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A case study of an English-Japanese bilingual with monolingual dyslexia

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Abstract

We report the case of AS, a 16 year-old English/Japanese bilingual boy, whose reading/writing difficulties are confined to English only. AS was born in Japan to a highly literate Australian father and English mother, and goes to a Japanese selective senior high school in Japan. His spoken language at home is English. AS's reading in logographic Japanese Kanji and syllabic Kana is equivalent to that of Japanese undergraduates or graduates. In contrast, his performance in various reading and writing tests in English as well as tasks involving phonological processing was very poor, even when compared to his Japanese contemporaries. Yet he has no problem with letter names or letter sounds, and his phoneme categorisation is well within the normal range of English native speakers. In order to account for our data that show a clear dissociation between AS's ability to read English and Japanese, we put forward the 'hypothesis of granularity and transparency'. It is postulated that any language where orthography-to-phonology mapping is transparent, or even opaque, or any language whose orthographic unit representing sound is coarse (i.e. at a whole character or word level) should not produce a high incidence of developmental phonological dyslexia.

Keywords: Dyslexia; Phonological impairment; Hypothesis of granularity and transparency; Kanji and Kana

1. Introduction

We describe for the first time a bilingual and biscriptal boy who is severely

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dyslexic in just one of his languages. In the other, he performs at a superior level. We will argue that this case suggests that the theories of developmental dyslexia need to focus on the precise mappings between script and sound in orthographies.

1.1. Dyslexia and English orthography

The definition of developmental dyslexia put forward by the World Federation of Neurology states that '[dyslexia is] a disorder manifested by difficulty in learning to read despite conventional instructions, adequate intelligence, and sociocultural opportunity' (Chrichey, 1975). That is, central to the concept of developmental dyslexia is the idea that some children may experience unexpected reading problems that cannot be attributed to poor hearing or vision, low intelligence or inadequate educational and social opportunities (Snowling, 1987; Ellis, 1993). These dyslexics form a substantial minority group, and indeed it is said that between 2 and 10% of the population of the English speaking world fall into this group (Rutter and Yule, 1975; Rodgers, 1983). Developmental dyslexia was once considered to be a unitary syndrome with a single underlying deficit giving rise to the common symptoms of all cases of dyslexia (Ellis, 1985), for example, developmental dyslexia is caused by some sort of general perceptual deficit or faulty eye movements (Stanley, 1978, 1991; Pavlidis, 1981). Lovegrove et al. (1986) argued for a low-level visual deficit in a large percentage of dyslexics. However, Seymour (1986) presented a detailed study of 21 dyslexics and their controls revealing that individual dyslexics showed markedly heterogeneous patterns of visual and phonological difficulties in their reading. Thus many researchers have now come to the view that dyslexics are not all alike. They focus on individual differences in the strength and weakness of the various component processes involved in reading (Marshall, 1984; Ellis, 1993). This is because reading and writing skills are considered to be multi-component skills, which involve sub-skills such as letter identification, word recognition and production, semantic access and so on. Therefore, it is possible to assess which of these sub-skills are relatively intact or impaired in dyslexics (Castle and Coltheart, 1993; Ellis, 1993).

It is, thus, useful to examine theories or models of normal reading development (Frith, 1985; Snowling, 1987). For example, Frith (1985) suggests that reading development proceeds in three successive stages: a visual logographic stage which primarily focuses on salient features of words and allows instant recognition of known words from a limited set of responses. A subsequent alphabetic stage permits sequential decoding of unfamiliar words by applying knowledge of individual sounds and their corresponding letters. Finally visual orthographic skills develop which allow instant word recognition based on a systematic analysis of words into orthographic units. Some researchers (e.g. Stuart and Coltheart, 1988; Seymour, 1990; Masterson et al., 1992), however, argue that some children may learn to read alphabetically without passing through a logographic stage. This might be because the teaching strategies to which the child was exposed may have masked the parallel development of early logographic and alphabetic strategies (e.g. Sey-

mour and Elder, 1986). Thus, later models argue that these stages may not be necessarily acquired in a particular order.

More importantly, however, both Frith (1985) and Seymour (1987) agree that the acquisition of both a lexical (logographic) strategy based on whole word recognition and a sub-lexical (alphabetic) processing strategy based on a grapheme-to-phoneme conversion (e.g. Stuart and Coltheart, 1988) or orthographic analogy using onsets and rimes (e.g. Treiman, 1986; Goswami, 1988, 1991, 1993; Goswami and Bryant, 1990) is necessary for skilled reading, especially of a language such as English. Failure to acquire either of these strategies is characteristic of developmental dyslexia, in particular, failure to acquire appropriate sub-lexical (i.e. alphabetic processing) skills is characteristic of developmental phonological dyslexia (Broom and Doctor, 1995; Frith, 1995). Frith suggests (Frith, 1985, 1992) that the dyslexic learners do not develop the ability to make quick and automatic links between letters and their sounds, and that they become arrested at the logographic stage. Further, Seymour (1987) postulates that the development of an orthographic lexicon depends on establishing both a core 'logographic lexicon' and an 'alphabetic lexicon', and this in turn depends on the acquisition of phonological awareness. Phonological awareness is the capacity to reflect on and manipulate the sound structure of words and is assessed in tasks such as rhyme judgements, phoneme deletions/additions and so forth. This is because reading draws on a wide range of psychological processes and cognitive skills, which may not necessarily be specific to reading, and may even begin their development well before children start to read (Ellis, 1993).

It thus seems that there is a strong correlation between the poor performance with the phonological awareness tasks and phonological dyslexia. For example, Stuart and Masterson (1992) examined the reading of a group of 10-year-old children, who they had first assessed as 4-year-old pre-readers. The children as 4-years olds with higher scores on phonological awareness tasks proved to be better readers at the age of 10 than those with lower scores (see also Frith et al. (1995) for dyslexics having a subtle and circumscribed cognitive deficit in the phonological system). Another such example can be seen in RE studied by Campbell and Butterworth (1985): RE was a compensated phonological dyslexic and a university student at the time of testing. She showed that her ability to read real words was within the normal range for her age and education, but her ability to read nonwords was very poor. She was also poor at phonological tests that require awareness of phonemic structure, such as rhyme or homophone judgements, and was poor at segmenting heard words into their component sounds. RE also had a restricted short-term memory. Instead of being able to use mappings from letters to phonemes to bootstrap her reading (Share, 1995), she painstakingly acquired a 'sight vocabulary' of new words, their meanings and pronunciations on a whole-word basis as she came across them. Other compensated developmental phonological dyslexics such as for example, Louise studied by Funnell and Davison (1989), or M-J studied by Howard and Best (1994, 1996) are all said to have impaired reading of unfamiliar words or nonwords with normal word reading. The impaired reading was also coupled with an impairment in phonological processing (e.g. impaired phonological segmentation and assembly) and impaired short-term memory span. Similarly, Snowling and her colleagues (Snowling et al.,

1986, 1992, 1994; Snowling and Hulme, 1989; Hulme and Snowling, 1992) carried out a longitudinal study of J.M., a boy with developmental phonological dyslexia. The study showed that despite his high I.Q., JM's reading ability was consistently delayed by two to three years compared to his chronological age group. He was also poor at reading nonwords: for reading 2-syllable nonwords, his age-matched control subjects read with an accuracy of 92%, while JM could read none. His short-term memory span was severely reduced.

1.2. Genetic basis of developmental dyslexia

It has now become clear through investigations of twins and families that developmental dyslexia has a genetic origin (Stevenson et al., 1987; Pennington, 1990, 1994, in press; DeFries, 1991; Cardon et al., 1994). Pennington (1994) reviewed literature on twin studies as well as family studies in both the USA and UK. He confirmed that dyslexia aggregates in families: (1) a substantial majority of affected children had affected relatives, (2) the average recurrence rate among first-degree relatives is high, and (3) there is frequent transmission across two or more generations. Similarly, greater concordance for the trait of dyslexia was found amongst monozygotic than dizygotic twins. Pennington further postulated that dyslexia is not a single-gene recessive disorder, but instead dyslexia is due to 'several, more frequent quantitative trait loci that are involved in the transmission of both dyslexia and normal variations in reading skill' (p. S74). That is, several trait loci are jointly responsible for dyslexia, and Pennington claims that these quantitative trait loci best describe the genetic influences of many continuous behavioural traits including dyslexia.

1.3. Japanese Orthography

Before the discussion of dyslexia in the Japanese language, an introduction to the Japanese orthography is given. The Japanese writing system consists of two qualitatively different scripts: logographic, morphographic Kanji, derived from Chinese characters, and two forms of syllabic Kana, Hiragana and Katakana which are derived from Kanji characters (see Sampson, 1985; Wydell et al., 1993 for further discussion). These three scripts are used to write different classes of words as shown in Table 1. Kanji characters are used for nouns (which are not inflected in Japanese) and for the root morphemes of inflected verbs, adjectives and adverbs. Hiragana are used mainly for function words and the inflections of verbs, adjectives and adverbs, and for some nouns with uncommon Kanji representations. Katakana are used for the large number of foreign loan words (e.g. テレビ /terebi/TV) in contemporary Japanese.

1.3.1. Japanese Kana

Both forms of Kana have an almost perfect one-to-one relationship between character and pronunciation (and the very few exceptions, such as one or two Hiragana function words, which are of extremely high frequency). That is, one

Table 1
Japanese Kanji, Hiragana and Katakana. Kanji is transcribed in upper-case while both Hiragana and Katakana are transcribed in lower-case

Word class	Word	English translation
Noun	学生 GA-KU-SE-I	student
Verb	学ぶ MA-NA-bu	to learn
Adjective	美しい U-TSU-KU-shi-i	beautiful
Function word	しかし shi-ka-shi	but
Foreign loan word	テレビ te-re-bi	TV

character always represents one particular syllable or mora (syllable like unit) of the Japanese language, and its sound value does not change whether the character appears in the first position, the middle position or at the end of a multi-syllable word. This is different from English, where orthographic units not only map onto sub-syllabic phonological units, but the mapping will also depend on context, i.e. the location within the word. For both Hiragana and Katakana, there are 46 basic Kana characters (Takebe, 1979) but with diacritical marks (either " or o) and others, all the 110 syllabic or moraic sounds which exist in the Japanese language can be transcribed.

In the first year of primary school education (6–7 years old), Hiragana is taught first and then Katakana. Because of the transparent relationship between a Kana character and its pronunciation; one character represents a whole syllable/mora, it is known that children master both Kana scripts very quickly. Most children learn Hiragana script even before they start primary school education (Makita, 1968; Muraishi, 1972; Sakamoto and Makita, 1973; Gibson and Levin, 1975).

1.3.2. Japanese Kanji

In contrast, Kanji characters are at the other extreme end of the continuum - the relationship between character and pronunciation in Kanji is very opaque. This is because each Kanji character is a morphographic element that cannot phonetically be decomposed in the way that an alphabetic word can be. There are no separate components of a character that correspond to the individual phonemes (see Wydell et al., 1995 for a further discussion).

Words in Kanji have 1–5 characters with two being the modal number, and 2.4 the mean (Yokosawa and Umeda, 1988). Also, most Kanji characters have one or more ON-readings, (pronunciations that were imported from spoken Chinese along with their corresponding characters) as well as KUN-reading from the original Japanese spoken language. Some characters have no KUN-reading, but for those which have, the KUN-reading is almost always the correct reading when this character constitutes a word on its own. For example, the character 花 pronounced as /

hana/ in KUN-reading is a single-character word meaning ‘flower’. Also, the same KUN-reading can be seen in two-character words such as 花束/hanataba/(bouquet), or 花屋/hanaya/(florist). However, the same character is also pronounced as /ka/ in ON-reading as in 花瓶/kabin/ (vase) or 花粉/kafun/ (pollen).

Kanji learning is essentially by rote[1]: children are introduced to new Kanji characters in texts. The learning method which is commonly in use is repeated writing (Kusumi, 1992) or rehearsal by writing (Naka and Naoi, 1995) including KUSHO, literally meaning write in the air (see Sasaki, 1987 for a more detailed account of Kusho). During the six years of primary school education, children are introduced to 996 different Kanji characters, which are prescribed in the List, GAKUNENBETSU KANJI HAITO HYO by the Japanese Ministry of Education. By the end of compulsory education (age 16 years), a total of about 2000 Kanji characters are taught. It should be noted, though, that adults need some 3000 characters for most everyday activities (e.g. reading a national newspaper).

Thus, the two different types of scripts, syllabic/moraic Kana and logographic Kanji, require Japanese children to use different learning strategies. For Kana, the relationship between a Kana character and its sound is one-to-one and transparent, they use a simple script-to-sound translation in reading. On the other hand, for Kanji, a Kanji character and its sound is often one-to-many, and the correct pronunciation is determined at the word level. Thus, children learn Kanji characters/words by rote, essentially by repeated writing. Therefore, cases of developmental dyslexia, in particular phonological dyslexia, as defined by the World Federation of Neurology, would not be expected because of the nature of the Japanese orthography.

1.4. Dyslexia in Japan

Having to cope with not just one but three different scripts, it might be reasonable to assume that Japanese children would experience greater difficulty in learning to read and write than native English speaking children learning the English alphabet. However, the concept of developmental dyslexia is relatively unknown in Japan, and some research (e.g. see Makita, 1968 for his nation-wide survey) revealed that less than 0.1% of children have a reading disability in Japan. Makita (1968), Sakamoto and Makita (1973), and Muraishi (1972) all presented evidence for the ease with which the Japanese writing system is learnt. They all attribute the high rate of literacy to the writing system.

In order to test the validity of this proposal, Stevenson et al. (1982) in co-operation with Chen-chin Hsu and Seiro Kitamura conducted reading tests on fifth grade

[1]Japanese children are not taught analytical ways of looking at Japanese Kanji characters (e.g. phonetic radicals and semantic radicals) until they are at Junior High School level. This is partly because the children learn simple characters first which do not contain phonetic or semantic radicals. Further, even when they learn complex Kanji characters, which contain both phonetic and semantic radicals, the phonetic radicals are not necessarily an accurate guide to the correct pronunciation. For example, the phonetic radicals give no clue at all to KUN-reading, and in a sample of 1668 commonly used Kanji characters analysed by Saito et al. (1995), only 32% have ON-readings identical to their phonetic radicals. Thus, Kanji character learning is at the level of whole characters, if not at the whole word level. We thank a reviewer of this paper to draw our attention to clarify this point.

primary school children in America, Japan and Taiwan. The tests consisted of reading meaningful textural material, presented in clauses, sentences and paragraphs rather than single word reading. The children were asked to respond to true-false and multiple choice questions. It was found that there were children in all three countries who were performing at least two grade levels below average fifth graders, and the percentage of these children in the United States, Japan and Taiwan were 6.3%, 5.4% and 7.5% respectively. The performance of the Chinese and Japanese children in these tests is consistently related to cognitive abilities, in particular, general information (i.e. common knowledge that a child has accumulated through everyday experience) and verbal memory. Their study did not include any single word reading tests where no contextural information can be utilised. In general single word reading tests are used as diagnostic tools to identify children with reading impairments. Thus their study does not permit any conclusions to be made about the occurrence of phonological dyslexia in any of the countries.

More recently, rather than group studies, single case studies of children with reading disorders in Japanese have started to emerge. For example, Kaneko et al. (1997, 1998) reported a case study of K.A., a second grade primary school boy (7 years old) who showed severe difficulty in reading Kana and Kanji. He could read only 50% of the basic set of Kana characters and his accuracy in writing-to-dictation for the same set was only 60%, while normal 7-year-old children would have fully mastered the reading and writing of all of the Kana characters. He also showed a deficit in visuospatial perceptual tasks (e.g. copying a drawing of a cube or the block design test). Further, his SPECT (single photon emission computed tomography) revealed reduced cerebral blood flow in the left inferior parietal lobules, including the angular gyrus. For such reported cases, there is often an identifiable neurological cause for the reading difficulty. The majority of children in Japan who are classified as having a leaning disability (LD) have both reading and writing difficulties, and often the writing impairment is more severe than the reading impairment. Significantly, in Japan there are very few reported cases of children with reading impairments only. The Japanese researchers usually attribute these reading and writing impairments among children to ‘visual’ or ‘visuospatial’ processing problems (e.g. Uno et al., 1995; Kaneko et al., 1997; Uno and Kamibayashi, 1998) rather than phonological processing problems.

It should be pointed out however that such cases are still rare, and as Makita claimed back in 1968, the great majority of children learn how to read and write in Japanese without noticeable problems. Even when the children are identified as having reading disabilities, these children tend to have specific other cognitive deficits as well (Stevenson et al., 1982). Further, these reading disabilities tend to be due to visuospatial rather than phonological processing impairments (e.g. Uno et al., 1995; Kaneko et al., 1997, 1998). Therefore, these children are different from the developmental dyslexic children defined by the World Federation of Neurology. In order to account for differences in the occurrence of dyslexia, and differences in the nature of the reading problems between Japan and English speaking countries, as well as to explain the current case, we postulate the ‘Hypothesis of Granularity and Transparency’.

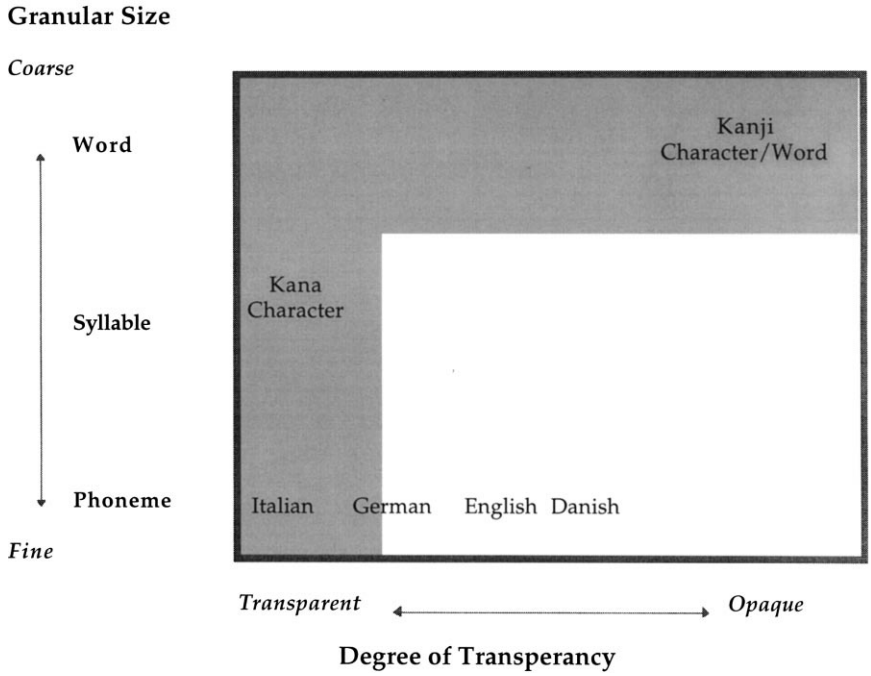
1.5. Hypothesis of granularity and transparency

As discussed earlier, learning to read English is essentially acquiring complex mappings of sub-syllabic phonological components (i.e. phonemes) to the letter level (i.e. graphemes). Failure to acquire appropriate sub-syllabic skills is characteristic of developmental phonological dyslexia. The 'Hypothesis of Granularity and Transparency' we put forward here maintains that orthographies can be described in two dimensions: 'transparency' and 'granularity' and argues that: (1) any orthography, where the print-to-sound translation is one-to-one or transparent will not produce a high incidence of phonological dyslexia regardless of the level of translation, i.e. phoneme, syllable, character, etc. This is the 'transparency' dimension, and (2) even when this relationship is opaque and not one-to-one, any orthography whose smallest orthographic unit representing sound is coarse, i.e. a whole character or whole word, will not produce a high incidence of phonological dyslexia. This is the 'granularity' dimension.

Any orthography used in any language can be placed in the transparency-granularity orthogonal dimension described by this hypothesis. This is illustrated in Table 2.

The hypothesis argues that any orthography that falls into the shaded area in Table

Table 2
Hypothesis of granularity and transparency and orthography-to-phonology correspondence. The shaded area on the 'transparency' dimension represents almost 100% transparency



2 should not produce a high incidence of phonological dyslexia. Given the characteristics of Japanese orthography, both Japanese Kana and Kanji can be placed in the shaded area. For example, for Japanese Kana, the granularity of the smallest orthographic unit representing phonology is finer than the whole word, but coarser than the grapheme, and its orthography-to-phonology translation relationship is at the level of syllables and one-to-one. For Kanji, on the other hand, the unit of granularity is much coarser, i.e. a character or a whole word, and the relationship between orthography and phonology is very opaque, hence Kanji can be placed in the shaded area. Therefore, by this hypothesis of granularity and transparency, then, neither of the two orthographies used in Japanese should lead to a high incidence of phonological dyslexia. In contrast, with this categorisation, English can be placed outside of the shaded area, since the granularity for English is fine, however, the translation between orthography and phonology is not always one-to-one and not transparent. By this hypothesis, English orthography may lead to a high incidence of phonological dyslexia. Given the differences between the two orthographies used in Japanese and English, therefore, the hypothesis of granularity and transparency argues that it might be possible for an English-Japanese bilingual individual to be dyslexic in English but not in Japanese.

Evidence supporting the 'transparency' dimension of the hypothesis can be found in the study of Landerl et al. (1997) where they examined reading and phonological processing skills in English and German dyslexic children against their normal age-matched and reading-level matched controls. They found that although the same underlying phonological processing deficit might exist in both German and English dyslexic groups, there were differences in the severity of reading impairment; English dyslexic children showed a marked adverse effect on acquisition of reading skills compared to German dyslexic children. These differences were also apparent between the normal German and English control subjects in reading performance. Landerl et al. suggested that these differences were due to differences in orthographic 'consistency'. That is, different orthographies have different mapping rules, and there is a wide range in the degree of consistency with which alphabets represent phoneme by grapheme. 'Consistency' here is interchangeable with 'transparency'. For orthographies such as Italian, Spanish or Turkish, the grapheme-to-phoneme mapping is, in general, one-to-one, and consistent/transparent. For others, on the other hand, such as English or Danish, the grapheme-to-phoneme mapping is often one-to-many (e.g., pint vs. hint, lint or tint; food vs. hood vs. flood or blood), and less consistent/transparent (e.g. Parkin, 1982; Seidenberg et al., 1984). Thus it was assumed that orthographic consistency/transparency affects both the nature and degree of reading difficulties.

Landerl et al. further argued that phonological recoding itself may not necessarily be a demanding task. When grapheme-to-phoneme mappings are consistent/transparent, children can easily acquire the grapheme-phoneme correspondence rules, and use these to assemble pronunciations for novel letter strings, as with Italian or Spanish children. The phonological recoding may become a demanding task, only when the grapheme-phoneme relation in an orthography is not consistent/transparent, such as for example, English or Danish. Therefore, if the grapheme-phoneme

relation is consistent, even children with phonological deficits may be able to learn to map print onto sound without showing a delay in reading acquisition. Similarly, the 'hypothesis of granularity and transparency' in particular, the transparency dimension predicts that developmental phonological dyslexia should not manifest itself in a writing system where the print-to-sound relationship is transparent regardless of the size unit of granularity. Also, the granularity dimension of the hypothesis predicts that developmental phonological dyslexia should not manifest itself in a writing system where the unit of granularity is coarse at a whole character or whole word level. It should therefore be possible to find a bilingual individual with monolingual dyslexia, especially between two orthographies such as English and Japanese[2].

2. Case report

2.1. Case history

AS was a 16-year-old boy at the time of the first assessment, and is the oldest of three siblings. He was born in Japan to highly literate Australian father and English mother. His father is an internationally known investigative journalist and writer, and his mother is an English language teacher. Although both of his parents are left-handed, AS and his siblings are right-handed. The spoken language at home is English. AS's reading and writing problem in English was first noticed by his parents, in particular, by his father, who claims that he had similar problems[3] when he was a child in Australia (although he has now compensated for his pro-

[2]One of the reviewers drew our attention to the study of Rickard Liow (in press) on a Chinese-English bilingual who showed difficulty in reading and writing only in English. However, the main bulk of this paper is about Chinese-English and Malay-English bilingual children in Singapore, and the actual case study on the Chinese-English bilingual child is very brief. Rickard Liow noted that in Singapore, Malay-English bilingual children perform better in English than do Chinese-English bilingual children. She argued that this difference was due to the different reading strategies adopted by the two groups of bilinguals. That is, the Chinese-English bilingual children learn to read (logographic) Chinese through visual analytical strategies rather than a phonological strategy, hence they lack phonemic awareness. In contrast, the Malay-English children learn to read (alphabetic and shallow) Malay through a phonological strategy, and thus it is easier for them to transfer from Malay to English. By Rickard Liow's definition, then it appears that all Chinese children who learn to read Chinese first are dyslexic in English. If her hypothesis is applied to our AS who, we assume for the sake of argument, learned to read Kanji and Kana first, he must lack phonemic awareness, hence his performance in English should be poor just like his Japanese contemporaries. However, it will become clear that the Japanese controls perform better in English than does AS. Further, the pattern of reading/writing performance of AS in English is very different from that of the Japanese controls but similar to that of English phonological dyslexics.

[3]We also conducted various tests on all the members of AS's family except for the youngest. The performance levels of AS's father on these tests in English were all at ceiling level. However, his phonological lexical decisions took more than twice as long as orthographic lexical decisions (3.34 and 1.37 min, respectively), while AS's mother showed much smaller discrepancy over time in her phonological and orthographic lexical decisions (2.35 and 1.52 min, respectively). This might be a tantalising piece of evidence that perhaps AS's father is a compensated dyslexic, as he himself claims to be.

blems). This is consistent with the genetic origins of dyslexia in English (e.g. Pennington, 1990, 1994).

2.1.1. AS up to the age of 6–7 years

AS's home language has been English. His mother is an English language teacher, and she used to read him English storybooks almost every night from the age of 1 to 14 years (e.g. Winnie the Pooh, Roald Dahl, and some Australian Children's books). AS was taught to read English at home by his mother. She used the British Ladybird reading series. At about age seven and about 'Book Five' of the Ladybird series, she first noticed that AS was 'reading' these books back to her, even when words in the text were covered.

2.1.2. AS at 6/7–12 years old

AS began his formal education in Japan when he was 6 years old, and progressed to a local junior high school at 12 years old. English language teaching at home continued - at the age of about 10 years, AS's mother used the Oxford University Press's English Today series for teaching English as a foreign language. AS completed up to Book Five, and also the OUP Activity Books for Children (ABC) one to six.

2.1.3. AS at 13–15 years old

Despite his good spoken English, AS's reading and writing of single words in English were said to be below the class average at his junior high school, although his comprehension and translation into Japanese of English sentences and passages (where context could help him) were well above average. When AS was 13 years old, he was diagnosed as dyslexic by The Dyslexia Institute in London; at the time both his reading and writing were several years below his chronological age (both 6:1 years), while his arithmetic age was 14:6 years. They reported on AS's IQ as 'at least average from the Slosson IQ test', adding that 'Given his level of ability, and his good spoken language skills, one would expect [AS] to acquire the written language skill without any particular difficulty.' Further, on the Vernon reading test they reported that '...His errors revealed that while he is building a sight vocabulary when faced with a word he does not recognise, he resorts to guessing on minimal clues. For example, he read 'Friday' for 'friendly', 'o'clock' for 'ocean' and 'mother' for 'mouth'...'. It also revealed a discrimination difficulty with 'b's and 'd's. He read 'dirty' for 'beauty' and 'different' for 'before'.

His mother continued to teach English reading to AS at home. Also, after the assessment at the Dyslexia Institute in London, AS had extra tuition in reading and writing by an English speech therapist who was recommended by one of the international schools in Japan. She used two textbooks, 'Word Attack Basics' and 'Decoding' (McMilland McGraw Hill, Chicago, 1988), consisting of a teacher presentation book and student's workbook. Due to confinement of the speech therapist, AS's mother took over teaching with these text books, three to four times a week for a year until AS finished the workbooks. AS's mother being unable to find the next books in the series, concentrated on helping AS with his English class work at his

junior high school, for roughly two hours a week of one-to-one teaching. Throughout the junior high school, AS's mother read him such books as the Hobbit, and the Narnia Chronicles, answering questions on words he did not understand so that AS could increase his vocabulary in English.

2.1.4. AS at 16–18 years old

AS attended a Japanese state-maintained selective senior high school, which is regarded as one of the best and most selective schools in the area. The majority of children from this school go on to higher education at the age of 18 years old. If he had shown any sign of reading impairment in Japanese, he could not have passed the competitive written entrance examinations (personal communication with the headmaster of his school). AS was highly motivated to learn English, since he hoped to study for a degree in a university abroad rather than a university in Japan. He was a confident and popular member of his school, and was elected to be the vice-president of the students council at his senior-high school where approximately 1000 students attended. He regularly wrote Japanese book reviews in Japanese for the school library. AS read by himself American English books describing a role-playing game, and began translating them into Japanese in his final year at his senior high school so that his Japanese-speaking friends could play the game with him. When he graduated the senior high school he must have had a Kanji vocabulary of 3000 characters since this is the minimum required for the assessment test below. He now attends an English speaking university outside of Japan.

3. Assessments

AS was assessed twice, once in London, UK in 1995 when he was 16 years old and again in Japan in 1996 when he was 17 years old. We also compared AS's performance on some of the tests with both that of his Japanese classmates at his senior high school and English age-matched control subjects.

3.1. Assessments in Japanese

3.1.1. SUUKENSHIKI CHINOU KENSA - IQ test

Suukenshiki Chinou Kensa was the standard IQ test, which was used in all the schools throughout Japan. AS's Suukenshiki Chinou Kensa IQ scores[4] when he was in the second grade (7 years) and the sixth grade (12 years) at his primary school were 58 and 57 respectively, while the standardised national average was 50 (instead of the mean of 100 in the western IQs). AS was in the top 31 percentile.

[4]Majority of the prefectures including Tokyo (i.e. analogous to the states in the USA or county in the UK) in Japan no longer automatically administer IQ tests on school children. By the time AS became a junior high school pupil, the prefecture that he has lived decided not to carry out IQ tests on their children.

Table 3
Examples of two-character Kanji word stimuli used to test AS

Target word	Reading	Correct pronunciation	LARC pronunciation[a]
(1) Consistent-ON			
気候	ON	KI-KOU	N/A
(2) Inconsistent-ON			
家屋	ON	KA-OKU	IE-YA (KUN)
(3) Inconsistent-KUN			
毛糸	KUN	KE-ITO	MOU-SHI (ON)
(4) Jukujikun			
雪崩	JUKUJIKUN	NADARE	SETSU-HO (ON) YUKI-KUZURE (KUN)

[a]LARC, legitimate alternative reading of components.

3.2. Reading ability in Japanese

3.2.1. Kanji

Table 3 shows examples of two-character Kanji word stimuli used to assess ASs Kanji word reading ability. In order to perform this test within the range of normal adults, knowledge of 3000 Kanji characters is required.

The stimuli of two-character Kanji words were taken from the experiments that Wydell et al. (1997) conducted with Japanese normal adults. The stimuli consist of 160 stimulus words which were evenly divided into four different word types: Consistent-ON, Inconsistent-ON, Inconsistent-KUN, and Jukujikun. Each word type was further dichotomised into high and low frequency words. Consistent-ON words were those in which each constituent character has only a single ON-reading and no KUN-reading. Inconsistent-ON words were those in which either one or both characters have a KUN-reading, but a target word takes an ON-reading. These items were regarded as inconsistent regular, as ON-reading is more typical when two or more characters form words. Inconsistent-KUN words were those in which each character has both an ON-reading and a KUN-reading, but a target word takes an atypical KUN-reading, hence these words are regarded as inconsistent irregular. Jukujikun is a limited and unusual set of Kanji words, in which a whole word has a unique pronunciation that does not correspond to any standard ON- or KUN-reading of the component character. For example, 雪崩/nadare/ meaning avalanche, the first character means ‘snow’, and is typically pronounced /setsu/, and the second character means ‘to collapse’, which is typically pronounced /hou/ in multi-character words. These characters occur in many words, and also have KUN-readings, /yuki/, and /kuzu(reru)/, respectively. Therefore, the correct pronunciation of a Jukujikun can only be assigned by knowing the word (see Wydell (1998) for more details).

Table 4 shows the accuracy data of AS together with those of the normal Japanese adults taken from Wydell et al. (1997).

Also shown are AS’s median RTs (in italics) for each condition together with the

Table 4
AS's performance on two-character Kanji word naming test

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

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

median RTs (*in italics*) of the two youngest subjects (aged 20 and 22 years) taken from Wydell et al. (1997).

His accuracy in reading two-character Kanji words is equivalent to Japanese undergraduate level[5] except for low familiar Jukujikun ($z = -3.63$, $P < 0.0009$). The latter may be due to the fact that he has not had enough exposure to low familiar Jukujikun. When AS was tested with these words, he was 16 years old, while the youngest subject who participated in the experiment of Wydell et al. (1997) was 20 years old (mean age was 31 years old). Kanji learning is essentially a life-long continuous learning process. If he were continuously educated within the Japanese educational system, he would most probably be able to read these low familiar Jukujikun by the time he graduated from a Japanese university. AS's naming latency is also comparable with those of the two young adults from the study of Wydell et al. (1997). His shorter latency for low frequency Jukujikun words suggests a sort of RT and accuracy trade-off, that is, he only knew a smaller set of these words, and those he knew he could pronounce fast.

3.2.2. Kana

It was assumed that AS should have no problem with his skill in reading Kana, especially since the Kana script is the very basic form of the Japanese written language. The Japanese children learn how to read in Kana first, and then Kanji characters are gradually introduced to them. Without Kana one cannot learn Kanji. Nevertheless, just for the sake of completeness of the data, a Kana reading test was carried out on AS. The stimuli were taken from the experiments conducted by

[5]Another piece of evidence which shows that AS has an above average command of Kanji vocabulary for his age is seen in his accuracy score on the 100 RAKAN Kanji Word Reading Test (Kondo and Amano, 1996) administered in 1997. AS's accuracy was 57%, while other subjects with senior high school education (19–22 years) scored on average 30% correct. It is said that those with the accuracy rate of above 70% on this test are regarded as truly accomplished adult readers in Kanji.

Table 5
AS's performance on Katakana word naming test. The control data are from the adult data from Wydell and Humphreys (in press)

Word type	AS	(Control)		AS	(Control)
	High frequency (n = 40)			Low frequency (n = 40)	
Katakana word	100%	(99.75%)		100%	(96.25%)
Kanji in Katakana	97.5%	(97.25%)		97.5%	(95%)
Nonword in Katakana			91.3% (92.1%)		

Wydell and Humphreys (in press) with Japanese normal adults, and consist of either 3-syllable or 4-syllable Katakana strings. There were three types of stimuli: Kanji words transcribed into Katakana (e.g. ガクセイ (student) for 学生), Katakana proper words (e.g.テレビ (TV)) and word-like nonwords where the 2nd syllable of three syllables were changed (e.g. KA-MI-RA; カミラ for KA-ME-RA; カメラ (camera)) or the second and third syllable of a four-syllable word were swapped (e.g. SA-PU-N-RU; サプンル for SA-N-PU-RU; サンプル (sample)). There were altogether 240 Katakana stimulus strings: 40 high frequency and 40 low frequency words for each word condition, the Katakana transcriptions of Kanji and Katakana words, and 80 Katakana nonwords. AS's performance on this test is shown in Table 5 together with the performance of 10 normal Japanese adult subjects who had participated in Wydell and Humphreys' study.

His ability to read Katakana strings is again equivalent to that of any accomplished reader. Note especially that he had no problem with reading nonwords that sounded like real words (similar to English pseudo-homophones) as well as those that did not. This is in marked contrast to phonological dyslexics in English such as RE (Campbell and Butterworth, 1985), and as we shall show, to AS's reading in English.

Thus, AS did not show any apparent impairment in reading Kanji and Kana. In fact, his ability to read both Kanji and Kana at the age of 16 years old was superior to that of many of his Japanese contemporaries, and was well within the range of accomplished adult readers.

3.3. Assessments in English (I)

3.3.1. Comparison with the English control subjects

Table 6 summarises the results of AS's performance on various tests in English. The table also includes the results from English age-matched pupils[6] as his control subjects from two schools (one selective and the other comprehensive) in London, for the selected tests. These are discussed where appropriate.

3.3.1.1. Phoneme categorisation. He had no problem with letter names, letter

[6]Due to time constraints, the pupils from Hampstead Comprehensive School completed six different tests, discussed later, while those from Latymer School completed 13 different tests (though one to two subjects did not complete all 13 tests).

Table 6
The results of AS's performance on various tests in English with the results from the English control subjects where available. The control data are from the age-matched English subjects from Latymer School in London

Task		Performance level		
		AS	Control	
Phoneme categorisation		Normal		
WAIS (written) Word comprehension/Definition		7/20 (35%)		
BPVS		Raw score: 105/150		
Digit span				
English	Forward	5		
	Backward	5		
Japanese	Forward	5		
	Backward	5		
Phonological tasks				
Gathercole and Baddley's Nonword Repetition		34/40 (85%)	38.4/40 (96%)	sig.
Spoonerising		10/20 (50%)	18.7/20 (93.5%)	sig.
Stuart's Consonant Deletion				
WORD		34/40 (85%)	95%	sig.
NONWORD		36/40 (90%)	91%	n.s.
Stuart's Consonant-Cluster Deletion				
WORD		24/40 (60%)	92.5%	sig.
NONWORD		31/40 (77.5%)	86%	sig.
Reading tasks				
Reading aloud (words)				
Schonell		34/100	(34%)	
NART		1/50	(2%)	
Patterson and Hodge's Surface List				
		Regular	Exception	
	High frequency	24/42 (57%)	22/42 (52%)	
	Medium frequency	18/42 (43%)	9/42 (21%)	
	Low frequency	13/42 (31%)	7/42 (17%)	
Reading aloud (nonwords)				
Glushko's nonwords		12/43(43%)	42/43 (97.7%)	sig.

sounds (except for N, for which he gave a Japanese nasal sound) or phoneme categorisations.

The phoneme categorisation test is a computerised test devised by Hazan and Adlard (1996). Given an example of rhyming word pairs, PEA and KEY, the artificial sounds between PEA and KEY are created so that KEY and PEA are at each extreme end of the same continuum. These sounds including KEY and PEA are given to a subject one at a time through a headphone. The subject is then asked to press one button if he/she thinks that the stimulus is KEY, and to press the other button if it is PEA, thus categorising the stimulus sound as either PEA or KEY. This test has been used as a diagnostic tool to identify children with reading impairments:

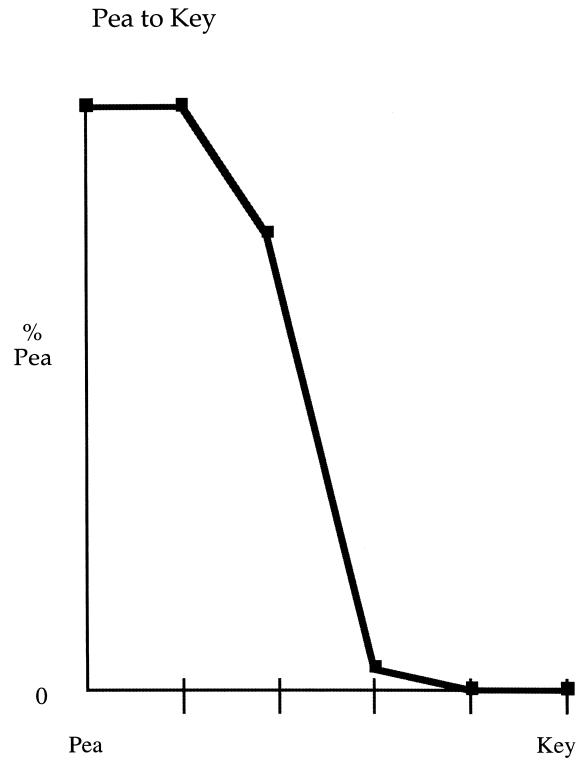


Fig. 1. AS's performance on phoneme categorisation (KEY/PEA).

idiosyncratic performance in this test correlates with poor reading performance (Hazan and Adlard, 1996). His performance for PEA/KEY categorisation is shown in Fig. 1 and this pattern is well within the normal range and that of a standard native English speaker (Hazan, personal communication).

3.3.1.2. Word comprehension/definition. AS was asked to read a stimulus word aloud first, and then give a definition of the word. The stimulus words used for this test are from WAIS (Wechsler, 1986). His performance here was also very poor[7].

3.3.1.3. BPVS (British Picture Vocabulary Scale; Dunn et al., 1982). This is a task where a subject is asked choose the right picture out of an array of four pictures (the three distracters consist of a semantically related picture, a phonologically related picture and a control picture) to a spoken word. His raw score was 105, and this is the

[7]We are aware that we should have given him the word definition test to spoken words rather than written words, but this particular test was one of the very early ones that we administered when we were not sure of the extent of his reading problem.

bottom 5th percentile. This result may be a reflection of him not being able to read, which is different from not wanting to read. Especially he is an avid reader in Japanese, and has a large vocabulary in Japanese for his age. Being able to read, and in turn reading is the major engine for increasing one's vocabulary. This conjecture can be supported by AS's erroneous responses; the words for which he gave wrong responses tended to be lower frequency and possibly one would call literal words[8].

3.3.1.4. Digit Span (WAIS). His digit span was five for both forward and backward in English, and this was the same in Japanese. These scores are 1 SD below the age-matched norm, and at the bottom of the normal range.

3.4. Phonological tasks

3.4.1. Nonword repetition

His performance on the multi-syllable nonword repetition of Gathercole and Baddeley (1996) (see also Gathercole et al., 1994) appears quite good. He scored 34/40 (85%) correct, however, this is significantly worse than the age-matched English control subjects; 12 pupils from Latymer School scored 38.4, on average ($z = -3.96$, $P < 0.0004$). His errors were very close to the stimuli, for example, phoneme addition: hampent → trampent; phoneme deletion: perplisteronk → per-pisteronk; confrantually → confantually; phoneme substitution: stopograttic → stopograffic; voltularity → vertularity.

3.4.2. Spoonerising (Perin, 1983)

In this test, a subject is asked to exchange the initial phonemes of two words, for example, Bad Manners should be changed to Mad Banners. This is a phonologically demanding task requiring not only to segment the words into consonantal onset and rime, but also to reassemble these segments into new phonological sequences (Perin, 1983; Campbell and Butterworth, 1985; Landerl et al., 1997). He had great difficulty in carrying out this task, and his responses were not spontaneous at all. He scored only 10/20 correct, which is substantially below the 11 control subjects from Latymer School whose mean score was 18.7 ($z = -5.08$, $P < 0.0001$).

3.4.3. Consonant deletion task (Stuart, in preparation)

This is a test of phoneme deletion from spoken monosyllabic stimuli. Subjects are asked, 'Say 'soil' without the /s/ (OIL).' AS scored 85% (34/40) correct for words, and 90% (36/40) correct for nonwords. The average correct scores of 11 normal English control subjects from Latymer School were 95% (38.6/40) for words; 91% (36.5/40) for nonwords. The difference between AS and the control subjects was only significant for words ($z = -2.69$, $0 < 0.003$).

[8]We are grateful to a reviewer for raising this point. AS made errors on lower frequency words that this reviewer might classify as literary words, such as for example, delectation, salutation, carrion, pinnacle, emaciated, deciduous, convergence, edifice, pedagogue.

3.4.4. Consonant cluster deletion task (Stuart, in preparation)

This is similar to the test above, and subjects are asked, 'Say 'brave' without the sound /r/ (BAVE).' He scored 60% (24/40) correct for words, and 77.5% (31/40) correct for nonwords. The average correct scores of the same subjects as above were 92.5% (37/40) for words and 86% (34.5/40) for nonwords, respectively. The difference between AS and the control subjects was significant for both the words ($z = -7.81$, $P < 0.0001$) and the nonwords ($z = -1.84$, $P < 0.032$).

3.5. Reading tasks

Reading aloud both words and nonwords are generally poor. Some of AS's erroneous responses are shown in Table 7.

3.5.1. Reading aloud words

For the Schonell List, he scored 42.5% while for NART (National Adult Reading test; Nelson, 1983), his correct response out of 50 items was only one ('simile' was read correctly). Yet, his actual responses were always spontaneous, as if he knew the words very well, and never laborious. Correctly pronounced words tend to be high frequency and high familiar words (e.g. book, school, little, postage). Some of these words are irregular words such as for example, island, but these tend to be fairly high frequency/familiar words and these words are probably well established in his orthographic lexicon, though assumed to be limited.

The SURFACE list from Patterson and Hodges (1992) was administered. There are altogether 252 stimulus words divided by word-type (either regular or exception) and by word frequency (either high, medium or low frequency), thus each cell has 42 words. AS's performance was also poor here. AS made as many as 18 errors out of 42 high frequency regular words. Some of his erroneous responses were lexical substitutions (e.g. same → thumb; while → will; air → are; girl → grill). This tendency was also seen in his errors with high frequency exception errors (e.g. own → one). The majority of the words he substituted were high frequency words, and when these high frequency words are presented to him, he could read them correctly. This implies that he is not segmenting the letters in a word, but he is consulting his limited orthographic lexicon, and comes up with the closest approximation (i.e. visually similar words). His data also showed no regularity effect (chi-square (2) = 1.83, in order to be significant at $P < 0.05$, the observed value of x^2 has to be equal to or greater than 5.99). There are no age-matched control data for AS.

3.5.2. Reading aloud nonwords

For the nonwords of Glushko (1979), his performance was extremely poor: he scored only 12/43 correct, while 12 English control subjects from Latymer School, on average, scored 42/43 correct ($z = 27.78$, $P < 0.0001$). Some word substitution errors such as for example, brobe → broad; gode → god or moop → mock, were seen in AS's errors, which are suggestive evidence that he might consult his limited orthographic and/or phonological lexicon in reading nonwords.

Table 7
Examples of AS's errors in reading words (Schonell and NART) and nonwords (Glushko). Pronunciation key (see Zorzi et al., in press): /i/ in bean, /A/ in bear, /O/ in born, /u/ in boon, /3/ in burn, /I/ in pit, /e/ in pet, / and / in pat, /V/ in bud, /0/ in pot, /U/ in good, /eI/ in bay, /aI/ in buy, /oI/ in boy, /@U/ in no, /aU/ in now, /e@/ in where, /I@/ in here, /tS/ in chain, /9/ in think, /T/ in this, /S/ in ship. Stressed syllables are proceeded by '

Target word	AS's response
Schonell	
Angel	Angry
Attractive	/@'tr@sItIv/
Beguile	/bI'gIl/
Biscuit	/'bIskOt/
Ceiling	Killing
Colonel	/k0-l0-nel/
Conscience	/k0nsI'kens/
Downstairs	/daUnes'trVs/
Fascinate	/'f and sient/
Genuine	/'dZentin3/
Gnome	/g@'n and m@l/
Orchestra	/0treI 'st@/I
Physics	/'peIsIks/
Pneumonia	/seI'menu@/
Sabre	/seI'bur/
Situated	/sI'teIted/
Soloist	/'s@UlIt/
Suceptible	/sVsI'pentibl/
Terrestrial	/'triz@ntrIl/
University	/VnIn'vestri/
Nart	
Ache	Archer
Bouquet	/'bl and kuet/
Camanile	/kl and mp@'n and li/
Debt	/'debet/
Gouge	/'g@Ug@U/
Heir	/'hirI@/
Idyll	/'Idjul/
Naïve	Nervy
Placebo	/'pl and k@bl@U/
Sidereal	/'sid3 – e'r0l/
Glushko's nonwords	
Brobe	Broad
Cath	/tS and s/
Doon	Dawn
Gode	God
Heef	/h39/
Lole	Lowly
Mune	/'h and n3/
Moop	Mock
Taze	/'tezU/
Wote	/hOt/

3.6. Discussion of English assessment (I)

Compared to his superior reading ability in Japanese, AS showed marked impairments in reading in English as well as in the tasks, which require phonological manipulation. For example, AS was severely impaired at the nonword repetition task. Some researchers argue that the impaired nonword repetition is a hallmark of developmental dyslexia, and that the task can be used as a diagnostic tool for identifying those children who might develop a reading impairment (e.g. Gathercole, 1995). He was also impaired at the task of 'Spoonerising', and so were the well-compensated adult phonological dyslexics studied by Paulesu et al. (1996). His responses were laborious and took considerably longer than his English control subjects. AS was poorer at homophone and pseudohomophone judgements (from Coltheart, 1980) than M.-J., an elderly compensated phonological dyslexic (studied by Howard and Best, 1996). Her performance was said to be significantly worse than that of the age-matched elderly control subjects.

AS's score on B.P.V.S. was poor, which might well be a reflection of him not being able to read English, since the usual engine of vocabulary increase is reading. His forward and backward digit span in both English and Japanese was 5, which is at the bottom of the normal range. Short-term memory is often impaired in developmental phonological dyslexics, and their memory span is shorter than normal subjects (e.g. Campbell and Butterworth, 1985; Funnell and Davison, 1989). Rack (1994) noted that 'one of the most reliable and often quoted associated characteristics of developmental dyslexia is an inefficiency in short term memory'. AS's short-term memory span is thus, indicative of AS being dyslexic in English. Why then does his short-term memory span not affect his reading in Kanji and Kana? According to Baddeley's working memory hypothesis (e.g. 1986), during reading the visual form is translated into a subvocal articulatory sequence, which then generates a phonological specification to be held into phonological store, which Baddeley calls the phonological loop. Further the phonological loop only appears to be critical in tasks requiring relatively complex analysis of the sound structure of printed material (Gathercole and Baddeley, 1993). The sound structure analysis of Kana is certainly simpler than English, since a single Kana character represents a whole syllable/mora, while for English phoneme blending is quite often required. This analysis for Kanji is qualitatively different from English, as discussed earlier, since each character is a morphographic element that cannot be phonetically decomposed in the way an English word can. Thus AS's ability to read both Kana and Kanji is not impaired.

Further, AS could read only one word correctly out of 50 N.A.R.T. words. Generally, the words that he could read were high-familiar/frequency words, and some of them were irregular words. Indeed, there was neither regularity effect nor regularisation error in AS's performance in reading the SURFACE list (Patterson and Hodges, 1992). His errors were most often 'random' errors in which no apparent or meaningful pattern could be found, except for some word substitution errors. The words he substituted tend to be visually similar high-familiar/frequency words (e.g. air $\rightarrow$ are), which might be already established in his 'limited' orthographic lexicon.

AS's nonword reading was severely impaired. Some of his errors were lexicalisations - he substituted the nonwords for words (e.g. moop → mock). Also, his performance level was significantly lower than that of his age-matched English control subjects. Thus, AS's English data revealed many traits of developmental phonological dyslexia.

3.7. Assessments in English (II)

3.7.1. Comparison with the Japanese and the English control subjects

In the next assessment AS's Japanese classmates were included as his Japanese control subjects. This was to eliminate the possibility that the lack of exposure to English might have caused AS's phonological dyslexia. These Japanese subjects had little exposure to English especially compared to AS. Ten science major classmates of AS participated in our experiments as his control subjects. These classmates started to learn English at Junior High School at the age of 12 as part of their school curriculum. Other than learning English at school, they had no exposure to English except occasionally from TV and films. It was hypothesised that the performance levels for these tests by his Japanese classmates could be similar to those of AS or perhaps lower than AS's. Certainly these children had far less exposure to English than AS both aurally and visually. Apart from these Japanese students, 25 English age-matched control subjects (from Hampstead Comprehensive School and Latymer School) were also compared using the same tests.

Table 8 shows the results of the performance of AS together with both the Japanese and his English control subjects on the selected tests.

3.7.1.1. Rhyme Judgements. This is a task where a subject is asked to determine whether a pair of words or nonwords rhyme. The stimulus list is from Howard and Franklin (1996) and consists of 20 orthographically similar rhyming word-pairs (e.g. cream/team; root/coot), 20 orthographically dissimilar rhyming word-pairs (e.g. train/crane; tough/fluff) and 20 non-rhyming word-pairs (e.g. rough/trout; shout/sort), while Best's (1996) stimulus list, modified from Brown (1990), consists of 50 nonword pairs, a half of which rhyme, and the other half do not. When the stimulus word pairs from Howard's list were presented to AS auditorily, he had no problem identifying which pairs of words rhymed (93.3% correct), however, when the same stimulus word pairs were presented to him visually, he had great difficult in identifying which pairs rhymed (43.4% correct). On word rhyme judgements, AS's score (26/60) was outside of the normal ranges of his English (40–60) and even Japanese controls (35–54). Further, it was significantly lower than those of both English and Japanese controls ($z = -6.26$, $P < 0.0001$ for the English subjects and $z = -2.76$, $P < 0.0029$ for the Japanese subjects, respectively). His performance on nonword rhyme judgements was outside of the range of the English controls (36–50) and was significantly lower than that of the English controls ($z = -5.72$, $P < 0.0001$), but not the Japanese controls.

3.7.1.2. Lexical decisions. Orthographic and phonological decisions[8] (Frith, in

Table 8
Comparison of the performance levels of AS on reading/spelling/phonological tests with those of English and Japanese control subjects

	Mean	Range	
Rhyme judgements			
Words (n = 60)			
English subjects (*n* = 23)	57 (95%)	40–60	sig.
AS	26 (43%)		
Japanese subjects (*n* = 10)	42.2 (70%)	35–54	sig.
Nonwords (n = 50)			
English subjects (*n* = 24)	46.8 (94%)	36–50	sig.
AS	28 (56%)		
Japanese subjects (*n* = 10)	31.7 (63%)	22–48	n.s.
Lexical decisions			
Phonological lexical decisions (n = 90)			
English subjects (*n* = 25)	82.8 (92%)	63–89	sig.
AS	46 (52%)		
Japanese subjects (*n* = 10)	57.0 (63%)	47–66	sig.
Orthographic lexical decisions (n = 90)			
English subjects (*n* = 25)	85.6 (95%)	74–90	sig.
AS	52 (57.8%)		
Japanese subjects (*n* = 10)	59.5 (66%)	54–65	sig.
Reading and spelling			
Reading (n = 50)			
English subjects (*n* = 25)	46 (92%)	34–50	sig.
AS	20 (40%)		
Japanese subjects (*n* = 10)	27.67 (55%)	23–39 ($P = 0.058$)	
Spelling (n = 50)			
English subjects (*n* = 25)	43.7 (87%)	26–50	sig.
AS	11 (22%)		
Japanese subjects (*n* = 10)	12.8 (26%)	9–18	n.s.

preparation) were used. For the phonological lexical decisions, a list of 90 written nonwords is given to a subject with the instructions, 'Does it sound like a word you know? If it does, write down a tick as 'YES', and it does not, write down a cross as 'NO'. Please work as fast and as accurately as possible.' For example, to a letter string such as 'brane', a subject is required to say 'yes'. For the orthographic lexical decisions, on the other hand, a list of the same 90 items (half of which are words and the other half are nonwords) is given to a subject with the instructions, 'Is it a correctly spelled word you know? If it is, write down a tick for yes, and if it is not, write down a cross for no. Please work as fast and as accurately as possible.' AS's performance on the phonological decisions (46/90) was outside of the normal ranges of his English controls (63–89) and even Japanese controls (47–66). His performance was significantly worse than that of both the English and Japanese controls ($z = -5.39$, $P < 0.0001$ and $z = -1.98$, $P < 0.023$, respectively). Similarly, on the orthographic decisions, his performance (26/90) was outside of the normal ranges of his English (74–90) and Japanese controls (54–65), and his performance was significantly worse than that of both the Japanese and English controls ($z = -9.00$, $P < 0.0001$ and $z = -1.96$, $P < 0.025$, respectively).

3.7.1.3. Reading and spelling. A half of Schonell's list with 100 words was used as the spelling test, and the other half as the reading test. On reading, AS's score (20) was outside of the normal range of the English controls (34–50) and even the Japanese controls (23–39). The difference was also statistically significant against the English subjects ($z = -6.84$, $P < 0.0001$), but the difference against the Japanese controls just failed to reach statistical significance ($z = -1.57$, $P = 0.0582$). On spelling, AS's score was well below that of the English controls (range 25–50; $z = -5.45$, $P < 0.0001$), but the difference in the scores between AS and the Japanese controls was not significant (range 9–18; $z = -0.72$, $P = 0.23$). However the type of errors that AS made are strikingly different from those made by the Japanese controls, and this also suggests that AS might be dyslexic in English, while his Japanese contemporaries are not.

3.7.2. Qualitative differences in the errors

The qualitative differences between his spelling and reading errors and those of his Japanese control subjects are shown in Table 9. For reading, Japanese subjects tend to produce a sort of 'regularisation errors' or LARC (Legitimate Alternative Reading of Components) errors (Patterson et al., 1995). This suggests that they can use grapheme-to-phoneme mappings, so for irregular words that they do not know, regularisation or LARC errors may be produced. In contrast, AS's errors are very different from those made by the Japanese control subjects, which suggests that AS appears to have no sound grasp of grapheme-to-phoneme mappings. Hence he is unable to segment letter strings appropriately. This is also apparent in his spelling.

Table 9
Qualitative differences between AS's spelling and reading errors and those of his Japanese control subjects. See Table 6 for pronunciation key

Target word	AS	Control
Reading		
University	/Vn-'yUnIsIti/	all correctly pronounced
Nourished	/'nOT3d/	/- SAd/; /- O -/
Beguile	/bI'gUl/	/- gUil/
Grotesque	/graU'teskel/	/- kyu/; / - kU/
Homonym	harmony	/h0'maUnIn/
Campaign	/'k and mpeg/	/- eI -/
Situated	/'stuted/	/- st -/; /- stu and - /
Judicature	/jekI'k and ntra/	/j and -/; /- 'k and tu/
Spelling		
Audience	ordience	oudience (majority); ordience
Antique	antiece	anteek (majority); antic
Attractive	atrcctinv	atractiv (majority); atlactiv
Nephew	nefaie	nefeu; nephue; nepue
Physics	fisicth	physicks; physicse; fisix; figgix
Preferential	prefrrencall	plefarental; preferanthele; prephalentul
Fascinate	fasanait	facinate (majority); fatsimate

3.8. Discussion of English assessment (II)

On the whole, AS's performance on rhyme Judgements, lexical decisions, and reading and spelling were not only worse than that of the English controls, but also that of the Japanese controls. On word rhyme judgements, he was significantly worse than the English control subjects as well as even the Japanese control subjects. On nonword rhyme judgements, however, he was significantly worse than the English subjects, but no worse than the Japanese subjects. Though his score was toward the lower range of the Japanese subjects. This is possibly because the nonword rhyme judgements were somehow more taxing for the Japanese subjects than the English subjects, and even AS. The discrepancy between the word and nonword rhyme judgements, i.e. a sort of lexicality effect was greater for the Japanese subjects than the English subjects or AS. AS's score on nonword rhyme judgements was in fact slightly better than that on word rhyme judgements.

For both the orthographic and phonological lexical decisions, AS was significantly worse than both the English and Japanese subjects. If lack of exposure to English is the cause of AS's poor performance on these phonological manipulation tasks, then the Japanese subjects who have had far less exposure to English than AS should not perform better than AS. The fact that AS was worse than the Japanese subjects on these tasks might be another indication of AS being dyslexic in English. There is a strong link between impaired phonological processing and phonological dyslexia. For example, Paulesu et al. (1996) showed that their adult well-compensated dyslexics, still showed residual phonological deficits on tests of phoneme deletion and spoonerisms (see Snowling et al., 1997 for a further discussion on phonological processing skills of dyslexia).

On reading and spelling, AS was significantly worse than his English control subjects. His reading score was also worse than that of the Japanese subjects, though this difference failed to reach significance. His spelling score was no worse than that of the Japanese subjects, though it is towards the lower range of that of the Japanese. Given the fact that he was taught English at home, no matter how informal and imperfect the teaching might have been, he should perform better than his control subjects who only started to learn English at the age of 11 to 12. Further, the qualitative analysis of errors revealed that the errors made by the Japanese subjects tended to be regularisation or LARC errors, indicating that they had some grasp of grapheme-to-phoneme translation, while the errors made by AS showed almost no regularisation errors. Also, on reading there seemed no apparent pattern in his errors apart from word substitution. This suggests that AS's ability to map between graphemes and phonemes in English is impaired and hence he could not make generalisations (e.g. Manis et al., 1996).

4. General discussion

AS is a well-balanced, intelligent, well-educated boy born into a caring and highly literate English speaking family. However, the various tests described in this paper

revealed that there is a clear dissociation between AS's ability to read (and write) English and Japanese. This dissociation was predicted by the 'hypothesis of granularity and transparency' with two orthogonal dimensions as postulated in the introduction. The orthographic 'transparency' dimension of the hypothesis would predict that AS should not have problems in reading syllabic (moraic) Kana, since character-to-sound translation is highly transparent with almost a perfect one-to-one relationship. The 'granular' dimension of the hypothesis would predict that AS should not have problems in reading logographic/morphographic Kanji either. This is because the grain-unit for Kanji is coarse, and is at the whole character or the whole word level.

AS has no difficulty at all in reading both Kanji and Kana words, and reading tests in Kanji and Kana revealed that his performance levels were equivalent to those of Japanese undergraduates and graduates. Thus, it is clear that AS is a skilled reader in Japanese. It is also clear, however, that AS has great difficulties in reading and writing in English, which go beyond any difficulties that might have been caused by lack of exposure to English. It was revealed that AS's performance on various reading/writing tests, and tests tapping phonological processing in English were always outside of the range of his age-matched English controls. This was also true with the age-matched Japanese controls (except for spelling and nonword rhyme judgements where he was just within the range of the Japanese subjects). If AS's poor performance in English were due to lack of exposure to English, then his Japanese classmates who had much less exposure to English should have shown a poorer performance in English than AS. Similarly, this should also eliminate an often raised concern that for (not balanced) bilinguals, one of the two languages is used primarily for oral communication, whereas the other is used for both oral and written communication, and thus, bilinguals will show reading/writing difficulties only in the former. This may be true in general, but not for the case of AS, since his reading/writing performance in English was poorer than that of the Japanese monolinguals who started to learn English at the age of 12 years.

AS could thus be described as a dyslexic in English, in particular, a phonological dyslexic as with RE (Campbell and Butterworth, 1985), Louise (Funnell and Davison, 1989) or JM (Snowling et al., 1994). AS is probably more similar to JM than RE or Louise, since he is not a compensated dyslexic, as his reading impairment is not confined to nonwords but also to words. His reading errors show no regularisation or LARC errors, but appear to be random guesses with a very few word substitutions or lexicalisations. Like other phonological dyslexics (e.g. Share, 1995), AS is poor at tasks involving phonological manipulation (e.g. rhyme judgements, Spoonerising, phoneme segmentations, etc.), and has an impaired short-term memory as with RE (Campbell and Butterworth, 1985), Louise (Funnell and Davison, 1989) and JM (Snowling et al., 1994). His reduced memory span is also reflected in his nonword repetition performance as with the other phonological dyslexics (see Gathercole, 1995 for further discussion). AS is also dysgraphic. The nature of his errors in spelling is quite different from that of his Japanese contemporaries, who showed a better knowledge of grapheme-phoneme mappings.

Thus, AS's reading and spelling errors in English indicate his inability to use

grapheme-to-phoneme mappings either based on grapheme-to-phoneme conversion rules (e.g. Stuart and Coltheart, 1988) or orthographic analogy using onsets and rimes (e.g. Treiman, 1986; Goswami, 1988, 1991, 1993). Without their support, AS cannot develop a normal functional orthographic lexicon (Skoyles, 1988; Frith, 1985, 1992, 1995; Share, 1995). As was discussed in the introduction, both Frith (1985, 1992) and Seymour (1987) agree that to be a skilled reader in English, both a lexical (logographic) strategy and a sub-lexical (alphabetic) processing strategy are required. As Frith (1985, 1992) argued, AS became arrested at the logographic stage, and did not/could not develop an alphabetic processing strategy. The alphabetic processing strategy in English requires the acquisition of spelling-to-sound mappings at the sub-syllabic level. What is especially taxing in English is that the mappings are not always one-to-one and transparent unlike Italian or Spanish. This kind of sub-lexical and sub-syllabic phonological processing required for English is not called upon for reading either Japanese Kana and Kanji.

The data further imply that the process of phonological recoding may be organised differently for English and Japanese, as Landerl et al. (1997) suggested for German and English. According to Landerl et al., the different organisation of phonological recoding may be triggered by the key orthographic feature distinguishing the two orthographies, that is, the difference in the consistency or 'transparency' of grapheme-phoneme relations for vowels. '..... the high consistency of the German grapheme-phoneme relations for single vowels allows for the immediate on-line assembly of syllables. (p. 328)'. Indeed Treiman et al. (1995) showed that in English for monosyllabic CVC-words with the same vowel graphemes, the consistency between the vowel graphemes and phonemes was only 60%. Therefore, the correct pronunciations of the vowels in English are determined by graphemic context, which prevent immediate on-line assembly of syllables. By contrast, in German the immediate on-line assembly of syllables are possible as with Italian or Spanish whose grapheme-phoneme relations are transparent and also the Japanese Kana.

In Japanese Kana, the smallest grain-unit required for a correct pronunciation of a word is much coarser than that in English; phonological recoding in Kana is essentially at the level of syllables/morae rather than phonemes. Moreover, there is perfect one-to-one relationship between a Kana character and its pronunciation, and thus Kana orthography is very transparent. What this means is that unlike English, but similar to German and perhaps even more similar to Italian and Spanish, for Kana reading 'no sequence of isolated phonemes has to be retained in working memory (Landerl et al., 1997, p. 329)'. This is particularly interesting, as AS's digit span in English was identical to that in Japanese, which was 5, for both forwards and backwards. And yet, the apparent impoverished short-term memory appears to be detrimental only when reading English and not Japanese.

Similarly, the smallest grain-unit required to read a Kanji word is at least at the individual character level making up words, if not at the word level, which is even coarser than the level of syllables/morae. More importantly, as Wydell et al. (1995) pointed out, each Kanji character is a morphographic unit that cannot phonetically be decomposed in the way that an alphabetic word or even a Kana word can be. There are no separate components of the character 花 (flower) which corre-

spond to the individual phonemes or syllable/mora in /hana/ or/ ka/. As discussed earlier, Kanji learning is essentially by rote, remembering whole characters as words. Indeed, studies with Kanji (e.g. Morton et al., 1992; Wydell et al., 1995) suggest that phonological processing in Kanji relies primarily on a whole-word level.

Suppose AS's reading and writing problems in English are essentially due to English orthography requiring a fine tuning of the orthography-to-phonology mapping, because English orthography is not completely transparent at the sub-syllabic level (i.e. smaller grain-unit than syllables). It can then be speculated that the occurrence of developmental phonological dyslexia should be equally high with other orthographies which are similar to English in the two orthogonal dimensions of the hypothesis, such as for example, Danish. Jensen (1973) claims that in Danish the rules that relate vowel graphemes to vowel phonemes could not be easily understood by students below the university level. Whether this statement is true or not, it is a fact that Danish also has an irregular orthography. And more importantly Denmark reports in Handbook in Reading (UNESCO, 1972) a high level of reading problems among children. Further, a recent national study funded by the Egmont Foundation and the Danish Ministry of Education revealed that approximately 12% adults in Denmark had difficulties reading at least half of the text types in the study (e.g. Elbo et al., 1995). Thus, the hypothesis of granularity and transparency suggests that it would be possible to find a Danish/Japanese bilingual individual who is dyslexic only in Danish, since Danish orthography also requires a fine 'grain' tuning of the orthography-to-phonology mapping. In the same vein, the hypothesis of granularity and transparency can account for a counter-intuitive case such as AS who is an English/Japanese bilingual with monolingual dyslexia in English.

Furthermore, AS's reading/writing problems might have a genetic origin, as Pennington (Pennington, 1994) suggested. Also, AS might suffer from neuroanatomical anomalies, just like the developmental phonological dyslexics described by Paulesu et al. (1996). Despite the possible existence of these genetic and neuroanatomical problems, it is clear that this kind of developmental dyslexia is not a general deficit that will apply to any orthography that the reader has learned, as theories of visual deficits (e.g. Lovegrove et al., 1986) or short-term memory deficit (e.g. Baddeley, 1986 for a review) would suggest. Rather this is an interaction between a cognitive deficit and the specific demands of the orthography to be learned. It may be the case that AS might have some cognitive deficit, but this deficit only affects the reading processes (demands) required for English. That is, English requires a fine 'grain' tuning of the orthography-to-phonology mapping, as the 'hypothesis of granularity and transparency' predicts, while Japanese only requires a much coarser grain tuning. Indeed, a further study on AS with a neuroimaging technique, in particular, magnetoencephalography is currently being carried out (Wydell and Kondo), and its outcome, though tentative, seems to suggest that he has no visuospatial impairments. Further analyses of the brain imaging data on AS will shed light on how and where print-to-sound translation takes place for English and Japanese Kanji/Kana.

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