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The effects of orthographic depth on learning to read alphabetic, syllabic, and logographic scripts

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The problem of how to represent spoken language in writing has historically been solved in different ways (Daniels & Bright, 1996; Gaur, 1992). One distinction is whether to "write what you mean" or "write what you say." Logographic systems such as Chinese and Japanese kanji use symbols to represent meaning directly and have no or comparatively few cues to pronunciation. Other writing systems represent speech sounds. The characters of syllabic systems such as the Japanese kana correspond with spoken syllables, whereas those of alphabetic systems correspond with separate phonemes. However, alphabetic orthographies vary in the degree to which they are regular in their representation of sound. The writing systems of Serbo-Croatian, Finnish, Welsh, Spanish, Dutch, Turkish, and German are on the whole much more regular in symbol–sound correspondences than those of English and French. The former are referred to as transparent or shallow orthographies in which sound–symbol correspondences are highly consistent, while the latter are referred to as opaque or deep orthographies that are less consistent because each letter or group of letters may represent different sounds in different words.

Do these different writing systems affect the ways in which children learn to read? What, if any, are the effects of a written language's writing system on rate of literacy acquisition? The orthographic depth hypothesis (Katz & Frost, 1992) speaks to these questions because it postulates that shallow orthographies should be easier to read using word-recognition processes that involve the language's phonology.

ABSTRACTS

The effects of orthographic depth on learning to read alphabetic, syllabic, and logographic scripts

THIS STUDY investigated the effects of orthographic depth on reading acquisition in alphabetic, syllabic, and logographic scripts. Children between 6 and 15 years old read aloud in transparent syllabic Japanese hiragana, alphabets of increasing orthographic depth (Albanian, Greek, English), and orthographically opaque Japanese kanji ideograms, with items being matched cross-linguistically for word frequency. This study analyzed response accuracy, latency, and error types. Accuracy correlated with depth: Hiragana was read more accurately than, in turn, Albanian, Greek, English, and kanji. The deeper the orthography, the less latency was a function of word length, the greater the proportion of errors that were no-responses, and the more the substantive errors tended to be whole-word substitutions rather than nonword mispronunciations. Orthographic depth thus affected both rate and strategy of reading.

Los efectos de la profundidad ortográfica en el aprendizaje de la lectura en sistemas de escritura alfabético, silábico y logográfico

ESTE ESTUDIO investigó los efectos de la profundidad ortográfica en la adquisición de la lectura en sistemas de escritura alfabético, silábico y logográfico. Niños entre 6 y 15 años leyeron en voz alta en el sistema transparente silábico japonés hiragana, en sistemas alfabéticos de opacidad creciente (albanés, griego, inglés) y en el sistema ortográficamente opaco de los ideogramas japoneses kanji. Los ítem fueron apareados según la frecuencia de las palabras en las lenguas estudiadas. El estudio analizó precisión latencia y tipos de error de las respuestas. La precisión correlacionó con la profundidad ortográfica: el hiragana se leyó más correctamente que, en orden decreciente, el albanés, griego, inglés y kanji. A ortografía más profunda correspondieron menor efecto del largo de las palabras sobre la latencia de las respuestas y mayor la cantidad de errores tendientes a ser sustituciones de palabras completas, en lugar de no-palabras. En síntesis, la profundidad ortográfica afectó tanto la velocidad como la estrategia de lectura.

Die Effekte orthographischer Vertiefung beim Erlernen des Lesens von alphabetischen, syllabischen und logographischen Schriften

DIESE STUDIE untersuchte die Effekte der orthographischen Vertiefung beim Erlernen des Lesens innerhalb alphabetischer, syllabischer und logographischer Schriften. Kinder zwischen 6 und 15 Jahren lesen laut vor, im transparenten syllabischen japanischen Hiragana, in Alphabeten mit steigender orthographischer Tiefe (albanisch, griechisch, englisch) und orthographisch unscharfen japanischen Kanji-Ideogrammen, mit Einzelheiten kreuzweiseliguistisch verglichen auf Worthäufigkeit. Diese Studie analysierte die Genauigkeit der Antwort, Latenz und der Fehlerarten. Genauigkeit verlief korrelativ mit der Vertiefung: Hiragana wurde sorgfältiger gelesen als, umgekehrt, albanisch, griechisch, englisch und Kanji. Je tiefer die Orthographie, je geringer war die Latenz als eine Funktion der Wortlänge, desto größer war das Verhältnis an Fehlern aufgrund von Nichtbeantwortungen, und um so mehr neigten die wesentlichen Fehler Ganzwortsubstitutionen zu sein, anstatt Nichtwort-Falschaussprachen. Orthographische Vertiefung beeinflusste daher beides, Grad und Strategie des Lesens.

アルファベット、音節文字、表語文字の読みの学習への正書法の深度の効果

本研究では、アルファベット、音節文字、表語文字における読みの習得に対する正書法の深度の効果を調査した。6歳から１５歳の子供達が、語の頻出度によって交差言語学的に組み合わせられた項目を、明瞭で音節的な日本語のひらがなと、正書法の深度が増す（アルバニア語、ギリシャ語、英語）アルファベット、そして、正書法的に不明瞭な日本語の漢字で音読した。応答の正確さと潜時、そして誤りの種類が分析された。正確さは、深度と相関した。ひらがなが、順にアルバニア語、ギリシャ語、英語、漢字の文字より正確に読まれた。正書法の深度が強ければ強い程、潜時はより語長の機能でなくなり、応答なしの誤りの割合は大きくなり、そして、本質的な誤りは、非単語の発音誤りよりはむしろ、単語全体の置き換えになる傾向がより強くなった。正書法の深度は、かくして読みの程度とストラテジーの両方に影響を及ぼした。

Les effets de la profondeur orthographique sur l’apprentissage de la lecture d’écritures alphabétique, syllabique, et logographique

CETTE ÉTUDE s’est intéressée aux effets de la profondeur orthographique sur l’apprentissage de la lecture avec des écritures alphabétique, syllabique, et logographique. Des enfants de 6 à 15 ans ont lu à haute voix avec le syllabique japonais transparent qu’est l’hiragana, avec des alphabets de plus grande profondeur orthographique (albanais, grec, anglais), et avec les idéogrammes orthographiquement opaques que sont les kanji japonais, les items ayant été appariés d’une langue à l’autre quant à la fréquence des mots. L’exactitude des réponses, leur latence et les types d’erreurs ont été analysés. L’exactitude est corrélée à la profondeur : l’hiragana est lu avec moins d’erreurs que, dans l’ordre, l’albanais, le grec, l’anglais, et le kanji. Plus l’orthographe est profonde, moins la latence dépend de la longueur du mot, plus grande est la proportion d’erreurs qui sont des non-réponses, et plus les erreurs substantielles tendent à être des substitutions de mots entiers plutôt que de mauvaises prononciations de non-mots. La profondeur orthographique affecte donc aussi bien la vitesse que la façon de lire.

Алфавитные, слоговые и логографические языки: влияние орфографической сложности языка на умение читать

Исследовалось влияние орфографической сложности языка – от слогового к алфавитному и логографическому – на развитие умения читать. Дети от 6 до 15 лет читали слова, написанные с использованием орфографически “прозрачной” японской слоговой азбуки хирагана, слова на албанском, греческом, английском (языки, чьи алфавиты имеют нарастающую орфографическую сложность) и, наконец, они читали орфографически непрозрачные японские идеограммы (иероглифы) канджи, причем списки слов на разных языках составлялись по принципу частотности употребления. В рамках исследования анализировались точность прочитанного, затраченное на чтение время и типы ошибок. Точность коррелировала со сложностью: слова на хирагана читались более точно, чем, соответственно, на албанском, греческом, английском и канджи. Чем орфографически сложнее был язык, тем меньше затраченное на чтение время зависело от длины слова, тем больше оказывалась доля непрочитанных слов, а существенные ошибки состояли скорее в замене целого слова на несуществующее, чем на реально существующее слово. Таким образом, орфографическая сложность влияла и на скорость, и на избираемую стратегию чтения.

It further predicts the consequence that children learning to read a transparent orthography where sound–symbol mappings are regular and consistent should learn to read aloud and to spell faster than those learning an opaque orthography where the cues to pronunciation are more ambiguous.

There have been some recent demonstrations that, as predicted by the orthographic depth hypothesis, learning to read a transparent orthography such as German (Wimmer & Hummer, 1990), Greek (Goswami, Porpodas, & Wheelwright, 1997), Italian (Thorstad, 1991), Spanish (Goswami, Gombert, & De Barrera, 1998), Turkish (Öney & Durgunoglu, 1997), or Welsh (Ellis & Hooper, 2001) is easier than learning to read an orthographically opaque language such as French or English (Goswami et al., 1998; Landerl, Wimmer, & Frith, 1997). Seymour, Aro, and Erskine (2003) compared the abilities of first-grade children to read familiar words and simple nonwords in English and 12 other European orthographies. The results showed that children from most European countries were accurate and fluent in reading before the end of the first school year, with word reading accuracies exceeding 90% in all except the more opaque orthographies of Portuguese, French, Danish, and, particularly, English. Seymour, Aro, and Erskine attributed these findings to orthographic depth, which affected both word and nonword reading, and to syllabic complexity, which affected nonword decoding. These findings suggested that the rate of learning to read in English was more than twice as slow as in the other orthographies.

The orthographic depth hypothesis and strategy of reading different scripts

The orthographic depth hypothesis postulates that there are different routes to fluent reading that are dependent on the nature of a particular orthography. Fluent English readers' ability to read nonwords like *nabe* or *sloppendash* demonstrates the availability of a route to reading using decoding, where pronunciation is assembled from known symbol–sound associations. Their ability to pronounce irregular or inconsistent words such as *island* or *Wednesday* implicates the availability of another reading route, one where the word cannot be decoded entirely by matching symbols and sounds. Learners of English use different strategies of reading at different stages of development; they move from recognizing whole words (logographic reading), through a stage where they begin to apply sound–symbol correspondences (alphabetic reading), to skilled reading that predominantly involves direct lexical access by way of the orthography, at least for high-frequency words (orthographic reading) (Ehri, 1999; Frith, 1985; Marsh, Friedman, Welch, & Desberg, 1981). Readers of transparent orthographies are more likely to succeed in reading by means of alphabetic reading strategies than readers of opaque orthographies, and their differential histories of success or failure may determine their respective strategies, with readers of transparent scripts being more likely to rely on alphabetic reading strategies. Thus, there are two sides to the orthographic depth hypothesis: (a) Transparent orthographies support word recognition involving phonology, and (b) opaque orthographies encourage a reader to process words by accessing the lexicon and meaning via the word's visual orthographic structure (Katz & Frost, 1992).

Support for this hypothesis comes from three types of evidence. First, learners of transparent orthographies are better able to read nonwords. Learners of German (Wimmer & Goswami, 1994) and Spanish (Lopez & Gonzalez, 1999) are more able to read nonwords than are learners of English (Rack, Snowling, & Olson, 1992). Second, learners of transparent and opaque orthographies produce different patterns of reading errors. Adherence to an alphabetic decoding strategy produces errors that are mispronunciations, whereas orthographic reading strategies generate visually similar, real-word substitution errors. The majority of the reading errors of German (Wimmer & Hummer, 1990) and Welsh (Ellis & Hooper, 2001) children are nonwords, whereas young English-speaking children make frequent reading errors that are actual words (Seymour & Elder, 1986; Stuart & Coltheart, 1988). Finally, there is a stronger relationship between word length and reading latency in transparent orthographies. Ellis and Hooper showed that word length determined 70% of the difference in times to read words in Welsh, but only 22% in English, suggesting that Welsh pronunciations were assembled by means of a left-to-right parse of the written string, with longer words consequently requiring more time to recognize.

Such findings support the hypothesis that transparent orthographies promote faster rates of reading acquisition and encourage an alphabetic reading strategy. The current study aimed to extend the comparison of effects of orthography on reading acquisition. Previous research assessed the effects of orthographic depth within alphabetic languages. The goal of the present study was to make further comparisons among alphabetic writing systems and to compare these with other types of script positioned more extremely on the dimension of orthographic depth, a highly transparent syllabic script and a deeply opaque logographic one.

Methods of cross-linguistic reading comparison

It is difficult to compare literacy development across different orthographies because the stimuli must necessarily be different. So, how can assessment materials across languages be matched? Traditionally, there have been three main approaches. First, readers of different languages can be compared for their ability to read nonwords. For example, Wimmer and Goswami (1994) showed that children learning to read German were better able to read nonsense words derived from number words such as *vechs* and *zieben* from *sechs* and *sieben* than were children learning to read English able to read items such as *tix* and *feven* from *six* and *seven.* This method has since been widely adopted because it provides an index of children's decoding abilities for novel material. Second, cross-linguistic translation equivalents can be compared for readability. Landerl et al. (1997) showed that German children were better able to read their transparent orthography instantiation of pairs of translation equivalents (e.g., *Pflug-plough*) than were matched learners of English. Thorstad (1991) translated a difficult passage of 56 words, taken from an Italian journal for adults, into English to be used as a reading and spelling test. Spencer and Hanley (2003) showed that Welsh children were better able than their English peers to read both nonwords and translation-equivalent words. A third approach has been to sample high-frequency words from children's school reading schemes. Thus, Goswami et al. (1998) showed that Spanish children were able to read more of a sample of eight monosyllabic and eight disyllabic words in their language than were matched French or English children. Seymour et al. (2003) had children read 18 familiar high-frequency content words and 18 function words. The words were sampled from the reading material used in the early stage of primary schooling in each language.

But each of these methods has its limitations as a comparative measure of reading acquisition in different languages. Nonword reading ability indexes children's decoding skill, but nonwords may not be good indicators of skill at reading real words. Translations are rarely equivalent either in the relative frequencies of words or symbols or in their range of usage in the respective languages. Although the sampling of test items from typical school textbooks is a reasonable start at controlling exposure factors, textbook writers tune their books to their audience and to the difficulty of the task with which their readers are faced, so there is no guarantee that a reading text in one language is equivalent for comparable children in another language.

The current study, therefore, took an alternative approach to the issue of whether it is easier to learn to read in one language than another. Specifically we developed parallel reading tests for which the items in the two languages were matched for word frequency. A longstanding method of assessing an individual's ability to read aloud has been to see how many items he or she can read from a standardized list of approximately 100 words of increasing difficulty. Illustrative examples are the Schonell Graded Word Reading Test and the Wide Range Achievement Tests. We extended this idea to construct parallel cross-linguistic tests where, for each language, the items are randomly selected from 100 frequency bands representing the most frequent to the least frequent words of the language. Thus, each test is a stratified random sample of the words of the language, with pairs of test items in the two languages being matched for frequency of written occurrence. The matching process should *not* control any other factors such as word length, imageability, utility, morphological complexity, syntactic role, semantic richness, orthographic complexity, sound–symbol consistency, or any other intrinsic aspects of the languages under study that might affect how easy or difficult it is to learn the words. Ideally, everything to do with learning opportunity should be matched; everything to do with language should be free to vary. The rationale is based on input-driven perspectives of language acquisition: The learnability of an item is largely dependent upon the amount of experience a learner has with it and with similar items. Thus, if children of two languages start learning to read at the same time, and they have roughly equivalent time on task, then, if the two orthographies are equally difficult to acquire, learners of similar experience should be able to read words at roughly the same frequency level.

Ellis and Hooper (2001) used this method in their comparisons of Welsh and English. The word types that composed a representative million written words of English (Baayen, Piepenbrock, & Van Rijn, 1995) and Welsh (Ellis, O'Dochartaigh, Hicks, Morgan, & Laporte, 2001) were sorted in decreasing frequency of occurrence and sampled so that a test word was selected at every decreasing step of 10,000 word tokens or its nearest approximation. The two lists of 100 words were then used as frequency-matched samples of written English and Welsh. This method is promising in assessing the acquisition of literacy in children learning to read in different languages and in the multiple languages of multiliterate individuals for several reasons. First, it produces tests that are matched in a principled fashion for input frequency. Second, it generates a broad range of frequencies of items, from approximately 60,000 words per million to just 1 per million, and so it is appropriately discriminating for learners at different stages of proficiency. Third, it is psychophysically scaled. Psycholinguistic experimentation shows that there is more of a linear relationship between proficiency and log exposure than between proficiency and exposure. The method of sampling used by Ellis and Hooper effectively provided items representing log-frequency strata.

Extending the range of comparison beyond alphabetic orthographies

In the present study, we therefore used these methods to develop tests matched cross-linguistically for frequency of written exposure in order to compare the rate of acquisition of reading in 6- to 15-year-old children reading a range of different native orthographies: the orthographically transparent syllabic Japanese hiragana system, alphabets of decreasing orthographic transparency (Albanian, Greek, and English), and the orthographically opaque ideographic Japanese kanji system. We also investigated whether these different types of orthography affect the strategies of lexical access adopted by learners, as is predicted by the orthographic depth hypothesis.

The orthographies investigated in this study

Hiragana

Japanese orthography comprises four types of script: hiragana and katakana (the kana), kanji, and romaji (Kess & Miyamoto, 1999). Hiragana and katakana are syllabic scripts. Most Japanese syllables have the canonical shape of a consonant–vowel (CV) combination and can be represented by single kana symbols. There is one-to-one correspondence between hiragana and katakana symbols, with both systems containing 46 basic symbols (called seion): 40 unvoiced CV combinations, five vowels, and one nasal coda. In addition to these, there are other characters, including 25 symbols that are the voiced equivalents of the basic seion formed by adding a special mark for voicing or semivoicing, making a total of 71 symbols in all. Most kana symbols have a single, unique pronunciation, although combinations of symbols and their use in certain word classes can modify the pronunciation slightly (Akita & Hatano, 1999). Hiragana is mainly used for function words, morphological endings, and the rest of the grammatical scaffolding of Japanese sentences. Although Japanese content words are usually written in kanji, it is possible to write all native Japanese words in hiragana. Katakana is mainly used for foreign loan words and Japanese interjections. Nomura (1980) estimated that journals published in Japan contain 50% hiragana, 30% kanji, and 10% katakana.

The regularity of the symbol–sound mappings makes hiragana an exceptionally transparent orthography. Furthermore, because children are better able to break up speech and identify its syllable parts than they are to segment it into phonemes (Alegria, Pignot, & Morais, 1982; Liberman, Shankweiler, Fischer, & Carter, 1974; Rozin & Gleitman, 1977), the canonical CV syllable shape of spoken Japanese allows for easy phonological segmentation. These two factors should thus combine to promote fast acquisition: The spoken language is easily segmented into its syllable parts, and each of these individual phonological units has its unique written symbol.

Learning to read and write in Japanese officially begins at the age of 6, in the first grade of elementary school. The seion symbols are first introduced, followed by the rest of hiragana. Katakana is introduced in the latter half of the first grade and is completed by the end of the second grade. Children also start learning some easier kanji in the first grade. Notwithstanding the official syllabus, most preschoolers are able to read at least the 46 basic hiragana by the time they start the first grade. Shimamura and Mikami (1994) reported that 16% of 3-year-olds, 59% of 4-year-olds, and 89% of 5-year-olds could read 60 or more of the 71 hiragana symbols.

Albanian

Albanian forms a single branch of the Indo-European family that is spoken by over three million people in Albania and in parts of the former republic of Yugoslavia, Greece, and Italy. The writing system was not introduced until 1909, hence few languages are more orthographically transparent than Albanian. It uses Roman characters and has 36 letters: 29 consonants and 7 vowels. Nine of the consonants are presented as bigraphs (*dh*, *gj*, *ll*, *nj*, *rr*, *sh*, *th*, *xh*, *zh*). These bigraphs are explicitly taught to the children as separate "letters" of the alphabet, and if they appear together are never considered as separate graphemes (this rule does not apply to compound words, which occur rather infrequently). The bidirectional grapheme–phoneme and phoneme–grapheme mapping is consistent for both consonants and vowels. These symbols do not change their sound according to their position in the word.

In Albania there are very few nursery schools, and only a minority of preschoolers go to kindergarten. The consequence is that most first graders in Albania enter school without letter or written word awareness. The teaching of reading in Albanian primary schools is introduced in year 1. The official teaching method is a whole-word method called the Global Method. However, many teachers who have been using phonics approaches for many years prefer to use mixed methods including both whole-word and phonics approaches (Hoxhallari, 2000).

Greek

Greek is highly regular in its symbol-to-sound mappings for reading, though less so in its sound–symbol mappings for spelling. In spoken Greek there are only five vowels that sound the same whether stressed or unstressed (Harris & Giannouli, 1999). While the majority of Greek words are polysyllabic, there are fewer than half the syllable types of English, with the majority of them being open syllables of the consonant–vowel type (V, CV, VC, CCV, CCCV) (Magoulas, 1979). As with Japanese, these syllable characteristics presumably allow children an easier task of phonological segmentation of their spoken language. In the written language, each letter's single sound remains relatively constant in different contexts (Chitiri & Willows, 1994).

Nevertheless, written Greek is not entirely transparent. Whereas the written form has remained essentially intact since its development as an alphabetic script, the spoken language has undergone major developmental changes in its evolution toward modern Greek (Babiniotis, 1980; Tombaidis, 1987; Triantaphyllidis, 1913). As a result, modern spelling is not entirely phonetic but has a morphophonemic nature that reflects the etymology of words (Porpodas, 1991, 1999). Spoken Greek is composed of 32 phonemes that are represented by the 24 Greek letters (Bakamidis & Carayannis, 1987; Triantaphyllidis, 1980). Several phoneme–grapheme inconsistencies occur, including homophone vowels and vowel and consonant clusters (diphthongs and dipsipha). The pronunciation of dipsipha varies according to their position in the word and the context in which they occur. In exceptional cases, some letters are almost voiceless (Porpodas, 1991; Tombaidis, 1987; Triantaphyllidis, 1913). Greek has the added feature whereby the position of prosodic stress is marked for each written word. Stress, which can occur on any of the final three syllables of a word depending on a variety of morphological, phonological, and lexical factors, must be properly interpreted for successful reading because there are many words that are differentiated only by stress (Tombaidis, 1986).

Reading instruction is standardized in Greece. It usually starts at 5.5 to 6 years old, beginning with letter–sound correspondences. Thereafter, a synthetic phonics method is used to encourage phonological recoding of simple CV syllables that form simple words, and there is an emphasis on rhyming words. Once children have established good letter–sound knowledge and have built an initial sight vocabulary, letter names are taught and a phonics method is used to teach grapheme–phoneme correspondences that include more complex syllables like CCV. The stress mark is also introduced. The basic reading process is typically well established by the end of the first grade (Harris & Giannouli, 1999; Porpodas, 1991).

English

The English alphabet consists of 26 letters (5 vowels and 21 consonants) that represent over 40 phonemes. Letters or letter combinations are often ambiguous in terms of the sounds they represent. As Venezky (1970) concluded from his analysis of the structure of English orthography, "a person who attempts to scan left to right, letter by letter, pronouncing as he goes, could not correctly read most English words" (p. 127). The 5 written vowels are particularly varied in their mappings to speech, and there are 12 vowel digraphs, 6 of which have alternate pronunciations according to their position. Consonants are more consistent in their grapheme–phoneme correspondences, with the exceptions of *c* and *g*, which are read differently according to the vowels that follow. Nevertheless, only three consonants (*n*, *r*, and *v*) have only one sound that cannot be produced by other combinations and are never silent (Venezky). Spoken English also has a complex syllable structure with many different types of syllables, most of them closed (e.g., CVC, CVCC, CCVC). These characteristics pose difficulty for children learning to phonologically segment their spoken language.

Although English is varied in its grapheme–phoneme correspondences, it has a higher degree of spelling–sound consistency at the level of the rime. Treiman, Mullennix, Bijeljac-Babic, and Richmond-Welty (1995) estimated that the pronunciation of modern English written vowels is only 51% consistent over different words, whereas initial and final consonants are much more consistent (96% and 91%, respectively), as are rime units (77%). For example, *a* is pronounced differently in *cat*, *call*, *car*, *cake*, and *care*, but it is pronounced the same in the rimes *cat*, *hat*, and *mat*. Phonological segmentation into onset-rime units and the use of orthographic rime analogies have been shown to be important processes in learning to read and spell English (Goswami, 1999, 2000; Goswami et al., 1998; Treiman et al., 1995).

The majority of English children begin prereading exposure quite early, at 3 or 4 years old. In Nursery, children are taught the shapes of most letters of the alphabet and introduced to book use. They are read to on a daily basis, and there is emphasis on repetition and rhyming. In Reception, there is at least 30 minutes per day dedicated solely to reading. There is much use of word-building, pattern recognition, and odd-one-out games. In year 1, the recognition of the words as a whole is supported with the use of look-and-say and odd-one-out games. Flash cards are used to introduce individual words, to build a starting sight vocabulary, and to form simple sentences. Children are taught families of word patterns that share orthographic and phonological resemblance at onset or rime. Phonics is typically introduced at the end of year 1, and children are encouraged to practice sounding out and blending phonemes. Literacy remains a significant part of the national curriculum right through Upper Key Stage 2, that is 9 to 11 years old. In sum, much time and effort is put into teaching children to learn to read in English.

Kanji

The kanji writing system originated in the logographs of Chinese orthography. Content words in Japanese are usually written in kanji because doing so resolves the ambiguity of the many homophones of spoken Japanese. The higher homophony rate in Japanese than in other languages is due to its simple CV spoken syllable structure, which restricts the number of possible spoken syllables that can be used individually and in combination to form a spoken word (Akita & Hatano, 1999). In general, there are two ways to read a given kanji, referred to as kunyomi or onyomi. *Kunyomi* is the Japanese word corresponding to the logogram; *onyomi* is a pronunciation that is similar to the original Chinese. Thus the kanji 木 (tree) has the kunyomi "ki" and the onyomi "moku"; the kanji 林 (forest) is pronounced, respectively, "hayashi" and "rin." According to Kess and Miyamoto (1999), between 12,000 and 50,000 entries are included in comprehensive kanji dictionaries. The Japanese educational system explicitly teaches a set of 1,945 Joyo Kanji (kanji for daily use). However, Kess and Miyamoto argued that most Japanese know many more than these and that 3,000 or more kanji are required to read a daily newspaper.

Children start learning 80 of the easier Joyo Kanji toward the end of the first grade. The sequence of introduction of kanji in the curriculum is standardized, and by the end of elementary school children are expected to have mastered 1,006 characters (National Language Research Institute, 1988). They are expected to master the complete set of Joyo Kanji by the end of the third year of junior high school.

Research questions

This study was designed to compare the rate of reading acquisition in 6- to 15-year-old children learning to read in a transparent orthographic system (the syllabic Japanese hiragana), in alphabets of decreasing orthographic transparency (Albanian, Greek, and English), and in the ideographic Japanese kanji system.

The orthographic depth hypothesis predicts that the more transparent the orthography, the faster children will learn to read aloud. The almost perfect symbol–sound correspondence of hiragana, its representation of psycholinguistically accessible syllables rather than phonemes, and the simple syllable structure of Japanese each contributed to the expectation that learning to read aloud will be easiest in hiragana. All of the alphabetic scripts provide cues to pronunciation, but some of the systems are more regular and consistent than others. Thus, we expected the alphabetic systems to be the next most easy to acquire, but that the ease with which reading is acquired would vary within alphabetic systems with the more transparent languages (Albanian and Greek) being easier to learn than the more opaque language (English). Finally, we believed that the ideographic kanji system, which contains few or no cues to assembled pronunciation, would be the most difficult to acquire.

The orthographic depth hypothesis also led us to predict that these different scripts would affect the strategies of lexical access that were adopted by learners, with transparent orthographies supporting word recognition involving phonology, and opaque orthographies encouraging readers to process words by accessing the lexicon and meaning via the word's visual appearance. As in Ellis and Hooper (2001), reading strategy was assessed by examining the relation between word length and response latency in each script, and by analyzing and categorizing the types of errors that children made while reading. It was predicted that opaque scripts would promote situations where a child is unable to make any response at all (nonresponses), along with mistakes where the child says a wrong word that is visually similar to the target (whole-word substitutions such as *computer* for *complete* and *near* for *never*). Transparent scripts, in contrast, were expected to be associated with relatively few nonresponses or whole-word substitutions, but with mistakes that result in mispronunciations that are nonwords (nonword errors such as *polical* or *poltac* for *political*).

Method

Summary of design

This study, designed to assess the effects of writing system upon reading acquisition among 6- to 15-year-old children, involved the comparison of opportunity samples of participants learning to read in five different native scripts in four countries. These children had been taught by different teachers, in different classrooms and schools, using potentially different methods of instruction in different cultures. It is impossible to control all of these potential confounds. However, we tried to ensure that our participants were matched on verbal and nonverbal abilities, and, when comparison cell levels were not exactly equated on these measures after selection, we statistically controlled them. Following Paulesu et al. (2000), we assessed children's verbal ability using a picture-naming task measuring accuracy and latency. Nonverbal reasoning ability was estimated with use of items from the Standard Progressive Matrices. Subsequent comparisons across language groups could thus be statistically controlled for any differences in these background abilities with use of analysis of covariance. The first wave of testing involved English, Greek, and Japanese scripts. The Albanian data were collected one year later in order to triangulate the Greek findings against another orthographically transparent script. Limited resources meant that we were only able to test Albanian children 7 to 9 years old and that we were unable to assess their ability on control measures relating to verbal and nonverbal abilities. This abbreviated testing means that the Albanian accuracy data must be viewed only as supplemental findings to add perspective on the more rigorous and extensive results from the other language groups. Within each language group we assessed the relation between word length and latency and performed qualitative analyses of the children's reading errors as evidence of their strategies of lexical access.

Participants

Children were recruited by opportunity sampling from areas close to the homes of the researchers. The parents, guardians, or teachers of each child received a brief description of the nature and the goals of the research and were asked to sign a consent form authorizing participation if the children themselves also agreed to take part. Our goal was to recruit roughly 15 students of each language at the following ages: 6 to 7 years, 8 to 9 years, 10 to 11 years, 12 to 13 years, and 14 to 15 years. The age characteristics of all language groups are shown in Table 1.

Greek children were recruited from among the investigators' friends and family in Volo, Athens, Pireaus, Evia, Rodos, and Korinthos. Japanese children were recruited from municipal primary and junior high schools in the Gifu prefecture of Japan. English children were recruited from four monolingual (English) private primary and secondary schools situated in North Wales (Colwyn Bay, Bangor, and Menai Bridge). The large majority came from monolingual English-speaking families, although a few were able to speak some Welsh.

The Albanian sample came from a primary school located in Korçë in southeast Albania. They were average-achieving pupils on the most recent math test administered by the classroom teacher.

Materials

Reading

The reading tests for each language were constructed with an adaptation of the method used by Ellis and Hooper (2001), sampling every decreasing 10,000 word token step from a frequency-sorted 1-million-word language corpus. This original

TABLE 1
NUMBER OF CHILDREN IN EACH AGE BAND FOR EACH LANGUAGE GROUP

	Age bands (months)						
Language	73–102	103–120	121–150	151–183	Total	Girls	Boys
English	15	14	11	27	67	37	30
Greek	18	26	5	30	79	33	46
Japanese	30		11	30	71	30	41
Albanian	34	26			60	29	31
Total	97	66	27	87	277	129	148

method, although broadly satisfactory in producing equal strata in terms of log frequency, did cause some deviation from linearity at lower frequencies (see Figure 1). To correct for this lack of linearity, we compiled 100-word reading tests for the different languages by selecting randomly from the 100 decreasing $\log_{10}$-frequency strata bounded by the most and least frequent words in 1-million-word counts. This helped to ensure that the reading tests were matched across the various languages in terms of word frequency. Word form lists were used, with inflected forms (e.g., *walked*, *walks*, *walking*) being enumerated separately rather than gathered under the root (*walk*). The resultant items for each language are shown in Appendix A.

The English test was formed by taking the word types that comprised 1 million token word frequency profiles for English in the CELEX Lexical Database (Baayen, Piepenbrock, & van Rijn, 1995), which estimated these written word frequencies from analysis of the 16.6 million token Cobuild corpus of samples of written English from hundreds of different sources including newspapers, magazines, fiction and nonfiction books, brochures, leaflets, reports, letters, and so on, with the majority of texts originating after 1990. This 1 million token list was made up of word types ranging in frequencies from 59,739 (*the*) down to 1 (*surveyed*). The list was then split into 100 log-frequency strata with a word being randomly selected from each of these.

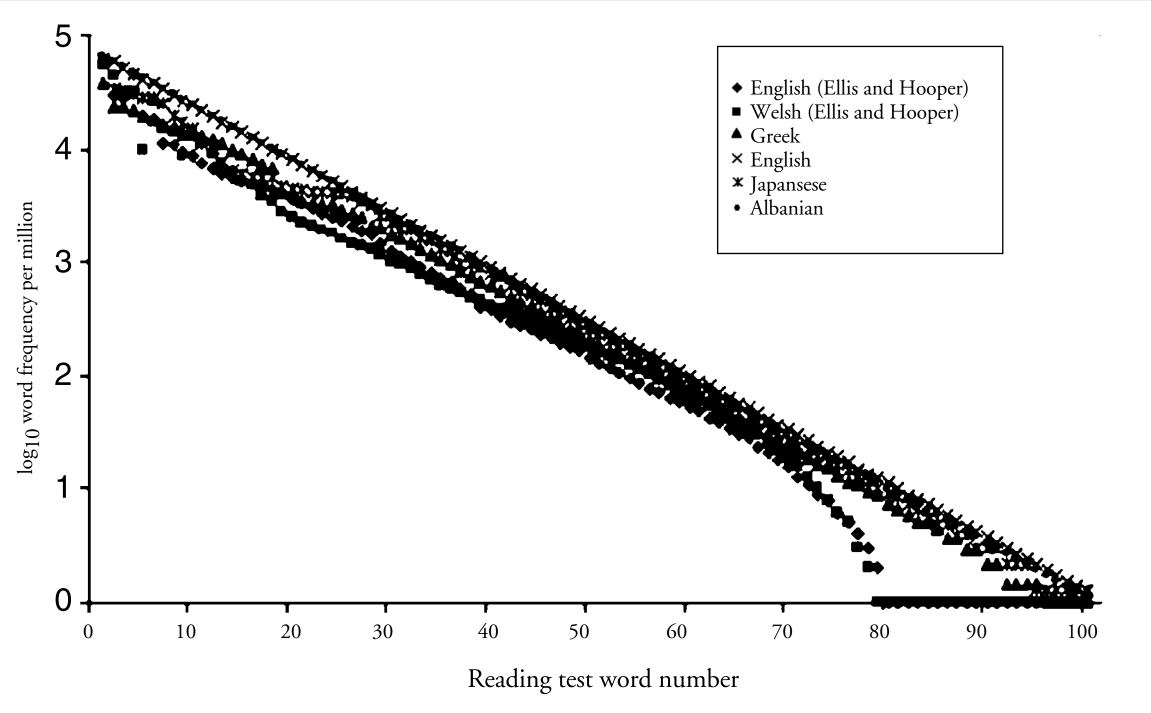
The Greek test was formed by taking the word types that composed approximately 1.5 million token word frequency profiles for Greek taken from the weekly newspaper *TO BHMA* by Stathis Stamatatos (personal communication, 2000) of University of Patras. A 1 million token subset was then counted to produce a word type list ranging in frequencies per million from 52,887 (και) to 1 (επικοινωνιακή). The list was then split into 100 log-frequency strata with a word being randomly selected from each.

The Japanese tests were based on the frequency lists from Nihongo-no Goitokusei (Lexical properties of Japanese) (Amano & Kondo, 2000). This database is the largest electronically provided frequency count database for Japanese words and characters in kanji, hiragana, and katakana and is taken from a corpus of the Asahi newspapers published over 14 years, from 1986 to 1998. A 1-million token subset was then counted to produce a word type list ranging in frequencies from 71,546 (の in both lists) to 1 (ほうふつ in kana, 訪仏 in kanji). The list was then split into 100 log-frequency strata with a word being randomly selected from each. Where possible, each of these words was then presented in its hiragana form for the kana test and its kanji form for the kanji test. This was not possible for the first 30 or so most frequent words of the language, which are all usually only written as hiragana.

The Albanian reading test was designed by randomly sampling one word from each of 100 successive strata of decreasing $\log_{10}$ written word frequency from an Albanian text corpus, created by the fourth author, comprising just over 1 million words, from a novel, the New Testament from the Christian Bible, one children's book, one online Albanian newspaper (dates ranging from early January to late February 2001), and two short passages from books advertised on the Internet. The most frequent word of the list was *të* (you) with frequency 67,713 in a million, and one of the last words was *lëvdoni* (praise), which occurred only once.

The resultant frequencies of test items for each of these reading tests are plotted in Figure 1 alongside those from the original Ellis and Hooper (2001) English and Welsh tests. This figure shows the improved linearity of log word frequency sampling that resulted from the changed sampling procedure. It also illustrates the tight frequency-matching of the

FIGURE 1
THE MATCHED WRITTEN FREQUENCY PROFILES OF THE HIRAGANA, GREEK, ALBANIAN, ENGLISH, AND KANJI READING TESTS, ALONG WITH THOSE OF ELLIS AND HOOPER (2001) FOR ENGLISH AND WELSH



items in the current English, Greek, Japanese, and Albanian tests. That this design produces tests of adequate internal consistency is indicated by the high reliability of the reading accuracy scores over these items for the English, kanji, Greek, and hiragana children, Cronbach's alpha = 0.976.

These scripts did differ in terms of the length in characters of the words sampled, with alphabetic scripts having most characters per word (English M = 5.25, SD = 2.65; Greek M = 6.28, SD = 3.25; Albanian M = 5.36, SD = 2.94), syllabic hiragana fewer (M = 3.13, SD = 1.64), and logographic kanji fewest of all (M = 2.04, SD = 0.84).

Picture naming

A picture-naming task was used to assess general verbal ability in the Greek, Japanese, and English children. The stimuli were 20 pictures developed by Snodgrass and Vanderwart (1980) that were standardized for such variables as familiarity and visual complexity. The particular items (objects and animals), chosen because of their high name agreement and name frequency, were the following: house, hand, saw, car, eye, book, key, watch, dog, telephone, television, hat, piano, pencil, guitar, lion, umbrella, elephant, helicopter, and butterfly.

Nonverbal reasoning

Items from the Standard Progressive Matrices were used to assess nonverbal reasoning ability in the English, Greek, and Japanese samples. Three practice items were followed by a selection of 15 items in increasing difficulty. The items were presented one at a time at the top of a page of paper and followed by six alternative answers.

Procedure

Children were tested individually by a native speaker of their respective languages either in a quiet familiar room within the school (for the English, Japanese, and Albanian children) or in the child's or experimenter's home (for the Greek-speaking children). The picture-naming task was presented first because of its ease and simplicity, followed by the reading test and then the nonverbal reasoning test.

Reading

An Apple Macintosh laptop programmed in SuperLab (Abboud & Sugar, 1997) presented the reading items. Accuracy, latency, and reading time were measured for each word. A microphone was used to detect the onset of the child's pronunciation of a spoken word, with voice onset time being measured in milliseconds from the visual presentation of the word midscreen. The experimenter pressed a key when the child had finished saying each word, thus allowing a measure of reading time for each word. The experimenter also keyed in whether each response was correct or not. Children's responses were tape recorded to allow subsequent analysis of errors.

The reading test items were presented in order of decreasing frequency after three high-frequency animal names had served as practice items in order to familiarize children with the procedure. Children were instructed to try to read aloud each word as quickly as possible after its appearance on screen. They were encouraged to "have a go" at each one, even if they did not know it at first sight. Testing stopped after the child had made five consecutive responses that were not correct. Each Japanese child did both the hiragana and then, after a short break, the kanji versions of the reading test.

The Albanian children were not tested by computer. Instead, the procedure of Ellis and Hooper (2001) was followed. The word list was printed with 17 words per A4-sized page, double-spaced, centered on the line, and set in bold lowercase 20-point Times font. Accuracy and reading latency for correct answers were measured. A piece of plain card was used to cover the list, and the child was asked to move the card down when the first experimenter said "next" and to read the following word immediately. A stopwatch was used to record latencies, from the onset of word presentation to the response onset, and responses were also tape recorded for further analysis. Use of a stopwatch in this way provided sufficient reliability of measurement. The interobserver correlation between the latencies measured by two separate observers measuring the word readings of the same child was $r = 0.93$, $p < .01$. Nevertheless, because latency was measured by stopwatch rather than by computer for the Albanian children, we do not analyze their latencies here.

Picture naming

The picture stimuli were presented in a similar fashion to that in the reading test, with a microphone being used to measure voice onset time and the experimenter determining whether each verbal response was appropriate as a name for that picture in their language. The pictures were presented in a fixed order as described in the Materials section of this article after three additional pictures had served as practice items. Children were instructed to name each picture as quickly as possible after its appearance on screen. For each child, we computed the total number of pictures correctly named and the average latency for these correctly named items.

Nonverbal reasoning

The experimenter showed the Standards Progressive Matrices items one at a time, and a child was asked to solve each puzzle by pointing out the picture alternative that would properly fill in the missing part of the top diagram. The test ended after five successive errors. The nonverbal score for each child was simply the total number correct.

Group matching

We attempted to match the three main language groups for age, picture-naming ability, and nonverbal reasoning. Limited resources meant that we were only able to recruit 7- to 9-year-old Albanian children and that we were unable to assess their ability on control measures relating to verbal and nonverbal abilities. The main language groups were fairly well matched for age in months, English ($M = 133.0$, $SD = 34.6$), Greek ($M = 125.1$, $SD = 32.1$), Japanese ($M = 127.3$, $SD = 42.8$), $F(2, 214)$, $p < 1$, *ns*. Nevertheless, with such a large age spread, it is appropriate that subsequent analyses of language differences either include age as an explicit factor or else control for age with use of ANCOVA. On picture-naming accuracy, the English, Greek, and Japanese groups were equally able: English ($M = 95.8\%$, $SD = 12.5$), Greek ($M = 93.0\%$, $SD = 10.0$), and Japanese ($M = 95.7\%$, $SD = 4.8$), $F(2, 212) = 2.05$, *ns*, age corrected $F(2, 211) = 1.80$, *ns*. However, it appeared that the Greek children were somewhat slower in their picture-naming RTs (msec): English ($M = 869.1$, $SD = 239.6$), Greek ($M = 1079.8$, $SD = 364.1$), and Japanese ($M = 898.4$, $SD = 253.3$), $F(2, 212) = 11.15$, $p < .001$, age corrected $F(2, 211) = 10.69$, $p < .001$. The English, Greek, and Japanese groups differed significantly in their nonverbal reasoning, with the advantage going to the Greek students. The number of Ravens problems solved correctly by each group were English ($M = 5.30$, $SD = 2.47$), Greek ($M = 6.82$, $SD = 3.36$), and Japanese ($M = 5.14$, $SD = 2.76$), $F(2, 213) = 7.60$, $p < .001$, age corrected $F(2, 212) = 11.29$, $p < .001$.

Thus the English and Japanese groups were broadly equivalent in their verbal abilities and nonverbal reasoning, but, for whatever reasons, the Greek students showed some advantage in nonverbal reasoning but a relative slowness in verbal access for picture naming. For these reasons, we used picture naming and nonverbal reasoning as covariates in subsequent analyses.

Results

Results focus on the comparison of English, Greek, and Japanese orthographies. Because only a younger sample of Albanian children were assessed, and then with only a subset of the measures, these are only described with regard to their reading accuracy and the nature of their errors.

Reading accuracy

There were statistically significant differences in reading accuracy as a function of orthography in both a by-word ANOVA using test words 1–100 as repeated measures across orthography, $F(3, 97) = 72.20$, $p < .001$, $\eta^2 = 0.420$, and in a by-subjects ANOVA using children within orthography group as the error term, $F(3, 283) = 21.01$, $p < .001$, $\eta^2 = 0.182$. Japanese children could read on average 91.4 ($SD = 12.8$) words in their hiragana reading test. Next came the Greek children who could read 86.8 ($SD = 14.9$) words. The English children could read on average 82.0 ($SD = 18.8$) words. Finally came the Japanese children reading in kanji who managed just 66.1 ($SD = 30.4$) words.

The effect of age was statistically significant, $F(1, 282) = 245.88$, $p < .001$, $\eta^2 = 0.466$. With age correction, the effect of script increased, $F(3, 282) = 40.47$, $p < .001$, $\eta^2 = 0.301$, with means corrected for an age of 128 months being Japanese hiragana ($M = 91.6$, $SE = 1.8$), Greek ($M = 87.9$, $SE = 1.8$), English ($M = 80.2$, $SE = 1.8$), and Japanese kanji ($M = 66.4$, $SE = 1.8$). The effect of orthography also remained significant when controlling statistically for age, picture-naming accuracy, picture-naming time, and nonverbal intelligence, $F(3, 275) = 37.76$, $p < .001$, $\eta^2 = 0.292$, with all pairwise comparisons being statistically significant at $p < .05$.

These differences are presented in Figure 2, which plots the proportion of children in each orthography group who were able to read each test word correctly. As log word frequency decreased from test word 1 to test word 100, so performance declined for all orthographies. But there were clear separations between them, particularly on the lower frequency items 70–100 where the vast majority of hiragana words were read by more than 80% of the children; next came the Greek items, typically read by 60–70% of the children; then the English and kanji items, which overlapped at these lowest frequencies but separated in the mid-frequencies 40–70 where the advantage is clearly to the English items.

Table 2 shows the reading accuracy levels as a function of orthography and age. When these effects were assessed in a two-factor ANOVA (four scripts × four age bands, as described in Table 1), the orthography-by-age interaction was statistically significant, $F(7, 273) = 33.63$, $p < .001$, $\eta^2 = 0.463$, thus qualifying the main effects of orthography $F(3, 273) = 33.93$, $p < .001$, $\eta^2 = 0.272$, and age band, $F(3, 273) = 147.24$, $p < .001$, $\eta^2 = 0.618$. These effects remained statistically significant when controlling for both verbal fluency (picture-naming time) and nonverbal reasoning ability: orthography by age interaction, $F(7, 266) = 33.35$, $p < .001$, $\eta^2 = 0.467$; script, $F(3, 266) = 31.65$, $p < .001$, $\eta^2 = 0.263$; and age band, $F(3, 266) = 132.54$, $p < .001$, $\eta^2 = 0.599$. Bonferroni testing showed that the four orthography groups were significantly different from one another in terms of accuracy in the youngest 73–102-month age band at $p < .001$; they did not differ significantly from one another at the two higher age bands spanning 121–150 and 151–183 months. Figure 3 illustrates this interaction of orthography and age on reading accuracy using more fine-grained age increments and including the supplemental accuracy data for the Albanian children. The Albanian year 1 children were able to read 79.5 of their words ($SD = 16.4$), the year 2 children 86.2 ($SD = 10.81$), and the year 3 children 94.7 ($SD = 4.73$)—a significant age effect, $F(2, 59) = 7.35$, $p < .01$. These levels are close, although numerically slightly superior, to those of the readers of Greek, which similarly is an orthographically transparent alphabet.

Reading onset latency

Analysis of the effect of orthography on latency using the orthography group mean latency on each of the test words 1–100 as repeated measures showed

FIGURE 2
THE PROPORTION OF CHILDREN IN EACH ORTHOGRAPHY GROUP READING EACH TEST WORD CORRECTLY

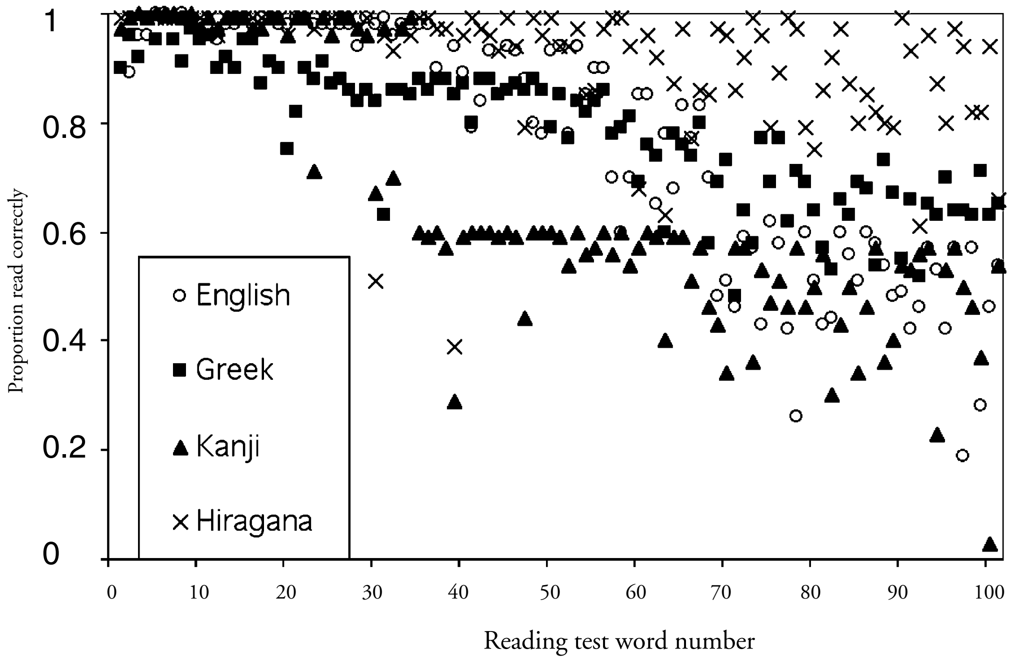


TABLE 2
MEAN (*SD*) NUMBERS OF WORDS READ CORRECTLY BY CHILDREN OF EACH ORTHOGRAPHY GROUP IN EACH AGE BAND

	Age bands (months)			
Orthography	73–102	103–120	121–150	151–183
Hiragana	89.0 (5.8)		84.0 (29.6)	96.4 (2.3)
Greek	70.8 (15.9)	87.6 (12.2)	89.6 (11.7)	95.3 (8.0)
English	57.5 (12.1)	80.3 (15.0)	90.9 (11.1)	92.8 (12.4)
Kanji	32.1 (6.9)		82.9 (4.0)	94.5 (3.5)

the effect of orthography to be statistically significant, $F(3, 97) = 23.46$, $p < .001$, $\eta^2 = 0.42$, with the mean latencies in milliseconds being Greek (M = 900.5, SD = 11.8), Japanese hiragana (M = 883.9, SD = 17.1), English (M = 827.1, SD = 19.0), and Japanese kanji (M = 786.5, SD = 14.3).

Table 3 shows the mean reading latency for each orthography and age band. Because the accuracy analyses showed that the youngest Japanese children were unable to read beyond the higher frequency words of Japanese that are written only in hiragana, the latencies in this cell do not properly reflect kanji usage, and these are therefore excluded from subsequent analyses. When latency was assessed in a two-factor ANOVA (three scripts [Greek, English, hiragana] × four age bands), there was a

FIGURE 3
THE PROPORTION OF WORDS CORRECTLY READ ALOUD IN HIRAGANA, ALBANIAN, GREEK, ENGLISH, AND KANJI BY CHILDREN OF EACH AGE

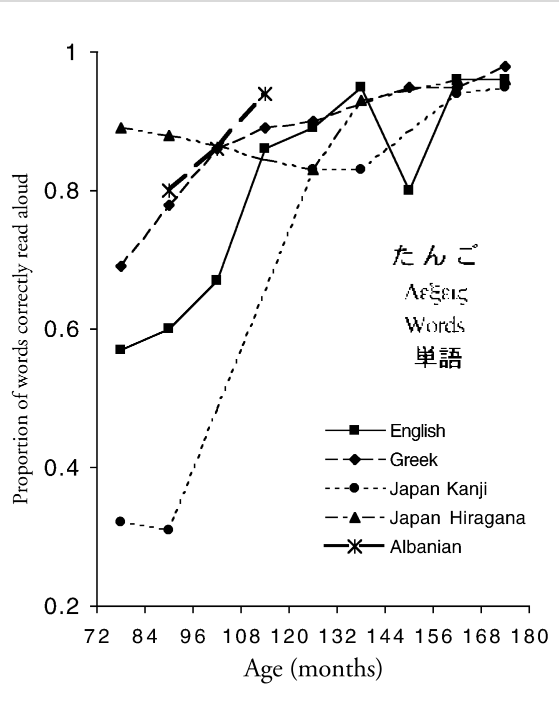
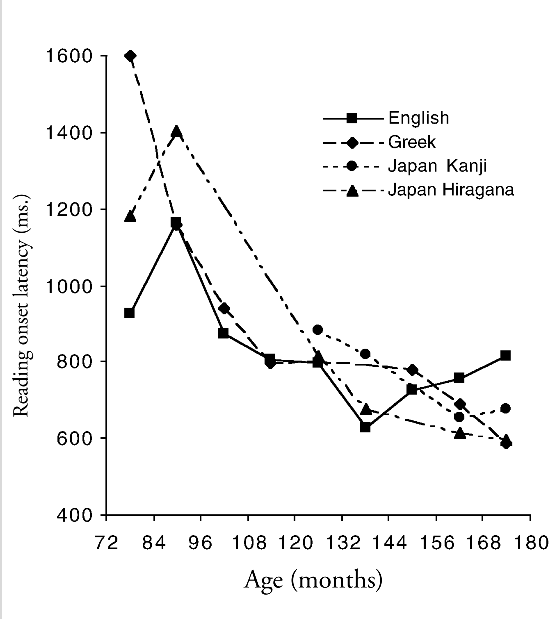


FIGURE 4
READING ONSET LATENCY FOR THE TEST ITEMS CORRECTLY READ ALOUD IN HIRAGANA, GREEK, ENGLISH, AND KANJI AT EACH AGE



significant orthography by age interaction, $F(5, 187) = 4.33$, $p < .001$, which qualified the main effects of age band, $F(3, 187) = 28.17$, $p < .001$, and orthography, $F(2, 187) = 2.71$, $p = .07$. These statistically significant effects remained when controlling for verbal fluency (picture-naming time) and nonverbal reasoning ability: orthography by age interaction, $F(5, 182) = 3.54$, $p < .005$, and age band, $F(3, 182) = 15.7$, $p < .001$. When we focused on latencies of the correct responses in the younger children in the 73–102-month age band, Bonferroni testing showed a statistically significant contrast between the Greek and English latencies ($p < .001$) and between the two more transparent orthographies, Greek and hiragana, combined against the more opaque English ($p < .001$). The four group latency averages did not differ significantly from each other at the two higher age bands spanning 121–150 and 151–183 months. Figure 4 illustrates the interaction of orthography and age on reading latency using more fine-grained age increments.

Latency as a function of word length

As already reported, there were differences in the average length of the reading test items across languages, with alphabetic orthographies having most characters per word (English, $M = 5.25$; Greek, $M = 6.28$; Albanian, $M = 5.36$), syllabic hiragana fewer ($M = 3.13$), and logographic kanji fewest of all ($M = 2.04$).

We analyzed reading onset time for correct items as a function of word length within each orthography. Regression analyses demonstrated that latency of correct responses is more a function of word length in hiragana ($B = 81.29$, $SE\,B = 6.63$, $\beta = 0.78$, $F[1, 98] = 150.39$, $p < .0001$) than it is in Greek ($B = 22.52$, $SE\,B = 2.87$, $\beta = 0.62$, $F[1, 98] = 61.47$, $p < .0001$), English ($B = 43.02$, $SE\,B = 5.77$, $\beta = 0.60$, $F[1, 98] = 55.54$, $p < .0001$), or kanji ($B = 44.36$, $SE\,B = 16.55$, $\beta = 0.26$, $F[1, 98] = 7.19$, $p < .01$]. The mean response times averaged for each length are shown in Figure 5 where the relationship between length and latency is more linear and, as shown by the tighter standard errors, more predictable as one moves from ideographic kanji through orthographically opaque English and orthographically transparent Greek alphabets, to syllabic

TABLE 3
MEAN (*SD*) LATENCY (MILLISECONDS) OF WORDS READ CORRECTLY BY CHILDREN OF EACH ORTHOGRAPHY GROUP IN EACH AGE BAND

	Age bands (months)			
Orthography	73–102	103–120	121–150	151–183
Hiragana	1200.9 (327.4)		801.1 (122.5)	607.9 (96.7)
Greek	1531.0 (1002.4)	852.8 (245.9)	800.5 (103.0)	714.1 (169.3)
English	941.3 (162.6)	825.4 (155.5)	732.5 (174.2)	783.2 (212.6)
Kanji	1032.3a (271.3)		877.1 (131.0)	662.7 (116.7)

[a]Because the youngest Japanese children were unable to read beyond the higher frequency words of Japanese that are written only in hiragana, these latencies do not properly reflect kanji usage.

hiragana. It is clear that reading latency is more clearly a function of word length in hiragana (R^2 = 0.60) than in Greek (R^2 = 0.38), English (R^2 = 0.36), or kanji (R^2 = 0.06).

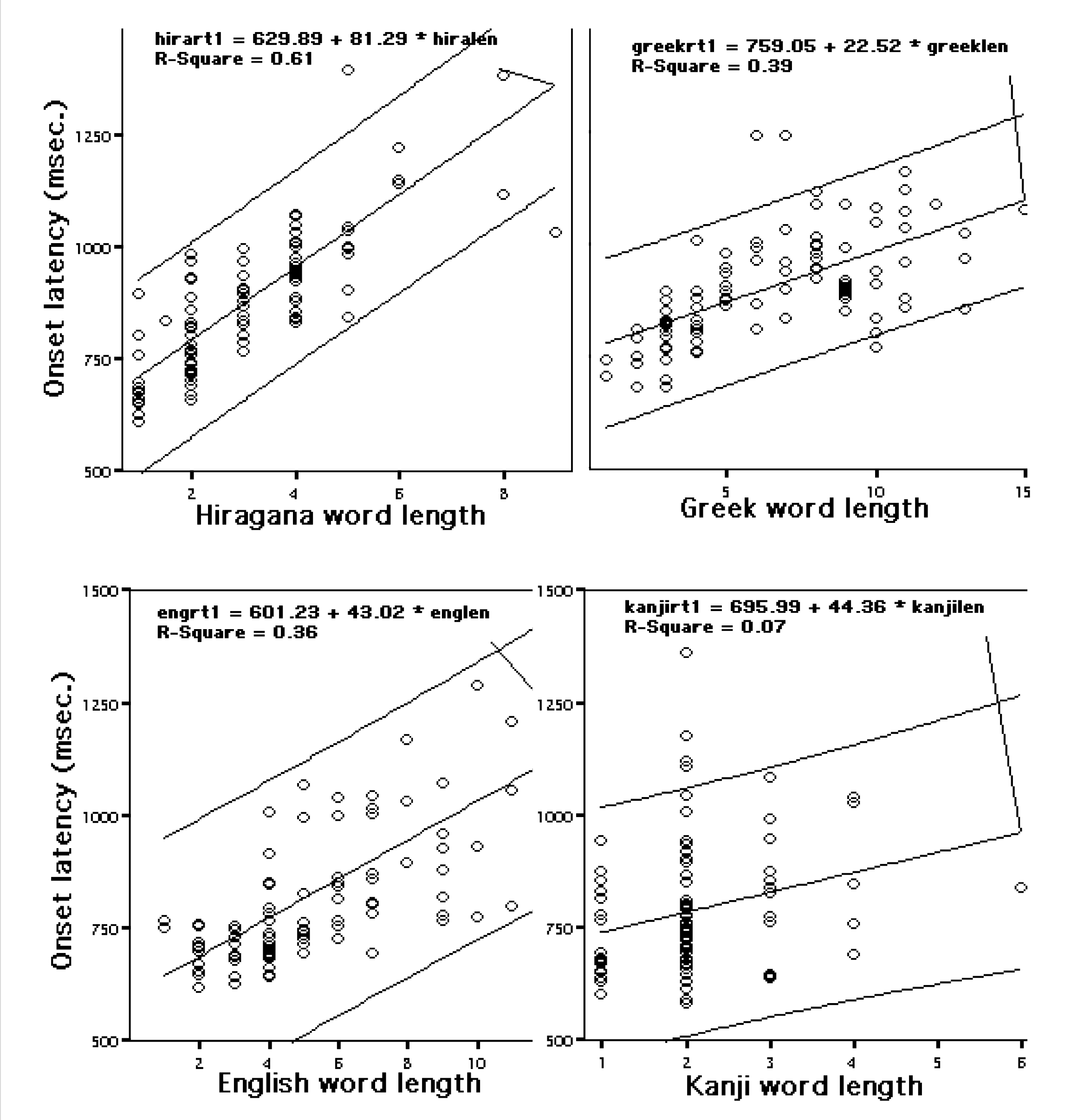
Reading errors

The reading test was discontinued after a child made five consecutive errors, a procedure that resulted in a variable number of total errors per child. We analyzed the tape recorded errors of 72 English children (M = 8.05 errors), 69 Japanese readers of hiragana (M = 7.03 errors), 72 Japanese readers of kanji (M = 8.20 errors), and 65 Greek children (M = 8.89 errors). Each error was classified into one of three categories: no response within 15 seconds, whole-word substitutions, and responses of nonwords. We used these categories because they are simple and clearly distinguishable. The number of items in each cell can be seen in Table 4 where the scripts are ordered in terms of decreasing orthographic transparency. There is a statistically significant association between orthography and error type, χ^2 (8, N = 2,887) = 1127.3, p < .00001.

The midsection of Table 4 shows these data as the percentage of the errors made on each orthography of these three different types. It also highlights the cells with the largest residuals, these being the ones that contributed most to the overall association between orthography and error type. The no-response data followed a linear relationship with orthographic transparency, with the percentage of errors of this type increasing from 1% for syllabic hiragana; through 2%, 14%, and 22%, respectively, for orthographically transparent Albanian and Greek and orthographically opaque English alphabets; to 66% for the kanji ideographs.

These large differences in the rate of no-response errors necessitated a separate analysis in order to determine the relative likelihood of the other error types. The bottom section of Table 4 shows the percentage of substantive errors that were whole-word substitutions or nonwords. There was a statistically significant association between orthography and these types of error, χ^2 (4, N = 2,273) = 144.3, p < .001. Whole-word substitutions constituted the large majority of substantive kanji errors at 69% (138 word substitutions : 63 nonword responses). In contrast, whole-word substitutions only constituted 31% of the substantive errors in Albanian (205 word substitutions : 457 nonword responses), with nonword errors predominating in Albanian. We had predicted that orthographically opaque scripts would tend to generate more whole-word substitution errors, and more transparent scripts would generate more nonword errors. The whole-word substitution rates of Albanian (31%), English (50%), and Kanji (69%) were in accord with this prediction. However, the proportions of this error type in Greek (53%) and hiragana (60%) were higher than were expected. Appendix B lists 30 error responses that are representative of those made within each orthography. In the discussion, these errors informed our consideration of the aspects of the Greek spelling system and of the Japanese language that helped explain these two unexpectedly high rates of word-substitution error.

FIGURE 5
READING ONSET LATENCY FOR CORRECT ITEMS AS A FUNCTION OF WORD LENGTH IN HIRAGANA, GREEK, ENGLISH, AND KANJI



Discussion

The orthographic depth hypothesis and rate of reading acquisition

Our first question concerned whether greater orthographic transparency led children to read aloud more quickly. The data clearly demonstrated such an association. All contrasts between the levels of reading accuracy in hiragana, Greek, English, and kanji by children in the youngest 73–102-month age band were statistically significant, with hiragana, the most transparent orthography, being the most successfully read, followed, in order of decreasing orthographic transparency, by Greek, then English, and then kanji. Consideration of the children ages 7.5 years old (90 months) allowed us to broaden the contrast set

TABLE 4
CLASSIFICATION OF THE READING ERRORS MADE BY CHILDREN READING HIRAGANA, ALBANIAN, GREEK, ENGLISH, AND KANJI

Orthography	No response	Whole-word substitution	Nonword	Total
	Error type			
		Raw count data		
Hiragana	7	286	189	482
Albanian	13	205	457	675
Greek	78	247	219	544
English	130	235	234	599
Kanji	386	138	63	587
Total	614	1,111	1,162	2,887
		Row percentages for all errors analysis[a]		
Hiragana	1 ⇓⇓	59 ⇑⇑	39	
Albanian	2 ⇓⇓	30 ⇓	68 ⇑⇑	
Greek	14 ⇓	45 ⇑	40	
English	22	39	39	
Kanji	66 ⇑⇑	24 ⇓	11 ⇓⇓	
Mean	21	38	40	
		Row percentages for analysis of substantive errors only[b]		
Hiragana		60 ⇑	40	
Albanian		31 ⇓	69	
Greek		53	47	
English		50	50	
Kanji		69 ⇑	31	
Mean		49	51	

[a]All errors analysis χ^2 (8, N = 2,887) = 1,127.3, p < .00001.
[b]Substantive errors analysis χ^2 (4, N = 2,273) = 144.3, p < .001.
⇓⇓ Haberman standardized residuals < −10.0
⇓ Haberman standardized residuals < −2.0
⇑ Haberman standardized residuals > 2.0
⇑⇑ Haberman standardized residuals > 10.0

with the addition of Albanian, the most transparent alphabetic orthography tested here. Japanese children were successful on 88 of their hiragana test items, Albanian children on 80 of theirs, Greek children on 78, and English children on 60. Japanese children managed just 31 of their kanji items, but, because the most frequent Japanese words are written only in hiragana, 31 of the items of this test were actually in hiragana; in other words, Japanese children at this age are hardly able to read kanji at all.

Zipf's law (Zipf, 1935) describes how for any language, when the number of occurrences of words is plotted as the function of their rank frequency (e.g., 1st, 2nd, 3rd), the functional form has an exponential distribution with the higher frequency word types of a language accounting for a very large proportion of word tokens. Thus, for example, while there are more than 114,000 word families in *Webster's Third New International Dictionary* (Merriam-Webster, 1961), just the thousand most frequent words of English suffice to account for about 80% of the total language we experience on a daily basis. One consequence of this law, as was demonstrated when we used our sampling procedures to work backwards from samples to corpora, is that, on average, 7.5-year-old Japanese children could successfully read 99.8% of the word tokens they might meet in hiragana, Albanian children 87.7% of word tokens that might typically occur in their written language, Greek children 85%, and English children just 69.7%. Thus, it is much harder to learn to read aloud in orthographically opaque scripts. Children schooled in these writing systems have greater difficulty and take longer in achieving this goal.

Does this ability to read aloud constrain children's comprehension of written words and their literacy development as a whole? We believe the literature says it does. First, even learners of orthographically opaque scripts like English pass through an alphabetic stage of reading, with phonology paving the development of the lexical reading pathway (Ehri, 1999; Frith, 1985; Marsh et al., 1981). Share (1995) dubbed phonological recoding the sine qua non of reading, since it is by "self-teaching" that children eventually achieve direct access to meaning. Share holds that a child's alphabetic reading (grapheme–phoneme decoding, blending, and assembled pronunciation), if successful, results in appropriate whole-word pronunciations while the corresponding orthographic patterns are still available for scrutiny. In this way larger chunks of orthography can become associated with larger chunks of pronunciation, orthographic rimes with rhymes, larger spelling patterns with more reliable pronunciations, and eventually lexical orthographic specifications with whole-word pronunciations. This process can succeed only with consistent patterns where an alphabetic reading strategy generates a "barking at print" that is approximate enough to allow recognition of the appropriate word, which implies that self-teaching might be more difficult in orthographically opaque scripts than in transparent ones. Second, phonological impairments in dyslexic (Frith, 1981; Snowling, 1998) and deaf (Perfetti & Sandak, 2000) individuals profoundly restrict their acquisition of literacy. Finally, phonological processing is a necessary component even in Chinese character identification (e.g., Perfetti & Tan, 1999; Spinks, Liu, Perfetti, & Tan, 2000), an observation that prompted DeFrancis (1989) to observe a "diverse oneness" whereby all writing systems are in essence "visible speech," sharing a common goal of representing phonetic utterances with written symbols.

Notwithstanding these arguments relating orthographic depth and reading comprehension, the effect of orthographic transparency on rate of acquisition of reading comprehension is an empirical issue, and the rankings of learnability of scripts may look different if investigation focuses on reading comprehension rather than reading aloud. Symbol–sound consistency covaries with symbol–meaning consistency. In transparent orthographies there are many homographs where the same written word is associated with a number of different senses. Evolutionary changes in language create irregularities in symbol–sound correspondences when a word's spelling becomes influenced by its morphemic structure (e.g., *heal/health*, *signature/sign*, and the spelling of the plural morpheme *-s* despite its varying sound as in *ropes*, *robes*, *roses*) (Chomsky & Halle, 1968; Ellis, 1993; Nunes, Bryant, & Bindman, 1997; Rayner & Pollatsek, 1989; Venezky, 1970). Meaning is similarly spelled out for us in the disambiguation of homophones (e.g., *be/bee*, *too/two*, *witch/which*). The clearer marking of morphology in logographic scripts may therefore provide their readers with a less ambiguous route to semantic access, and thus it may afford some consequent advantages for reading comprehension. Further research is needed therefore to extend the current comparisons by applying the frequency-sampling cross-linguistic assessment method to measure comprehension alongside naming.

The orthographic depth hypothesis and strategy of reading

Another focus of our study concerned the strategy implications of the orthographic depth hypothesis. Do differences in orthographic transparency result in different reading strategies? We looked for evidence from reaction times and from error patterns. There were various confirmations. First, word length determined 60% of the variance of reading latency in hiragana, 38% in Greek, 36% in English, and 6% in kanji. Second, readers of transparent orthographies had longer reading latencies. Third, the rate of no-response errors increased from 1% for hiragana, through 2%, 14%, and 22%, respectively, for Albanian, Greek, and English alphabets, to 66% for kanji. Finally, readers of opaque orthographies tended to make whole-word substitution errors while those of transparent orthographies tended more to make nonword mispronunciations. We considered each finding in turn.

The data demonstrated that the more transparent the orthography, the much more linear the relation between successful word-naming time and word length. This is the pattern that would result if pronunciation were assembled by means of a left-to-right parsing of the graphemes that constitute each word, with concomitant decoding of the corresponding phonemes; the more graphemes to process, the longer is the assembly time. That readers of English were not so affected by word length suggested that they are less likely to attempt to construct pronunciations in this way and instead they use partial cues, with words being discriminated by reference to a subset of their component letters, particularly those at the beginnings and ends of words (Ehri, 1997; Stuart & Coltheart, 1988). The fact that readers of kanji were little affected by word length represented the extreme of this process. Kanji provides comparatively few cues for pronunciation (Perfetti & Tan, 1999), and what little association there is between word length and naming latency for kanji probably reflects the processes of blending kanji symbols and hiragana inflections in some of the grammatically marked words.

The younger children reading the two more transparent orthographies, Greek and hiragana, evidenced significantly longer correct reading onset latencies than did readers of orthographically opaque English. Ellis and Hooper (2001) reported similarly that the latencies of children reading orthographically transparent Welsh were longer than those of matched English readers. This overall pattern suggests that longer latencies are a natural consequence of using a phonological route to lexical access because decoding takes time; the longer the words, the longer the time.

The different nature of the reading errors in the five orthographies generally supported the strategy implications of the orthographic depth hypothesis and the ways these were evidenced in Ellis and Hooper (2001). First, the greater the proportion of no-response errors for more opaque orthographies indicates that children reading these scripts are unable to successfully synthesize pronunciations by means of decoding. Readers of opaque orthographies also tended to make whole-word substitution errors, with 69% of substantive kanji errors being of this type, compared with only 31% for transparent Albanian. Inspection of the real-word errors in Appendix B shows that these substitutions are on the whole visually similar to the targets, a finding that supports the idea that readers of opaque orthographies tend to recognize written words on the basis of partial visual analysis of the reading stimuli. In contrast, the 68% nonword mispronunciation error rate in Albanian confirms the suggestion that children learning to read transparent orthographies attack each new word by means of a left-to-right parse of the graphemes, decoding of the corresponding phonemes, and subsequent pronunciation assembled from a blending of these parts. The Albanian nonword errors in Appendix B tend to be mistakes whereby correct segments are interspersed with substitutions, gaps, or misorderings—all processes that result in nonwords.

However, this pattern whereby transparent orthographies promoted more nonwords and opaque orthographies more real-word substitution errors was not absolute over all five orthographies in our sample. Although transparent Albanian produced few real-word substitutions, the proportions of this error type in hiragana and Greek were higher than were expected from previous findings with transparent orthographies. What factors might have led to this? Inspection of the reading errors in Appendix B gives some pointers. The hiragana errors tended to be very close to the targets, differing usually in only one character, which is often visually similar to the original (e.g., わぎ / わざ まん / ほん) or where there is a single character addition or omission. One factor in determining the likelihood of real-word reading-error substitutions is the lexical density of an orthographic neighborhood. The orthographic neighborhood of a word is the range of strings that can be made by changing one letter or character at a time. Imagine all possible single-letter substitutions from the word *pig*: aig, big, ..., zig, pag, pbg, ..., pzg, pia, pib, ..., piz. Relatively few of these are actual words, (e.g., *big, dig, pit*), 21 of them to be precise. A lexically dense neighborhood is one where many words are created; a sparse neighborhood is one where few are generated: *scratch* has but 4 neighbors. The simpler syllable structure of Japanese constrains the possible combinations of spoken sound sequences, and this results both in there being relatively high rates of homophony in spoken Japanese and in the orthographic neighborhoods of written kana being relatively more lexically dense. Thus, a single stroke or character substitution is more likely to generate another real word in hiragana than it is in an alphabetic orthography representing a syllabically complex language like English. In order to test this supposition informally, a computer program was written to generate random letter strings by choosing characters from the English alphabet or hiragana character set at random and then stringing them together into character sequences. We generated 100 two-letter strings and three-letter strings each for English and hiragana and then had a native speaker check how many of these were words. In the 200 random strings for each language, there were 21 Japanese words but only 6 English words. Thus the Japanese lexicon does seem to make more use of the possible permutations of written hiragana character sequences than does English, and this greater lexical density makes the misreading of a hiragana character more likely to generate a real-word substitution error in Japanese.

What of Greek? As described previously, there are many homonyms that share the same phoneme sequence but are differentiated by a change in acoustic stress that causes a shift in meaning and, usually, a change in spelling. For example, word 73 καίρια, (/kéria/) meaning "vital," becomes on change of stress the word καιριά (/kerjá/), which is correctly spelled κειριά and means "candles." Errors involving changes in the positioning of stress are shown for Greek in Appendix B. For the corpus, stress errors resulted in 48.6% of the real-word substitution errors and 41.6% of the nonword errors and were thus responsible for at least some of the higher-than-expected incidence of real-word errors in Greek.

Finally, what about the substantive kanji errors? Given the opacity of kanji, how might children make any substantive errors at all—don't they either know it or not? Clues are to be found in the facts that the majority of words written in kanji comprise more than one character, that children are likely to have previously encountered these characters on their own or in combination with other characters, and that there is a high degree of homography. Thus, for example, the pronunciation of the 54th test word, 見方, is "mikata." Some children read this as "kenpou,"an incorrect but logical pronunciation for that word. Kanji have different pronunciations. When the word 見方 is separated, 見 can be read as "mi" or "ken" and 方 can be read as "kata," "gata," "hou," or "pou." Kanji are first learned singly and only later as combinations with other kanji. Thus, when confronted with combinations that they have not yet seen before, children very sensibly try to synthesize a correct pronunciation from knowledge of the parts. Ninety-seven of the 201 substantive kanji errors were of this type (50 of 138 being 36% of the real-word substitutions and 47 of 63 being 75% of the nonword errors).

Limitations

There are many factors other than orthographic depth affecting literacy, with national economic and social development outstripping orthographic transparency in determining reading attainment (Lundberg, 2002; Stevenson, 1984; Stevenson, Stigler, Lucker, Lee, Hsu, & Kitamura, 1982). In countries with strong economies and high levels of health and adult literacy, most students become competent readers (Elley, 1994). Lack of access to written materials, lack of parental involvement in promoting literacy, and lack of educational opportunity can prohibit literacy development before any modulating effects of orthographic transparency can take hold. Such international differences in wealth, health, education, expectation, and educational practices, as they affect children's literacy attainments, point to limitations of this research that must be borne in mind in its interpretation. The study managed only a relatively small and nonrandom opportunity sample of participants. These children were taught by different teachers in different classrooms and schools using different methods of instruction in different cultures. We simply could not control these potential confounds. Further research with larger samples and better control is clearly warranted.

Other limitations concern the adequacy of language corpora as indexes of learners' language exposure. The method of language sampling has the same principled advantages as does the survey method in the description of people and populations (Kidder & Judd, 1986), hence the continued interest in corpus linguistics over the last 20 years (McEnery & Wilson, 1996). Nevertheless, as pollsters and politicians know, there is always scope for sampling error. The corpora we used were largely drawn from adult written language rather than from child input. Although the particularities of a corpus probably have little effect upon the higher frequency words of a language, they can have marked influence upon frequency estimates of less common items, and so, lack of adequate representation necessarily results in measurement error. It would be better to sample the language from literature for children. It would also be preferable to have individual random sampling for every test, with computerized sampling of log frequency using psychophysical methods of threshold detection, rather than just one sample frozen and duplicated for all children.

In light of these limitations, further research is required to fully describe and compare the rates and processes of learning to read in different orthographies. Then, when different patterns of learnability and strategy have been firmly identified, there will be subsequent need for guided experimentation into the cognitive factors that might underpin these differences. These experiments would control other factors while targeting particular facets of the language or orthography such as the lexical range of the language, alphabet size, letter sequence complexity, phonological structure, phonotactic complexity, morphological complexity, word length, word frequencies, type–token ratios, accenting, and so forth.

Meanwhile, the pattern of differences in reading acquisition identified in the present study suggests that it does matter whether an orthography writes what is meant or writes what is said. Orthographies that represent pronunciation encourage faster learning for reading aloud, and the more transparently they do this, the faster the learning rate and the more they encourage lexical access via phonology. Such results illustrate a more general principle that, in solving a particular problem, learners find and exploit the regularities that help them to achieve their task, and as they practice, so their representations and strategies become tuned to that particular problem space.

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MIWA NATSUME, KATERINA STAVROPOULOU, NICOLETTA POLYZOE, MARIA-LOUISA TSIPA, and **MICHALIS PETALAS** were advanced undergraduate students at University of Wales, Bangor, at the time of the study reported here. Miwa Natsume went on to postgraduate study in child development, Katerina Stavropoulou in autism, Nicoletta Polyzoe in consumer psychology, Maria-Louisa Tsipa in social intervention and health, and Michalis Petalas in cognitive behavioral therapy. They may be contacted c/o Dr. Nick C. Ellis at the School of Psychology, University of Wales, Bangor, LL57 2AS, UK.

REFERENCES

ABBOUD, A., & SUGAR, D. (1997). *SuperLab* (Version 1.03) [Computer software]. Phoenix, AZ: Cedrus.

AKITA, K., & HATANO, G. (1999). Learning to read and write in Japanese. In M. Harris & G. Hatano (Eds.), *Learning to read and write: A cross-linguistic perspective* (pp. 214–234). Cambridge, UK: Cambridge University Press.

ALEGRIA, L., PIGNOT, E., & MORAIS, J. (1982). Phonetic analysis of speech and memory codes in beginning readers. *Memory & Cognition, 10*, 451–456.

AMANO, N., & KONDO, K. (2000). *NTT database series—Nihongono goitokusei dai 7 kan: Hindo* [Lexical properties of Japanese, Vol. 7, Frequency Database 1]. Tokyo: NTT Communication Science Laboratories Producer 1.

BAAYEN, R.H., PIEPENBROCK, R., & VAN RIJN, H. (1995). *The Celex Lexical Database* (Release 2) [CD-ROM]. Philadelphia: Linguistic Data Consortium, University of Pennsylvania [Distributor].

BABINIOTIS, G. (1980). *Theoritiki glossologia* [Linguistics in theory]. Athens, Greece: University of Athens Press.

BAKAMIDIS, S., & CARAYANNIS, G. (1987). "Phonemia": A phoneme transcription system for speech synthesis in modern Greek. *Speech Communication*, *6*, 159–169.

CHITIRI, H.F., & WILLOWS, D.M. (1994). Word recognition in two languages and orthographies: English and Greek. *Memory & Cognition*, *22*, 313–325.

CHOMSKY, N., & HALLE, M. (1968). *The sound pattern of English.* New York: Harper & Row.

DANIELS, P.T., & BRIGHT, W. (Eds.). (1996). *The world's writing systems.* New York: Oxford University Press.

DEFRANCIS, J. (1989). *Visible speech: The diverse oneness of writing systems.* Honolulu: University of Hawaii Press.

EHRI, L.C. (1997). Learning to read and learning to spell are one and the same, almost. In C.A. Perfetti, L. Rieben, & M. Fayol (Eds.), *Learning to spell: Research, theory, and practice across languages* (pp. 237–269). Hillsdale, NJ: Erlbaum.

EHRI, L.C. (1999). Phases of development in learning to read words. In J. Oakhill & R. Beard (Eds.), *Reading development and the teaching of reading* (pp. 79–108). Oxford, UK: Blackwell.

ELLEY, W.B. (Ed.). (1994). *The IEA study of reading literacy: Achievement and instruction in thirty-two school systems.* Oxford, UK: Elsevier Science.

ELLIS, A.W. (1993). *Reading, writing, and dyslexia: A cognitive analysis.* Hillsdale, NJ: Erlbaum.

ELLIS, N.C., & HOOPER, A.M. (2001). It is easier to learn to read in Welsh than in English: Effects of orthographic transparency demonstrated using frequency-matched cross-linguistic reading tests. *Applied Psycholinguistics*, *22*, 571–599.

ELLIS, N.C., O'DOCHARTAIGH, C., HICKS, W., MORGAN, M., & LAPORTE, N. (2001). *Cronfa Electroneg o Gymraeg/A 1 million word lexical database and frequency count for Welsh.* Retrieved August, 2001, from University of Wales, Bangor, website: http://www.bangor.ac.uk/ar/cb/ceg/ceg_eng.html

FRITH, U. (1981). Experimental approaches to developmental dyslexia: An introduction. *Psychological Research*, *43*, 97–109.

FRITH, U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, M. Coltheart, & J. Marshall (Eds.), *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading* (pp. 301–330). London: Erlbaum.

GAUR, A. (1992). *A history of writing.* London: The British Library.

GOSWAMI, U. (1999). Causal connections in beginning reading: The importance of rhyme. *Journal of Research in Reading, 22*, 217–240.

GOSWAMI, U. (2000). Phonological representations, reading development and dyslexia: Towards a cross-linguistic theoretical framework. *Dyslexia, 6*, 133–151.

GOSWAMI, U., GOMBERT, J.E., & DE BARRERA, L.F. (1998). Children's orthographic representations and linguistic transparency: Nonsense word reading in English, French, and Spanish. *Applied Psycholinguistics, 19*, 19–52.

GOSWAMI, U., PORPODAS, C., & WHEELWRIGHT, S. (1997). Children's orthographic representations in English and Greek. *European Journal of Psychology of Education, 12*, 273–292.

HARRIS, M., & GIANNOULI, V. (1999). Learning to read and spell in Greek. In M. Harris & G. Hatano (Eds.), *Learning to read and write: A cross-linguistic perspective* (pp. 51–70). Cambridge, UK: Cambridge University Press.

HOXHALLARI, L. (2000). *Teacher's beliefs about learning to read Albanian, English, and Welsh: The effect of a regular orthography.* Unpublished manuscript, University of Wales, Bangor, UK.

KATZ, L., & FROST, R. (1992). Reading in different orthographies: The orthographic depth hypothesis. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 67–84). Amsterdam: New Holland.

KESS, J.F, & MIYAMOTO, T. (1999). *The Japanese mental lexicon: Psycholinguistic studies of kana and kanji processing.* Philadelphia: John Benjamins.

KIDDER, L.H., & JUDD, C.M. (1986). *Research methods in social relations* (5th ed.). New York: Holt, Rinehart and Winston.

LANDERL, K., WIMMER, H., & FRITH, U. (1997). The impact of orthographic consistency on dyslexia: A German-English comparison. *Cognition, 63*, 315–334.

LIBERMAN, I., SHANKWEILER, D., FISCHER, F.W., & CARTER, B. (1974). Explicit syllable and phoneme segmentation in the young child. *Journal of Experimental Child Psychology, 18*, 201–212.

LOPEZ, M.R., & GONZALEZ, J.E.J. (1999). An analysis of the word naming errors of normal readers and reading disabled children in Spanish. *Journal of Research in Reading, 22*, 180–197.

LUNDBERG, I. (2002, June). *Reading in a second language with the extra load of dyslexia.* Keynote presentation at the International Conference on Multilingual and Cross-Cultural Perspectives on Dyslexia, Washington, DC.

MAGOULAS, G. (1979). *Eisagogi sti neoelliniki phonologia* [Introduction to modern Greek phonology]. Athens, Greece: University of Athens Press.

MARSH, G., FRIEDMAN, M.P., WELCH, V., & DESBERG, P. (1981). A cognitive-developmental theory of reading acquisition. In T.G. Waller & G.E. MacKinnon (Eds.), *Reading research: Advances in theory and practice* (Vol. 3, pp. 201–215). New York: Academic Press.

MCENERY, T., & WILSON, A. (1996). *Corpus linguistics.* Edinburgh, UK: Edinburgh University Press.

MERRIAM-WEBSTER, A. (Ed.). (1961). *Webster's third new international dictionary of the English language.* Springfield, MA: G. & C. Merriam.

NATIONAL LANGUAGE RESEARCH INSTITUTE. (1988). *The acquisition of common kanji by elementary and secondary school children.*

Tokyo: Tokyo Shoseki.

NOMURA, M. (1980). Chinese characters content of weekly's writing. *Mathematical Linguistics*, *12*, 215–222.

NUNES, T., BRYANT, P., & BINDMAN, M. (1997). Morphological spelling strategies: Developmental stages and processes. *Developmental Psychology*, *33*, 637–649.

ÖNEY, B., & DURGUNOGLU, A.Y. (1997). Beginning to read in Turkish: A phonologically transparent orthography. *Applied Psycholinguistics*, *18*, 1–15.

PAULESU, E., MCCRORY, E., FAZIO, F., MENONCELLO, L., BRUNSWICK, N., CAPPA, S.F., ET AL. (2000). A cultural effect on brain function. *Nature Neuroscience*, *3*, 91–96.

PERFETTI, C.A., & SANDAK, R. (2000). Reading optimally builds on spoken language: Implications for deaf readers. *Journal of Deaf Studies & Deaf Education*, *5*, 32–50.

PERFETTI, C.A., & TAN, L.H. (1999). The constituency model of Chinese word identification. In J. Wang, A.W. Inhoff, & H.-C. Chen (Eds.), *Reading Chinese script: A cognitive analysis* (pp. 115–134). Mahwah, NJ: Erlbaum.

PORPODAS, C.D. (1991). The relation between phonemic awareness and reading and spelling of Greek words in the first school years. In M. Carretero & M.L. Pope (Eds.), *Learning and instruction: European research in an international context* (Vol. 3, pp. 203–217). Oxford, UK: Pergamon Press.

PORPODAS, C.D. (1999). Patterns of phonological and memory processing in beginning readers and spellers of Greek. *Journal of Learning Disabilities*, *32*, 406–416.

RACK, J.P., SNOWLING, M.J., & OLSON, R.K. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly*, *27*, 28–53.

RAYNER, K., & POLLATSEK, A. (1989). *Psychology of reading*. Englewood Cliffs, NJ: Prentice-Hall.

ROZIN, P., & GLEITMAN, L.R. (1977). The structure and acquisition of reading II: The reading process and the acquisition of the alphabetic principle. In A.S. Reber & D.L. Scarborough (Eds.), *Toward a psychology of reading* (pp. 55–141). New York: Erlbaum.

SEYMOUR, P.H.K., ARO, M., & ERSKINE, J.M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, *94*, 143–174.

SEYMOUR, P.H.K., & ELDER, E. (1986). Beginning reading without phonology. *Cognitive Neuropsychology*, *3*, 1–36.

SHARE, D.L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition*, *55*, 151–218.

SHIMAMURA, N., & MIKAMI, H. (1994). Acquisition of hiragana letters by preschool children: In comparison with the investigation by the National Language Research Institute [In Japanese with English summary]. *Japanese Journal of Educational Psychology*, *42*, 70–76.

SNODGRASS, J.G., & VANDERWART, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 174–215.

SNOWLING, M. (1998). Dyslexia as a phonological deficit: Evidence and implications. *Child Psychology & Psychiatry Review*, *3*, 4–11.

SPENCER, L.H., & HANLEY, J.R. (2003). Effects of orthographic transparency on reading and phoneme awareness in children learning to read in Wales. *British Journal of Psychology*, *94*, 1–28.

SPINKS, J.A., LIU, Y., PERFETTI, C.A., & TAN, L.H. (2000). Reading Chinese characters for meaning: The role of phonological information. *Cognition*, *76*, B1–B11.

STEVENSON, H.W. (1984). Orthography and reading disabilities. *Journal of Reading Disabilities*, *17*, 296–301.

STEVENSON, H.W., STIGLER, J.W., LUCKER, G.W., LEE, S.-Y., HSU, C.-C., & KITAMURA, S. (1982). Reading disabilities: The case of Chinese, Japanese and English. *Child Development*, *53*, 1164–1181.

STUART, M., & COLTHEART, M.C. (1988). Does reading develop in a sequence of stages? *Cognition*, *30*, 139–181.

THORSTAD, G. (1991). The effect of orthography on the acquisition of literacy skills. *British Journal of Psychology*, *82*, 527–537.

TOMBAIDIS, D.E. (1986). *Epitomi tis historias tis Ellinikis glossas* [Compendium of the history of the Greek language]. Athens, Greece: OEDB (Organization of Textbooks Publishing).

TOMBAIDIS, D.E. (1987). *Synoptiki historia tis Ellinikis glossas* [Concise history of the Greek language]. Athens, Greece: OEDB.

TREIMAN, R., MULLENNIX, J., BIJELJAC-BABIC, R., & RICHMOND-WELTY, E.D. (1995). The special role of rimes in the description, use, and acquisition of English orthography. *Journal of Experimental Psychology: General*, *124*, 107–136.

TRIANTAPHYLLIDIS, M. (1913). *Horthographia mas* [Our orthography]. Athens, Greece: Estia.

TRIANTAPHYLLIDIS, M. (1980). *Neoelliniki grammatiki* [Modern Greek grammar]. Athens, Greece: Estia.

VENEZKY, R. (1970). *The structure of English orthography*. The Hague, the Netherlands: Mouton.

WIMMER, H., & GOSWAMI, U. (1994). The influence of orthographic consistency on reading development: Word recognition in English and German children. *Cognition*, *51*, 91–103.

WIMMER, H., & HUMMER, P. (1990). How German speaking first graders read and spell: Doubts on the importance of the logographic stage. *Applied Psycholinguistics*, *11*, 349–368.

ZIPF, G.K. (1935). *The psycho-biology of language: An introduction to dynamic philology*. Cambridge, MA: MIT Press.

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APPENDIX A

THE ITEMS OF THE SINGLE WORD READING TESTS FOR THE FIVE SCRIPTS

Word number	English	Greek	Hiragana	Kanji	Albanian
1	the	και	の	の	të
2	a	να	を	を	e
3	of	του	は	は	në
4	and	το	に	に	dhe
5	to	της	たろ	たろ	i
6	in	η	が	が	që
7	it	την	る	る	për
8	I	που	と	と	me
9	is	με	で	で	një
10	he	από	し	し	nga
11	for	ο	い	い	ka
12	that	για	ている	ている	më
13	you	των	も	も	se
14	to	οι	なら	なら	është
15	with	σε	て	て	do
16	be	τη	から	から	nuk
17	on	στην	れる	れる	së
18	at	τις	する	する	u
19	his	στη	こと	こと	por
20	was	μια	せよ	せよ	edhe
21	but	αλλά	など	など	ai
22	not	ένα	な	な	si
23	they	έχει	にち	日	tij
24	this	ή	なる	なる	kanë
25	that	αυτό	さ	さ	po
26	or	στις	ある	ある	duke
27	we	όμως	や	や	janë
28	which	όπως	い	い	kishte
29	as	μου	いう	いう	shumë
30	been	κατά	にほん	日本	këtë
31	me	οποία	この	この	ta
32	are	γιατί	えん	円	prej

(continued)

APPENDIX A

THE ITEMS OF THE SINGLE WORD READING TESTS FOR THE FIVE SCRIPTS (continued)

Word number	English	Greek	Hiragana	Kanji	Albanian
33	into	στους	まで	まで	gjithë
34	like	αυτά	ませ	ませ	qenë
35	its	χρόνια	もんだい	問題	sipas
36	two	ούτε	やく	約	disa
37	these	καθώς	まん	万	ne
38	than	πώς	どう	同	para
39	down	υπάρχουν	しゅしょう	首相	deri
40	also	είχαν	でる	出る	jetë
41	being	πλέον	おもう	思う	kam
42	between	αυτός	みる	見る	policisë
43	always	κάποια	かんけい	関係	ose
44	really	υπουργός	じけん	事件	cilët
45	under	κάνουν	つよい	強い	mënyrë
46	long	πια	さんか	参加	tjerë
47	child	λόγο	せいけん	政権	nëpër
48	case	είπε	いく	行く	o
49	know	αληθεια	ばあい	場合	lidhur
50	think	συνέχεια	あたらしい	新しい	jenë
51	car	έξω	こんかい	今回	deklaruar
52	parents	τμήμα	じつげん	実現	rast
53	make	πράξη	じかん	時間	jezu
54	city	έγιναν	みかた	見方	ditët
55	where	μόνος	もっとも	最も	ati
56	round	Γερμανία	めだつ	目立つ	vrarë
57	areas	επιχείρηση	そう	総	bëra
58	various	Κυριακή	しぼう	死亡	gjithnjë
59	through	εξωτερικό	もりこむ	盛り込む	komisariatit
60	growing	ηνωμένες	しゅうちゅう	集中	rakipi
61	normal	φράση	さんにん	三人	prokurori
62	theatre	συνδέεται	うんてん	運転	yt
63	minute	αμερικανών	れんぽう	連邦	firmosur
64	prices	θέματος	しゅるい	種類	rrethit
65	chosen	αξιολόγηση	なんど	何度	mal
66	transport	δίκαιο	ちょういん	調印	njihet
67	weak	μέθοδο	たいりょう	大量	lashtë
68	cabinet	ευρύ	うりあげぜい	売上税	datë

(continued)

THE ITEMS OF THE SINGLE WORD READING TESTS FOR THE FIVE SCRIPTS (continued)

Word number	English	Greek	Hiragana	Kanji	Albanian
69	criticism	προβάλλει	そうさ	操作	qëndrimi
70	crucial	εξυπηρετεί	めいがら	銘柄	personale
71	adequate	σπανίως	いったい	一体	paguajë
72	continues	προσπαθειών	とびだす	飛び出す	flasim
73	awareness	καίρια	しんとう	浸透	organizatë
74	phenomenon	μέλλοντος	きみ	気味	prodhimit
75	thirteen	τονίζοντας	せんしん	先進	varrit
76	bought	διπλωματικό	きんゆうせいさく	金融政策	verifikuar
77	inequality	εμπειρογνώμονες	かわり	代り	sështë
78	thou	εκδόσεων	よめる	読める	ndan
79	underground	μελέτησε	せんかん	選管	valën
80	dedicated	υπογραμμίζουν	ていきんり	低金利	gjashtëdhjetë
81	urine	προτιμήσει	きずつく	傷つく	liderit
82	panting	εκλείψει	なざし	名指し	mjegull
83	third	φρασεολογία	つうしんもう	通信網	thelluar
84	coldly	ολίγοις	つきはなす	突き放す	grindjet
85	flew	προχωράει	うらはら	裏腹	përhershme
86	grounds	αναδόχου	りょうしき	良識	deklarimi
87	medals	μακραίωνη	たびだつ	旅立つ	premtimeve
88	governing	πολιτισμένου	りゃくだつ	略奪	klani
89	ceased	εμπνέεται	とりょう	塗料	llum
90	disdain	στηριζόμενη	きき	聞き	rivalitet
91	intervening	βαλκανικά	のばなし	野放し	numrash
92	anticipated	ευημερούσα	りょこうせんたー	旅行センター	mirënjohjeje
93	checkpoint	υπερτονίζει	つつみ	包み	servilizmi
94	amen	παρεκκλίνει	るいけい	類型	milleniumit
95	incorporating	πάψουμε	りんさんぶつ	林産物	nishan
96	worshipped	φιλειρηνική	うらやま	裏山	parakalimin
97	eulogy	λιμοκτονούσες	ぶんしん	分身	tepërtit
98	northwest	κοινωνοί	ろうどうきょうや	労働協約	imperialiste
99	bouquets	βαρύτητας	わぎ	和議	lëvdoni
100	surveyed	επικοινωνιακή	ほうふつ	彷仏	shkumës

APPENDIX B

THIRTY EXAMPLES OF READING ERRORS FROM FIVE SCRIPTS

Hiragana reading errors

Correct word	Error response	Real-word substitution	Nonword error
しゅうちゅう	しょうちょう	*	
りょこうせんたー	りょうこうせんたー	*	
しゅしょう	しゅうしょう	*	
じけん	じんけん	*	
うらはら	うらはう		*
りょこうせんたー	りょうこうせんたー	*	
りんさんぶつ	りんさつぶつ		*
しゅしょう	しゅうしょう		
しゅうちゅう	しゅうちゅう	*	
れんぽう	れんぼう		*
きんゆうせいさく	きゅうゆうせいさく		
きずつく	きづ（ず）つく	*	
たびだつ	とびたつ	*	
とりょう	とうりょう	*	
わぎ	わざ	*	
ろうどうきじゅんきょく	ろうどうきんじゅきょく		*
にほん	えほん	*	
まん	ほん	*	
せいけん	せいけい	*	
たいりょう	たいりゅう	*	
りょこうせんたー	りょうこうせんたー	*	
この	のこ	*	
かんけい	かんけ	*	
じけん	じっけん	*	
しゅうちゅう	ちゅうしょう	*	
うりあげぜい	うりあげざせん		*
りょうしき	きょうしき	*	
ぶんしん	もんしん	*	

(continued)

THIRTY EXAMPLES OF READING ERRORS FROM FIVE SCRIPTS (continued)

Kanji reading errors

Correct word	Error response	Real-word substitution	Nonword error	Kanji Structural error
売上税	そうじょうぜい		*	
金融政策	かんゆうせいさく	*		
代わり	かり	*		
名指し	めざし	*		
塗料	とそう	*		
旅行センター	りょうこうせんたー	*		
類型	るいがた		*	*
訪仏	ほうぶつ	*		*
首相	しゅそう	*		*
実現	じっけん	*		
盛り込む	のりこむ	*		
操作	そうさく	*		*
気味	きち	*		
代わり	だいわり		*	*
選管	きょっかん	*		
通信網	つうしんぼ	*		
突き放す	ふきはなす	*		
裏腹	うらばら		*	*
類型	しゅるいがた	*		
訪仏	しんぶつ	*		
首相	しゅそう	*		*
操作	そうさく	*		*
名指し	めざし	*		
略奪	りゃくふん		*	
塗料	そうりょう	*		
野放し	のはなし		*	*
類型	るいがた		*	*
分身	ぶんみ		*	*
訪仏	ほうぶつ	*		*

(continued)

THIRTY EXAMPLES OF READING ERRORS FROM FIVE SCRIPTS (continued)

Greek reading errors

Correct word	Error response	Real-word substitution	Nonword error	Greek Stress error
αυτός	αβτός		*	
συνδέεται	συνδέται		*	
μια	μία	*		*
έχει	έχεη		*	
όπως	οπώς		*	*
οποία	όποια	*		*
είχαν	έιχαν		*	
μόνος	μονός	*		*
επιχείρηση	επιχέρισε		*	
ηνωμένες	ενωμένος	*		
συνδέεται	συνδέει	*		
Αμερικανών	Αμερικάνων		*	*
αξιολόγηση	αξιολόγησε	*		
δίκαιο	δίκιο	*		
ευρύ	εύρυ		*	*
εξυπηρετεί	εξυπερέτει		*	
σπανίως	σπάνιος	*		*
καίρια	κεριά	*		*
τονίζοντας	τονιζόντας		*	*
εμπειρογνώμονες	εμπειρογόμονες		*	
εκδόσεων	εκδοσών		*	
προτιμήσει	προτίμησε	*		
εκλείψει	έκλειψη	*		*
ολίγοις	ολίγο	*		
αναδόχου	ανάδοχου		*	*
μακραίωνη	μακραίνω	*		
εμπνέεται	εμπνέει	*		
στηριζόμενη	στηριζομένη		*	*
λιμοκτονούσες	λιμοκονούσες		*	

(continued)

THIRTY EXAMPLES OF READING ERRORS FROM FIVE SCRIPTS (CONTINUED)

English reading errors

Correct word	Error response	Real-word substitution	Nonword error
case	ce----		*
know	now	*	
think	stink	*	
parents	presents	*	
areas	ar----		*
various	va---		*
through	thu		*
theatre	th-e-tree		*
prices	prince	*	
transport	train	*	
criticism	cristian	*	
crucial	circkle	*	
adequate	adik		*
awareness	aya		*
crucial	cruksal		*
adequate	adequacy	*	
really	rally	*	
child	chill	*	
parents	presents	*	
city	sixty	*	
various	varies	*	
through	though	*	
growing	going	*	
normal	normally	*	
area	are-as		*
through	though	*	
theatre	there	*	
criticism	cartisms		*
crucial	crukial		*

(continued)

APPENDIX B

THIRTY EXAMPLES OF READING ERRORS FROM FIVE SCRIPTS (continued)

Albanian reading errors

Correct word	Error response	Real-word substitution	Nonword error
dhe	dhë		*
nga	nxha		*
duke	buke	*	
janë	lajnë	*	
disa	dëshia		*
para	pata	*	
policisë	përlisë		*
ose	poste	*	
mënyrë	mynynë		*
tjerë	tjetër	*	
lidhur	litur		*
deklaruar	dikur	*	
ditët	dritën	*	
vrarë	vrar		*
gjithnjë	ngjithë		*
komisariatit	komisatia		*
prokurori	prakuri		*
njihet	njeht		*
lashtë	keshtë		*
personale	presonëte		*
paguajë	pakuja		*
flasim	fitsim		*
prodhimit	prodhimeit		*
varrit	vend	*	
verifikuar	verikuar		*
ndan	mban	*	
liderit	lidrit		*
servilizmi	filizmi		*
parakalimin	kalimin	*	
imperialiste	impraliste		*