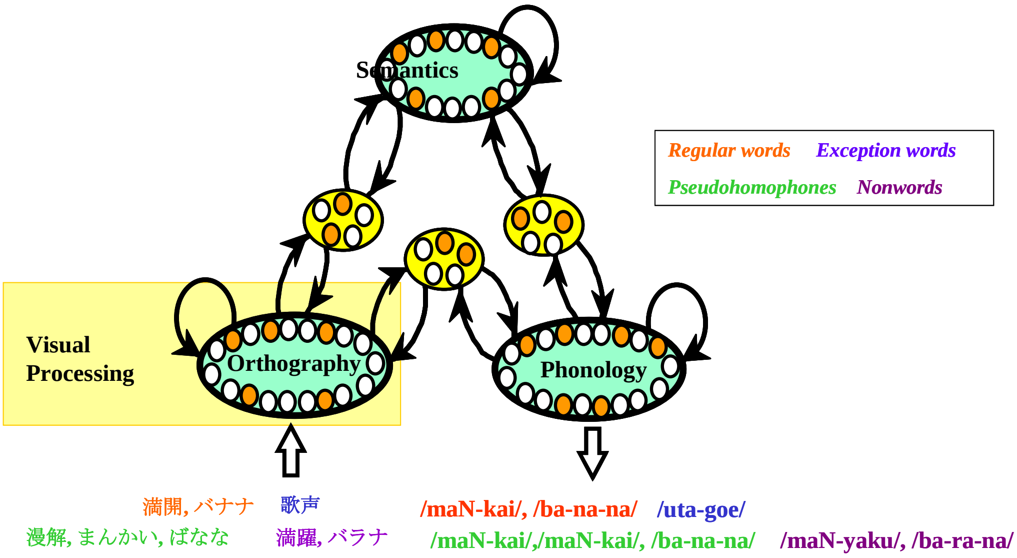


Fig. 106. The modified Japanese version of the triangle model.

The way of depicting visual processing is identical to the figure for the triangle model of reading as presented by Lambon Ralph and Patterson (2005). Within this framework, which assumes that a set of characteristics of visual processing is interrelated to orthographic activation, one can predict that the interaction between some characteristics of visual processes and language processes would firmly contribute to recognition of orthographic stimuli.

9.4. Recommendation for future research

This study demonstrated the evidence that supports a phonological and semantic impairment hypothesis based on the triangle model. Therefore, this study approves the triangle model's view that reading is parasitic on the cognitive systems for spoken language processing and visual processing. Based on a phonological and semantic impairment hypothesis, this study presented the predictions of phonological and surface dyslexia patterns in Japanese. So, one of the future research directions is to conduct not only single case studies but also series of case studies of Japanese patients with acquired dyslexia in order to verify the empirical predictions, and also to test the reliability of the Differential Efficiency Hypothesis for interpreting dyslexia patterns in Japanese Scripts.

A study that investigates the relationship between the degrees of visuo-spatial impairment and the severity of oral reading impairment is another direction for future research. This would provide a coherent explanation for pure alexia (letter-by-letter reading), attentional, neglect, and visual dyslexias, whose causes are considered to be a general visual deficit. Studies of patients with central dyslexia (surface dyslexia and deep-/phonological dyslexia) and patients with peripheral dyslexia will, together, provide a more clear picture of dyslexia patterns in patients with both visual and spoken language processing impairment (i.e. multiple deficits).

Moreover, exploring the processing mechanisms of recovery (and treatment) in aphasic patients' language performance is another important area of research. Within the triangle model's framework, any language disorder would be explained by the degree of impairment of the three primary components (semantics, phonology and orthography/vision). Thus, a phonological and semantic impairment hypothesis can provide a prediction for a recovery pattern of reading and speaking performance in aphasia. So, research on how and why recovery from aphasia occurs will bring new perspectives on understanding language disorder in aphasics, resulting in a new categorisation of aphasia types. Since the vast majority of cognitive neuropsychological research has been conducted by using chronic patients who show stable cognitive ability, and patients with progressive disease such as semantic dementia, it is crucial to investigate recovery patterns of aphasia in the non-chronic stage, and treatment effects in the chronic stage. This is because a study of aphasia recovery will tell us the dynamic nature of the brain networking for written and spoken language.

Glossary

Terms that relate to the Japanese language (mainly orthography) are listed alphabetically. Cross-references in the glossary are in bold type. Page numbers at the end of an explanation show the location of the first appearance of the term in this thesis.

Consistent words. A type of two-character Kanji word**,** in which each constituent character has an identical pronunciation across the **orthographic neighbours**. (p.134).

Gairaigo. A type of Japanese vocabulary consisting of loan words from foreign languages (e.g.バナナ for banana). The proportion of this type of word is about 10% in common Japanese vocabulary (Takashima, 2001), but the more recent trend has been to increase loan words. Gairaigo is written using **Katakana** (e.g. レモン *lemon*) (p.122).

Hiragana. A type of Japanese **Kana** created by simplifying Chinese characters as a whole, and its pronunciation is taken from the reading of the base Chinese character (e.g. /o/ →ろ/ro/; 波/ha/ →は ha/). (p.125).

Hiragana words. Some **Wago** are written with Hiragana characters and they are called Hiragana words. The majority of Hiragana words are of 3- or 4-character length. (p.137).

Inconsistent-atypical words. A type of two-character Kanji word in which each constituent character has more than one legitimate pronunciation across the **orthographic neighbours**, and where one or both constituent characters of a target word take a statistically atypical pronunciation. (p.134).

Inconsistent-typical words. A type of two-character Kanji word in which each constituent character has more than one legitimate pronunciation across the **orthographic neighbours**, but where a target word takes a statistically typical pronunciation of each character. (p.134).

Joyo Kanji. Daily usage **Kanji** that consist of 996 Kyoiku Kanji and 949 commonly used Kanji characters which are mainly taught in junior-high school (between the ages of 13 and 15). The Japanese language council selected these standard Kanji characters. (p.140).

Jukuji-KUN. A **KUN-reading** for the target Kanji words as a whole. The pronunciation for Kanji words, which have Jukuji-KUN, cannot be predicted by reading each constituent character. For instance, the pronunciation of 大人 *adult* is /o-to-na/, though 大 has one ON-reading /dai/ and one KUN-reading /ou/ and 人 has two ON-reading /jiN/, /niN/ and one KUN-reading /hito/. (p.130).

Kana. A general term used for Japanese phonograms which consist of the two forms of Kana: **Hiragana** and **Katakana**. Hiragana and Katakana are exact phonological equivalents (e.g. あ /a/ and ア /a/) and they comprise 75 characters. Kana represents a Japanese mora (i.e. a subsyllabic unit) and has a regular and transparent relationship between a character and its pronunciation. Kana characters are conventionally divided into three groups: i) the basic set comprising 46 Hiragana /Katakana characters, which corresponds to C or CV (e.g. ぬ, ヌ /nu/); ii) the diacritical set comprising 25 Hiragana/Katakana characters which have a diacritical mark representing a phonetic distinction (e.g. ぎ, ギ /gi/); and iii) the complex set comprising 36 Hiragana/Katakana two-character compounds, corresponding to CjV (e.g. びょ,ビョ /bjo/). Kana characters are taught as part of the curriculum in the first year of primary school (between the ages of 6 and 7) (p.37).

Kango. A type of Japanese vocabulary consisting of imported Chinese words and coined words, which were created by Japanese people using the word-forming capacity of Chinese characters mainly in the Meiji era (1868-1912) in order to translate western foreign words (e.g. 社会 for *society*, and 政治 for *politics*). Kango is written using **Kanji** (e.g. 位置 *position*) (p.122).

Kanji. A term used for Japanese morphograms which are imported Chinese characters from the 3rd and 10th century. In Japanese this means the Hun Chinese orthography, which was systematised during The Hun era (206 BC and AD 221). There are the two types of reading for Kanji: **ON-reading** and **KUN-reading**. In a sample of 1,945 **Jyoyo Kanji** characters the average number of pronunciations per Kanji character is 2.94 (Fushimi et al., 1999). For instance, 男 *man* has three pronunciations: /o-to-ko/ (KUN-reading), /daN/(ON-reading), and /naN/(ON-reading). Kanji has various degrees of character-sound correspondence. The standard Kanji characters known as **Jyoyo Kanji** are learned in compulsory education between the ages of 6 to 15 , but many Kanji characters (about 3000) are used in daily newspapers. (p.37).

Kanji words. All **Kango** and many **Wago** are written using **Kanji** characters and they are called Kanji words. About 85% of written Japanese words (N=68,732) are Kanji words (Amano & Kondo, 1999). Although there are a single-character Kanji words (e.g. 水 /mizu/ *water*) and multiple-character Kanji words (e.g. 水筒 /sui-tou/ *water bottle*, 水族館 /sui-zoku-kaN/ *aquarium*, 水陸両用 /sui-riku-ryo-yo/ *amphibious*), the vast majority of Kanji words are two-character words. While more than 80% of two-character Kanji words (N=32,220) have **ON-reading**, 60% of single-character Kanji words (N=1,657) have **KUN-reading**. The proportion of KUN-reading for single-character Kanji words is modulated by familiarity (e.g. about 80% of them in the high familiarity band have KUN-reading). The pronunciation of Kanji words is determined by each constituent character's reading in the intra-word context, but there is a small number of exceptions which are known as **Jukuji KUN** (N≒100). (p.130).

Katakana. A type of Japanese **Kana** created by taking part of a Chinese character whose pronunciation was identical to the base Chinese character (e.g. 伊/i/ → イ/i/; 宇/u/ → ウ/u/) (p.125).

Katakana words. All **Gairaigo** are written using Katakana characters and they are called Katakana words. Three, 4-, and 5-character length words are in the majority, but Katakana words of more than 6-character length are not unusual. (p.137).

KUN-reading. A type of pronunciation for **Kanji** in which spoken Japanese words were assigned to the pronunciation for Chinese characters based on the meaning of the character. For example, 心, which means soul in Chinese, was read as /ko-ko-ro/ which is the spoken Japanese word for soul. (p.125).

Kyoiku Kanji. Educational **Kanji** consisting of 996 basic Kanji characters which are taught in primary school education (between the ages of 6 and 12). Kyoiku Kanji is frequently used for basic **Kanji words**. (p.139).

ON-reading. A type of pronunciation for **Kanji**, which approximated to Chinese pronunciation with Japanese phonology (i.e. Japanese pronunciation of Chinese characters). So, it often happens that the same ON-reading is assigned to different Chinese characters which have different Chinese phonology (e.g. 小, 少, 松, 消, 勝, 商, 焦, 章, 賞, 症, 生, 省 have ON-reading /ʃo/), resulting in many homophones for **Kanji words**. (p.125).

Orthographic neighbours. A term used for **Kanji words** that share the same Kanji character in the same position. With this definition (Fushimi et al., 1999), Kanji words which share the same Kanji character at different positions, such as 手紙 and 右手, are not orthographic neighbours. (p.135).

Orthographic plausibility. A term used for a psycholinguistic variable of Japanese written words, referring to orthographic acceptability (Amano &

Kondo, 1999). Since all Japanese words can be written using phonographic Kana, Kana transcriptions are acceptable in informal documents but psychological acceptability of Kana transcriptions varies, depending on the vocabulary type of the base words. Usually, Hiragana/katakana transcriptions of **Kanji words** (e.g. がっこう and ガッコウ for 学校 *school*) have low orthographic acceptability. In the case of Hiragana transcriptions of **Katakana words** like めろん for メロン *melon*, orthographic acceptability is much higher than Hiragana/Katakana transcriptions of Kanji words. However, there are some exceptions, in which Kana transcriptions are highly acceptable. For instance, apple can be written by Kanji, Hiragana and Katakana (林檎,りんご, and リンゴ) and all of them have high orthographic plausibility as written words. (p.137).

Script-dependent dyslexia pattern. A Japanese acquired dyslexia pattern pointed out by classical case studies, which considers that three types of Japanese acquired dyslexia are script-dependent (surface dyslexia is a Kanji-specific reading disorder, phonological dyslexia is a Kana nonword-specific reading disorder, and deep dyslexia is a Kana -specific reading disorder). The rationale for these categorisations was based on the analogy that Kana words, Kanji words and Kana nonwords could parallel regular words, exception words and nonwords in English, respectively. (p.155).

Script-independent dyslexia pattern. A Japanese acquired dyslexia pattern reported by recent case studies which revealed a consistency effect on Kanji word reading in surface dyslexia patients and a lexicality effect on reading aloud of both Kanji and Kana strings in phonological dyslexia patients. (p.179). Before this thesis, there had been no studies which examined this characteristic of Japanese deep dyslexia. (p.179).

Wago. A type of Japanese vocabulary consisting of Japanese words with their origins in the time before the import of Chinese characters/words. Wago is written using **Kanji**, **Hiragana** and Kanji-Kana compound (e.g. 鈴 *bell*; のんびり *take it easy*; 鮮やか *vivid*). (p.122).

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