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Chinese–English biliteracy acquisition: cross-language and writing system transfer

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Abstract

This study investigated cross-language and writing system relationship in biliteracy acquisition of children learning to read two different writing systems—Chinese and English. Forty-six Mandarin-speaking children were tested for their first language (Chinese-L1) and second language (English-L2) reading skills. Comparable experiments in Chinese and English were designed focusing on two reading processes—phonological and orthographic processing. Word reading skills in both writing systems were tested. Results revealed that Chinese onset matching skill was significantly correlated with English onset and rime matching skills. Pinyin, an alphabetic phonetic system used to assist children in learning to read Chinese characters, was highly correlated with English pseudoword reading. Furthermore, Chinese tone processing skill contributed a moderate but significant amount of variance in predicting English pseudoword reading even when English phonemic-level processing skill was taken into consideration. Orthographic processing skill in the two writing systems, on the other hand, did not predict each other's word reading. These findings suggest that bilingual reading acquisition is a joint function of shared phonological processes and orthographic specific skills.

Keywords: Chinese; English; Phonological; Orthographic processing; Word reading

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1. Introduction

Learning to read is essentially learning to map between the spoken form and print form of the language (e.g. Adams, 1990; Perfetti, 1992; Treiman, 1993). Phonological and orthographic processing are the two basic processes involved in acquiring reading skills for young children. Different phonological and orthographic processing skills are entailed in reading depending on the nature of the language and writing system (e.g. Chen & Tzeng, 1992; Feldman, 1987; Frith, Wimmer, & Landerl, 1998; Goswami, Gombert, & Barrera, 1998; Leong & Tamaoka, 1998; Perfetti, 1999). However, recent research has shown that learning to read two alphabetic languages such as Spanish and English concurrently rests on common phonological processes; thus these phonological skills can be transferred from one language to the other (e.g. Cisero & Royer, 1995; Durgunoglu, Nagy, & Hancin-Bhatt, 1993; see Durgunoglu, 2002 for a review). Spanish and English readings share the fundamental alphabetic principle. Chinese and English, however, contrast sharply in their writing systems as well as their spoken forms of the language. In learning to read Chinese and English, children have to confront the unique demands of the different writing systems and languages. Whether there exists any relationship in learning to read across different writing systems is a theoretical and empirical question remaining to be answered. In this study, we investigated cross-language and writing system transfer among a group of Chinese–English bilingual children. We were interested in a general theoretical issue: Is the development of bilingual reading across writing systems a matter of specific language and writing system acquisition? Are there basic skills in phonology and orthography that transfer when moving across systems that differ both in their principles and their scripts?

1.1. Cognitive consequences in learning to read across writing systems

Different cognitive demands are involved in reading different writing systems. Chinese, a nonalphabetic writing system, presents a highest contrast to alphabetic systems such as English (e.g. Perfetti, 1999; Perfetti, Zhang, & Berent, 1992). The basic unit of the Chinese writing system is the character. Unlike alphabetic systems, the graphemes in Chinese do not map onto individual phonemes; instead, they map onto syllabic morphemes (DeFrancis, 1989; Mattingly, 1992). Chinese has a rich orthographic system; each character is composed of basic strokes. These strokes are then combined to form component radicals, for example, 工 and 扌. The radical is the most basic unit of a Chinese character. Radicals are then combined to form characters, for example, 扌 and 工 are combined to form the character 扛 (meaning “carry with shoulder”, pronounced as /kang/2). The majority of Chinese characters are compound characters, in which there are two or more radical components. The configuration of the radicals in compound characters follows normally either a left–right or top–bottom structure. The compositional relationship of radicals to form characters in the Chinese writing system is different in principle from the compositional relationship of letters to form words in alphabetic writing systems (Perfetti, Liu, and Tan, in press).

The syllable is the basic speech unit of Chinese, and each syllable is divided into two parts: the onset and the rime. Mandarin is one of the major dialects among the Chinese population. The onset of a Mandarin Chinese syllable is always a single consonant. In most syllables, the rime segment consists of mainly vowels. As a result, Mandarin Chinese, like other dialects, has a much smaller number of syllables than does spoken English (Hanely, Tzeng, & Huang, 1999). There are only about 400 different syllables in Mandarin Chinese. The number of homophones in Chinese is large. However, because of the existence of tone in Chinese syllables, the number of homophones is reduced. There are about 1300 tone syllables in spoken Chinese (Taylor & Taylor, 1995). The nature of tone in spoken Chinese is suprasegmental; it is attached to the rime. There are four tones in Mandarin (high-level, often labeled as 1, high-rising, 2, falling-rising, 3, and high-falling, 4). A change in the tone of a syllable leads to a change in its meaning. For example, the same syllable /ma/ can have four different meanings when it is spoken with the four different tones: /ma/1 妈 "mother", /ma/2 麻 "linen", /ma/3 马 "horse", and /ma/4 骂 "scold". Another important feature of tone is that it is not represented in written Chinese and is, therefore, not useful for distinguishing morphemes in written Chinese. Table 1 illustrates the three major contrasts between Chinese and English: mapping principles, graphic forms and tone.

These contrasting features of Chinese language and writing system have led to some differences in how reading works in Chinese compared to English. In learning to read an alphabetic writing system such as English, a large volume of research has revealed that children's skills at processing small phonological units–phonemes–are powerful predictors of individual differences in learning to read (e.g. Byrne & Fielding-Barnsley, 1995; Hulme et al., 2002; Lundburg, Frost, & Peterson, 1988; Muter, Hulme, Snowling, & Taylor, 1998). However, current models of Chinese reading (e.g. Perfertti et al., in press; Taft, Zhu, & Peng, 1999) emphasize the importance of a fully specified orthographic representation prior to the activation of phonological and meaning information in reading Chinese. There have been a series of recent studies testing the hypothesis that orthographic processing is the basic processing component in reading Chinese. These studies strongly suggest that component radicals and their positional information are explicitly represented in not only a native Chinese reader's lexicon (e.g. Peng, Li, & Yang, 1997; Shu & Anderson, 1999; Taft et al., 1999) but also in that of learners of Chinese as a second language (Wang, Liu, & Perfetti, in press; Wang, Perfetti, & Liu, 2003). Graphemic information and the requisite visual skills are also crucial in learning to read Chinese. For example, Huang and Hanley (1994) showed that a test involving visual, paired associate learning was significantly correlated with the reading performance of children in Hong Kong and Taiwan, but not with that of British children. In contrast, the reading performance of British children was better predicted by their performance on phonological

Table 1
Three major contrasts between the Chinese and English language and writing systems

Contrasts	Chinese 马 "horse" | /ma/3	English cat /k/ /æt/ /k/ /æ/ /t/
Grapheme mapping principle	Syllabic morphemes	Phonemes
Graphic form and spacial layout	Nonlinear	Linear
Tonal feature	Tonal	Nontonal

awareness tasks, even after controlling for the effects of IQ and vocabulary. There is some evidence for the role of phonological information in learning to read Chinese. Consistent with the literature on English reading acquisition, early phonological skills such as rhyme processing are useful in predicting accurate word recognition in Chinese children in the primary grades (Ho & Bryant, 1997a–c; Hu & Catts, 1998; McBride-Chang & Ho, 2000; Shu, Anderson, & Wu, 2000). Although, the literature indicates a role for phonological information in learning to read Chinese, it is important to note that phonological processing in Chinese is not at the phonemic level.

Giving the different cognitive demands posed by these two different writing systems, would the bilingual children who are acquiring these two systems simultaneously show any association between the two language and reading skills?

1.2. Cross-language transfer in bilingual and biliteracy acquisition

Recent research on biliteracy acquisition in two alphabetic language and orthographic systems such as Spanish–English and French–English has yielded two major findings. First, there is clearly a close phonological relationship between two alphabetic languages. Phonological skills in one language are highly correlated with phonological skills in the other language. Second, phonological skills in one language contribute to word reading skills in the other language. For example, a study by Durgunoglu et al. (1993) tested first grade Spanish-speaking children who were enrolled in a transitional bilingual education program on both Spanish and English reading skills. Their results demonstrated that children who could perform well on Spanish phonological awareness tasks were more likely to be able to read English words and pseudowords than were children who performed poorly on these tasks. The phonological awareness tasks included different linguistic units (the onset-rime and the phoneme) in Spanish words. Moreover, phonological awareness was a significant predictor of performance on word recognition tests both within and across languages. Cisero and Royer (1995) used longitudinal data to demonstrate this cross-language phonological transfer of Spanish–English bilingual children. Their results showed that phoneme detection in Spanish at Time 1 contributed to phoneme detection in English at Time 2. Ganschow and Sparks (1995) further showed that explicit, direct training in Spanish phonology resulted in significant gains in English phonological processing, word reading, and spelling in a group of Spanish–English bilingual children, many of whom had English reading difficulties. More recently this strong facilitation from L1 to L2 phonology was shown in research in Canada on English-speaking children learning to read French (e.g. Comeau, Cormier, Grandmaison, & Lacroix, 1999), Italian (e.g. D’Angiulli, Siegel, & Serra, 2001), and Hebrew (Geva & Siegel, 2000). However, to date very few comparable studies have been carried out on biliteracy acquisition of children learning to read in two different writing systems such as English and Chinese. It is not certain whether a similar pattern of cross-language relationship exists for two different writing systems as in the same writing system.

Some researchers have argued for a disconnection between learning to read across different writing systems. For example, Wydell and Butterworth (1999) studied a 16-year-old English/Japanese boy, who showed reading difficulties in English but not in Japanese. He performed as well as his Japanese peers on logographic Kanji and syllabic Kana reading tasks. However, he demonstrated much poorer performance on phonological processing tasks as well as reading and spelling tests in English, even compared to his Japanese counterparts. Their results point to a clear dissociation between the boy's skills in reading English and Japanese. The authors further propose the "hypothesis of granularity and transparency." According to this hypothesis, orthographies in the world differ in two dimensions: "transparency" and "granularity." Along the transparency dimension, for any orthography whose print-to-sound mapping is directly one-to-one or transparent, there will be a very low possibility of producing phonological dyslexia. This is independent of the level of mapping, that is, no matter whether it is the phoneme, syllable, or character. Along the granularity dimension, for any orthography whose phonology–orthography mapping is at a coarse level, there will also be a low incidence of phonological dyslexia. Based on Wydell and Butterworth's hypothesis of granularity and transparency, we expect that phonological and orthographic processing will have distinct roles in children learning to read Chinese and English simultaneously.

Some researchers even argue for a negative transfer effect from a nonalphabetic L1 to an alphabetic reading acquisition. Liow and Poon (1998) compared English reading skills across three groups of Singaporean children with different language backgrounds: English, Chinese (Mandarin), or Bahasa Indonesian. Bahasa Indonesian has a very shallow alphabetic orthography. Results showed that the Bahasa Indonesian children performed best on phonological awareness tests, followed by the English-speaking children and then the Mandarin-speaking children (see Liow, 1999 for a review). Other recent studies also supported the notion that readers with a nonalphabetic L1 tend to rely less on phonological information in reading English words compared to alphabetic L1 counterparts (see Wang & Geva, 2003; Wang, Koda, & Perfetti, 2003). However, these studies did not test the phonological and orthographic processing skills in both L1 and L2 skills, and therefore, could not test the cross-language and writing system relationship.

1.3. The present study

In the present study, we explored how reading skills in the two different writing systems are related to each other in a group of bilingual children who are concurrently learning to read an alphabetic and a nonalphabetic writing system. Chinese–English bilingual children provide a unique opportunity to study the cross-language and writing system transfer in biliteracy acquisition. We designed experiments in Chinese and English tapping phonological, orthographic and word reading skills. These experiments were conceptually comparable but adapted to each language and writing system. They were presented on a computer. The experiments that assessed Chinese phonological knowledge were onset, rime, and tone matching tasks. The comparable experimental tasks for English phonological skill included onset, rime matching, and most importantly, a phoneme manipulation task. Orthographic processing skills were tested in an orthographic choice task designed for Chinese and English separately. English word reading skills were tested in two naming tasks: real word and pseudoword naming. The corresponding Chinese reading measures used real character naming and Pinyin naming. While previous cross-language transfer research only focused on phonological skills, our study included orthographic skills to tap into the impact of cross-writing system differences on learning to read.

Our hypothesis is that bilingual reading acquisition is a joint function of shared phonological skills and writing system specific skills. Reading in both L1 and L2 builds on spoken language. Phonological transfer reflects this universal relation between spoken language and writing system. Orthographic skills, on the other hand, are writing system and script specific skills, which have limited generalization across scripts once general visual ability is accounted for. We specifically predict that sensitivity in English and in Chinese to onset and rime, common linguistic units in both languages, will be correlated. Pinyin reading skills will correlate with English word reading, since the two systems share the alphabetic principle.

2. Method

2.1. Participants

Forty-six Chinese immigrant children from the Washington, DC area participated in the study, which included 24 boys and 22 girls. The mean age of the participants was 8 years and 2 months (SD = 9.1 months). They attended grade 2 and 3 English classes in public schools and grade 2 and 3 weekend Chinese schools called Hope Chinese Schools in the Washington, DC area simultaneously. Twenty-six of them were enrolled in grade 2 and 20 in grade 3 English classes, 25 in grade 2 and 21 in grade 3 Chinese classes. All of the children had normal English proficiency; there were no reports from their English school teachers concerning any English proficiency problems. The Pinyin system is used and a simplified version of the characters is taught in the Chinese schools. Parents of the children were asked to fill out a short questionnaire with basic demographic information and family language and literacy experience. Twenty-seven of the children were born in USA, 17 were born in Mainland China, and 2 were born in European countries while their parents were visiting there. All children learned Chinese as their first language. Forty-two of them currently spoke both Mandarin Chinese and English at home; four spoke only Mandarin Chinese at home. About half of the parents spoke both Chinese and English at home and half spoke Chinese only at home. The majority of the families engaged in Chinese literacy activities such as reading Chinese books and practicing character writing at home during the week.

2.2. Chinese experimental tasks

2.2.1. Phonological tasks—onset, rime, and tone matching

This matching task was designed to tap into children’s ability to manipulate and differentiate between the phonological units in spoken Chinese characters. The child heard three spoken characters–one was the target sound, the remaining two were candidate sounds. The child was then asked to judge which of the two candidates shared the same onset, rime, or tone with the target sound. Onset-rime and tone are the two basic phonological dimensions in the Mandarin-Chinese spoken language. Tone is unique for Mandarin Chinese and it contrasts with languages encoded by alphabetic writing systems.

2.2.1.1. Materials. There were 84 items in total, 24 items for each condition. In the onset condition, the target shared its consonant onset only with the correct candidate syllable. In the rime condition, the target shared its rime only with the correct candidate. Because of the attachment of rime and tone in the Chinese syllable, tone was controlled for each item in the rime condition. In the tone condition, the target shared its tone only with the correct candidate (see Table 2, Section A). These materials were the same as those in Wang et al. (2003) except that the characters were presented in a written form in their study. Three practice items were given in each condition.

2.2.1.2. Procedure. Children were tested individually in a quiet room equipped with a laptop computer. All experiments involved in this study were implemented by E-prime (Psychology Software Inc., Pittsburgh, PA). The child was asked to listen carefully through a pair of earphones connected to the laptop. The first character sound was played along with a target sign on the screen—the target syllable. The target sign stayed on the screen for 2500 ms. Then the child heard two more syllables—the first one labeled with the number one ("1") sign on the screen and the second one labeled with the number two ("2"). The time interval between the two candidate syllable pronunciations was 2500 ms. The child's task was to choose the one of these two syllables that (1) started with the same sound as the target syllable in the onset matching condition; (2) ended with the same sound as the target syllable in the rime matching condition; or (3) had the same tone as the target syllable in the tone matching condition. The child was instructed to press the button marked with a "1" if he/she chose the first syllable or press the button marked with a "2" if he/she chose the second syllable. Children were instructed to do it as fast and accurately as possible. Both Reaction Time (RT) and accuracy data were recorded.

2.2.2. Orthographic choice task

The child was presented with a pair of noncharacter stimuli on the computer screen. The child was instructed to choose the one that looked more like a real character. The child was instructed to press the left mouse button if the stimulus on the left was more like a character, and to press the right button if the right one was more like a real character.

Table 2
Examples of items in Chinese and English phonological tasks

	Target	Candidate 1	Candidate 2
A. Chinese			
Onset	/jian/4	/you/3	/jing/1
Rime	/xian/1	/jia/1	/tian/1
Tone	/mang/2	/hui/2	/shu/1
B. English			
Onset	pob	zep	ponk
Rime	bisk	rint	kisk

The child was instructed to do this as fast and correctly as possible. This task consisted of 40 items. There were two conditions involved with 20 items each: The first condition measured children's sensitivity to the legality of the radical position. One of the pair stimuli contained a component radical in an illegal position, for example, in the pair [illegible] and [illegible], [illegible] contains a legal radical in an illegal position. The second condition measured children's sensitivity to the legality of the radical form. One of the pair stimuli contained a component radical with an illegal form, for example, in the pair [illegible] and 这, [illegible] contained an illegal radical. Illegal radicals were created by adding, deleting, or moving a stroke from one location to another within a legal radical (see Appendix A for a complete set of stimuli). Five practice items were given. Both RT and accuracy data were recorded.

2.2.3. Character naming

Thirty characters were used in this naming task. We generated this task from the Chinese curriculum with which the children were instructed. Characters progressed from simple to compound characters and varied in terms of stroke numbers and component radical numbers. There were 10 items each for characters containing one and two radical components, six items for those containing three radical components and four items for those containing four radical components. The number of strokes ranged from 2 to 15. Characters varied in terms of children's familiarity based on teachers' ratings of how familiar the characters were to the students. There were five practice items. Children's responses were recorded via a digital voice recorder. Children's responses were scored as correct or incorrect and only fully accurate pronunciations were accepted as correct.

2.2.4. Pinyin naming

A list of Pinyin words were shown to the child one at a time on the computer screen. The child was asked to read aloud the sound of the pinyin as best as he/she could. Two groups of items were included: real Pinyin and pseudo-Pinyin. The pseudo-Pinyin words did not sound like real Chinese syllables, in other words, these syllables are not in the Chinese phonological inventory, for example, *biu* and *puan*. These items were intended to measure the ability of children to map letters to sounds in Pinyin. There were 20 items for each group, five practice items for each group. Children's responses were recorded via a digital voice recorder. Children's responses were scored as correct or incorrect and only fully accurate pronunciations were accepted as correct.

2.3. English experimental tasks

2.3.1. Phonological tasks—onset and rime matching

The procedure for the English onset and rime task was the same as that for the Chinese onset and rime task except that English words were used instead of Chinese characters. The child was asked to choose one of the candidate words to match the beginning sound in the onset matching task and the ending sound in the rime matching task. One-syllable nonwords were used in this task, ranging from 3 to 5 letters in length. Nonwords were used to exclude any potential confound due to influence of lexical access of the items. Fifteen items were included for each condition. Materials were similar to those used by Bradley and Bryant (1983), Stanovich, Cunningham, and Cramer (1984) and Gottardo (2002) (see Table 2 Section B). In the onset matching condition, the onsets for all the items were single consonants. In the rime matching condition, 4 out of 15 items had consonant clusters as onsets, 5 had rimes which consisted of an vowel plus a consonant ending, 10 had rimes which consisted of an vowel plus a two-consonant cluster ending. Three practice items were given for each condition. Both RT and accuracy data were recorded.

2.3.2. Phonological task—phoneme deletion

Of the commonly used phonological processing tasks (e.g. blending, segmenting, rhyming, oddity), phoneme deletion has been found to be the most difficult for young children (e.g. Stanovich et al., 1984). Nonwords were used in this task to control for the effect of lexicality on children's performance. Children were encouraged to play a word game with the experimenter. A female native English speaker recorded the audio stimuli, which were presented via Windows Media Player. The child heard a word first, and was asked to repeat the word. Then the child was asked to remove a sound in the word. For example, the child was instructed as follows: "Say *mab*. Now say it again but don't say /b/." Twenty items were included in this task, similar to those used by Wade-Woolley (1999) and Gottardo, Yan, Siegel, and Wade-Woolley (2001). The position of the phoneme to be deleted from the word was varied. There were two items each for the beginning and ending consonants. There were four items each for the first phoneme of the beginning consonant cluster, the second phoneme of the beginning consonant cluster, the first phoneme of the final consonant cluster, and the second phoneme of the final consonant cluster. Children's responses were recorded via a digital voice recorder. Children's responses were scored as correct if the target phoneme was deleted accurately.

2.3.3. Orthographic choice task

The procedure was the same as for the Chinese orthographic choice task. The original stimuli set included 28 items, similar to those used by Treiman (1993) and Siegel, Share, and Geva (1995). Pseudowords were used. The task tapped into children's sensitivity to various orthographic patterns in English. For example, there is a legal position of certain double consonants, for example, "ff" does not occur at the beginning of a word. There are combination constraints for two consonants forming a beginning cluster, for example, "cr" is a legal combination, whereas "cd" is not. Because English orthography cannot be fully dissociable from phonology, in order to control for the potential confound of phonological legality, we conducted a quick survey among 14 native English-speaking graduate students at the University of Maryland. The participants were asked to rate the phonological legitimacy of the 28 orthographically illegal items according to a 3-point scale: 1, phonologically legitimate and occurs frequently; 2, phonologically legitimate but occurs rarely; 3, phonologically illegitimate. The average rating was 1.99 ($SD = 0.57$). In order to maintain a list of appropriate phonologically legal items, we decided to delete items rated higher than 2.5, for example, the item containing "cd" as a beginning cluster. This resulted in a set of 18 items whose average rating of phonological legitimacy was 1.65 ($SD = 0.41$) (see Appendix B for a complete set of stimuli). Five examples were given. Both RT and accuracy data were recorded.

2.3.4. Real word naming

The child was shown one word at a time on the computer screen and was instructed to say the word aloud as best as he/she could. The materials containing 35 words from the word recognition subtest of the Wide Range Achievement Test-Revised (WRAT-R) (Jastak & Jastak, 1984). Five examples were given. Children's naming responses were recorded via a digital voice recorder. Children's responses were scored as correct or incorrect and only fully accurate pronunciations were accepted as correct.

2.3.5. Pseudoword naming

The child was shown one item at a time on the computer screen and was instructed to sound out the letter string aloud as best as he/she could. Five examples were given. Materials were from the Word Attack subtest of the Woodcock Reading Mastery Test-Revised (Woodcock, 1987). Forty items were included. Children's naming responses were recorded via a digital voice recorder. Children's responses were scored as correct or incorrect and only fully accurate pronunciations were accepted as correct.

2.4. Nonverbal skill test

The Pattern Completion, subtest of the Matrix Analogy Test (MAT: expanded form, Naglieri, 1985) was used to test children's nonverbal ability. This measure includes 14 abstract designs of the standard progressive matrix type. The child was shown a picture with a missing piece in it, and was asked to choose one from five options to complete the pattern. The items require the child to detect the shapes and directions in an abstract diagram to decide which option fits the pattern. The child was allowed to either point or to say aloud the number of his or her answer.

2.5. Procedure

Children were tested in two sessions. One session was devoted to English tasks, which were administered by a trained graduate student, a native English-speaker. The other session was devoted to Chinese tasks, which were administered by a trained research assistant, a native Chinese-speaker. The order of the two sessions was randomized among the children. The order of the tasks within the session was also randomized for each child. The time interval between the two sessions was about two weeks. Each session took about 30 min and children were given a break in the middle of each testing session. Children were given school-related gifts for participation at the end of each testing session.

3. Results

Means and standard deviations of performance on Chinese and English language and reading tasks are shown in Tables 3 and 4, respectively. The RT data for correct responses were trimmed by removing any RT two standard deviations below or above the cell mean, which resulted in removal of less than 4% of the responses. One grade 3 child did not complete the English tests. The RTs for some children whose attention was diverted

Table 3
Means and standard deviations for English tasks by American school grade

	Grade 2		Grade 3	
	M	SD	*M*	SD
Matrix Analogy Test accuracy	84.89	11.31	84.29	9.44
Onset matching				
Accuracy	93.59	12.93	97.19	5.12
RT (ms)	674.63	264.17	462.60	143.41
Rime matching				
Accuracy	95.13	6.68	95.79	6.74
RT (ms)	626.72	190.93	460.33	208.65
Phoneme deletion accuracy	55.00	21.07	56.58	19.44
Orthographic choice				
Accuracy	84.83	10.72	85.09	7.87
RT (ms)	2029.19	536.34	2090.99	534.76
Real word naming accuracy	52.53	10.32	58.80	10.70
Pseudoword naming accuracy	67.40	14.60	67.11	12.14

Note: the accuracies are in percentages.

Table 4
Means and standard deviations for Chinese tasks by Chinese school grade

	Grade 2		Grade 3	
	M	SD	M	SD
Matrix Analogy Test accuracy	81.71	10.73	88.10	9.13
Onset matching				
Accuracy	92.17	13.73	95.63	3.60
RT (ms)	714.67	420.78	582.55	247.76
Rime matching				
Accuracy	95.83	8.84	96.63	4.09
RT (ms)	626.48	300.95	528.53	183.77
Tone matching				
Accuracy	66.00	14.57	65.08	14.94
Rt (ms)	1055.37	658.12	1014.70	873.56
Orthographic choice				
Accuracy	86.60	7.70	91.90	4.18
RT (ms)	2438.90	698.94	2034.45	577.46
Character naming accuracy	44.80	16.94	56.00	13.75
Pinyin naming accuracy	49.60	25.49	51.05	22.94
Pseudo-Pinyin naming accuracy	45.40	27.38	46.05	27.21

Note: the accuracies are in percentages.

during the testing was not used in the subsequent analyses. This included three children in English grade 2 and three in English grade 3, and one child in Chinese grade 2 and two children in Chinese grade 3. Percentage of correct items is reported for all accuracy data.

Overall, children improved their phonological and orthographic skills in both Chinese and English from grade 2 to grade 3. This improvement was reflected in both RT data and accuracy data, although many of the differences between the two grades were not statistically significant. Children also seemed to be faster and more accurate in processing Chinese onset and rime than processing tone. Phoneme deletion in English posed a particular challenge to children compared to onset and rime matching. We pooled the data of the two grades and focused on the cross-language transfer in the subsequent analyses.

3.1. Correlations between Chinese and English tasks

The bivariate Pearson correlations among all the experimental tasks are shown in Table 5. Accuracy data for all tasks were used to calculate the correlations (RTs yielded similar results). Several important observations were obtained. Chinese onset matching skill was significantly correlated with English onset and rime matching skills, $r=0.36$ and 0.33, respectively, $P\text{s}<0.05$. Pinyin reading (both real Pinyin and pseudo-Pinyin) was highly correlated with English pseudoword reading, $r=0.37$ and 0.38, respectively, $P\text{s}<0.05$. Pseudo-Pinyin was correlated with English phoneme deletion. Chinese tone matching was correlated with character reading, real Pinyin and pseudo-Pinyin reading, $r=0.38$, $P<0.05$; $r=0.44$, and 0.48, $P\text{s}<0.01$, respectively. Chinese orthographic choice was significantly correlated only with Chinese character naming, $r=0.58$, $P<0.01$, but not with English orthographic choice and word reading skills. Finally, the English phoneme deletion task correlated highly with English real word and pseudoword naming, $r=0.62$ and 0.70, respectively, $P\text{s}<0.01$.

3.2. Cross-language and writing system prediction

In this section, we focused our analyses on the cross-language and writing system prediction between Chinese and English skills. We were interested in whether the phonological and orthographic skills can be transferred from one language to the other in learning to read. We used regression analyses to explore the prediction from one language's phonological and orthographic skills to the other language's word reading skill. In order to reduce the number of variables thus to improve the power of the regression analyses, we decided to first identify the best predictors for Chinese and English reading separately using stepwise regression, then we used the best predictor(s) for one language reading combined with phonological and orthographic tasks from the other language as predictors for the cross-language prediction.

In identifying best predictors for Chinese reading, Chinese character reading was considered as the dependent variable; age, nonverbal skill, Chinese onset, rime, tone, Chinese orthographic choice, and Pinyin naming were predictors. Pinyin naming was a composite score of real Pinyin and pseudo-Pinyin items. Results of the stepwise regression analysis are shown in Table 6, Section A. Chinese orthographic processing was the most powerful predictor for Chinese character reading. Nonverbal skill also contributed

Table 5
Bivariate correlations among Chinese and English tasks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Nonverbal ability														
1. Matrix Analogy Test	–													
English tasks														
2. Onset matching	0.23	–												
3. Rime matching	0.10	0.09	–											
4. Phoneme deletion	0.26	0.26	0.32*	–										
5. Orthographic choice	0.18	−0.06	0.15	0.44**	–									
6. Real word naming	0.28	0.26	0.41**	0.62**	0.29	–								
7. Pseudoword naming	0.17	0.22	0.35*	0.70**	0.36*	0.72**	–							
Chinese tasks														
8. Onset matching	0.16	0.36*	0.33*	0.15	−0.07	0.12	0.28	–						
9. Rime matching	−0.08	−0.06	0.19	−0.08	−0.02	−0.12	0.14	0.74**	–					
10. Tone matching	0.05	−0.09	0.23	0.09	0.09	0.01	0.34*	0.31*	0.42**	–				
11. Orthographic choice	0.06	0.04	0.13	0.14	0.21	0.02	0.06	0.27	0.18	0.25	–			
12. Character naming	0.25	−0.23	0.14	−0.22	0.02	−0.18	−0.09	0.04	0.22	0.38	0.58**	–		
13. Real Pinyin naming	0.06	0.06	0.27	0.28	0.05	0.27	0.37*	0.04	0.13	0.44**	0.14	0.17	–	
14. Pseudo-Pinyin naming	0.17	−0.08	0.12	0.33*	0.15	0.20	0.38*	0.04	0.06	0.48**	0.16	0.09	0.79**	–

Note: $*P<0.05$, $**P<0.01$.

Table 6
Summaries of stepwise regression analyses for predicting Chinese character and English word reading

Variables	Mult R	Mult R^2	ΔR^2	F
A. Chinese character reading[a]				
Chinese orthographic choice	0.56	0.31	0.31	19.26***
Nonverbal skill	0.64	0.41	0.10	6.74*
Overall F (2, 41)=14.31, $P<0.001$				
B. English real word reading[b]				
Phoneme deletion	0.62	0.38	0.38	26.82***
C. English pseudoword reading[c]				
Phoneme deletion	0.70	0.49	0.49	40.94***

*$P<0.05$, **$P<0.01$, ***$P<0.001$.
[a] Predictor variables for Chinese character reading: age, nonverbal skill, Chinese onset, rime, tone matching, Chinese orthographic choice, Pinyin.
[b] Predictor variables for English real word reading: age, nonverbal skill, English onset, rime matching, phoneme deletion, English orthographic choice.
[c] Predictor variables for English pseudoword reading: age, nonverbal skill, English onset, rime matching, phoneme deletion, English orthographic choice.

a significant amount of unique variance to character identification. In identifying best predictors for English reading, two similar stepwise regression analyses were performed for English real word and pseudoword naming as the dependent variable. Age, nonverbal skills, English onset, rime matching, phoneme deletion, and English orthographic choice were the predictors. Results of the stepwise regression analyses predicting real English word and pseudoword reading are shown in Table 6, Sections B and C, respectively. Phoneme deletion skill was the only predictor that explained a significant amount of unique variance for both English real word and pseudoword reading skills. Furthermore, the phoneme deletion skill explained more unique variance in pseudoword reading than in real word reading ($\Delta R^2=0.49$ and 0.38 for predicting pseudoword and real word reading, respectively).

3.2.1. Prediction from Chinese to English reading

We performed a set of hierarchical regression analyses to determine whether Chinese phonological and orthographic processing would account for a unique amount of variance to English word reading independent of English phoneme deletion skill. Chinese onset, rime and tone processing were entered in one block within which stepwise method was selected to locate the significant predictors among the three. The Chinese tasks and English phoneme deletion were entered in two alternative orders into the regression equation. For English pseudoword reading, results showed that only Chinese tone processing skill contributes a significant amount of variance even after English phoneme deletion skill is taken into consideration (see Table 7). Chinese orthographic skill did not predict English pseudoword reading whether it was entered before or after Chinese phonological tasks. When the dependent variable was English real word reading, this cross-language phonological relationship disappeared.

Table 7
Hierarchical regression analyses predicting English pseudoword reading using Chinese and English phonological tasks

Variables	Mult R	Mult R^2	ΔR^2	F
Step 1: Chinese tone matching	0.36	0.13	0.13	6.16*
Step 2: English phoneme deletion	0.75	0.57	0.44	41.08**
Step 1: English phoneme deletion	0.70	0.49	0.49	40.20***
Step 2: Chinese tone matching	0.75	0.57	0.08	7.09*

Note: *$P<0.05$, **$P<0.01$, ***$P<0.001$.

3.2.2. Prediction from English to Chinese reading

A similar set of hierarchical regression analyses was conducted to determine whether English phonological and orthographic processing would account for a unique amount of variance to Chinese character reading. English onset, rime matching, and phoneme deletion were entered in one block. There was no additional cross-language prediction for Chinese character reading from English tasks once the Chinese orthographic and nonverbal skills were taken into account.

4. Discussion

Our study discovered that even when children learn to read two very different writing systems, there is a certain level of phonological transfer. We found that the unique Chinese phonological property, tone, contributed significantly to English pseudoword reading even when English phonemic-level processing skill was taken into consideration. This finding contributes to our existing knowledge of cross-language phonological transfer. We provided evidence for a unique level of phonological transfer between two languages that is different from the phonemic level relationship common to two alphabetic systems. The power of prediction of Chinese tone skill for English word reading may possibly reflect some shared phonological sensitivity in learning to read Chinese and English. Chinese tone processing and English pseudoword reading both require children's attention to spoken word forms and their constituents-phonemes for English and tones for Chinese. Our data demonstrated that phoneme deletion was significantly correlated with English word reading, and tone matching was significantly correlated with Chinese character reading.

Another possible interpretation for the relationship between Chinese tone processing skill and English pseudoword reading is that a general auditory processing skill is an underlying factor linking the two together. Some researchers (e.g. Tallal, 1980; Reed, 1989) have found evidence to support a relationship between auditory perception and reading skills in English. They found a significant correlation between pseudoword reading and tone order judgment ability (see also Bretherton & Holmes, 2003; Share, Jorm, Maclean, & Russel, 2002 for different results and arguments). The two tones used in their task were either high or low frequency. The child was simply asked to repeat the two different tones by pressing buttons. The significant correlation only existed when the two tones were presented at a fast pace; that is, when the interval between the two tones was short. It is noteworthy, however, that tone in Chinese is fundamentally different from the tone used in Tallal and others' research. Chinese tone is not only an auditory process and more complex than that used in Tallal and others' research, but more importantly, we want to emphasize that it is a phonetic process. The tone is carried on a vowel, and has lexical function. We argue that the relevant skill involved in tone processing is encoding phonological information. Our finding that Chinese tone might be predictive of English alphabetic reading adds an interesting twist to the well-established role of phonemic processing in English reading acquisition. Our results showed that an entirely different level of phonological processing—Chinese tone—also had a unique contribution to the acquisition of reading skills in English. Therefore, we suggest that if tone presumably does not depend on reading experience, it is possible to speculate that tone detection might be a good pre-literacy predictor of reading English. It would be interesting in future research to see whether this result will hold for native English-speaking children, and whether training in Chinese tone detection will help dyslexic children improve their English reading skills.

It is also worth noting that our tone task presented a particularly high challenge for children's phonological skill. It required children to segment the mismatched rime structures in the three stimuli (e.g. /mang/2: /hui/2 or /shu/1). Indeed, the accuracy for this tone matching task was only 66%. Therefore, one may wonder whether the predictive power of tone skill reflects the difficulty of the task rather than specifically its phonological nature. If this speculation is true, then we would expect that the most difficult task in the entire battery, Chinese character naming (with only 45% accuracy), would lead to some prediction of English tasks. Nevertheless, our data did not show any cross-language transfer between the character naming and English tasks. By ruling out this possible effect of difficulty of the task in interpreting the relation between Chinese tone and English word reading, a stronger claim can be made that this cross-language transfer is indeed due to shared phonological processes.

Significant correlations between Chinese onset, English onset, and rime matching skills also suggest that there may be a shared phonological skill (segmentation) that is indicated in these three tasks. These three tasks require attention to onsets within syllables, which helps with both Chinese and English. This result suggests that the awareness of the phonological structure of one language relies on some mechanism that is not specific to only one language system. Chinese rime is less correlated to English onset and rime because tone is important in the Chinese rime. We also want to point out that only single consonants were used in the onset matching task for both languages. Because consonant clusters are present frequently in English onsets, future research needs to take this into consideration, possibly including English items containing consonant clusters. It is worth noting that although the onset and rime structure (C-VC) are shared components of Chinese and English speech, and applicable to various languages (Bertelson, de Gelder, Tfouni, & Morais, 1989; de Gelder, Vroomen, & Bertelson, 1993; Cheung, Chen, Lai, Wong, & Hills, 2001), several important studies have failed to show this C-VC distinction in some other languages. For example, in Korean, Japanese, and Dutch, there appears to be a clear CV-C structure (e.g. Kubozono, 1996; Yoon, Bolger, & Perfetti, 2002; Geudens &

Sandra, 2003). Children showed a stronger preference for words having CV-C structure compared to C-VC structure.

The finding that Pinyin naming skill was highly correlated with English phoneme deletion and pseudoword naming suggests that reading skills in two alphabetic systems are related. It is interesting that when children are learning Chinese characters and Pinyin simultaneously, the Pinyin naming and English reading skills facilitate each other, but the Chinese character naming and English reading skills do not. It is interpretable given the sharp distinction between the two writing systems. Chinese–English bilingual children provided a unique opportunity for testing the relation between two alphabetic languages and between an alphabetic and a nonalphabetic one.

Orthographic skills in Chinese did not predict reading skills in English. This finding is important because it suggests that there is a writing system specific component in biliteracy acquisition in Chinese and English. We argue that this result reflects the contrasts in mapping principles and visual forms across the two writing systems. The consequence of these contrasts was difficulty in transfer of orthographic skills from Chinese to English. Recent neuroimaging work on Chinese–English bilingual adults by Tan and his colleagues (e.g. Tan et al., 2001; 2003) has shown that reading Chinese resulted in more activation in some brain areas that are responsible for coordinating and integrating visual-spatial analyses of logographic Chinese characters compared with reading English. Liu and Perfetti (2003) used Event-Related-Potential (ERP) techniques to compare Chinese–English bilingual adults on naming words in both languages, and found differences in the brain areas activated. Reading Chinese involves both left and right occipital activation, whereas reading English involves only left occipital activation. They interpret that the right occipital areas are more responsible for detection of two-dimensional spatial relationships of radicals, which allows discrimination among visually similar characters and is a more character-specific skill. In our study, we also demonstrated in a bilingual group of children the distinctive contribution of phonological and orthographic processing skills to English and Chinese reading. Taken together, we suggest that orthographic transfer across two writing systems is less likely. In the mean time, we argue against a simplistic visual processing view of reading Chinese. The Chinese orthographic choice task used in our study taps more than just low-level visual-spatial skill; it is a character-specific measure. The ability to identify the forms of Chinese characters is obtained through reading experience.

To conclude, the findings from the present study support our hypothesis that bilingual reading acquisition is a joint function of shared phonological processes and orthographic-specific skills. Even when learning to read two different writing systems there is a certain level of phonological transfer. Onset skill in Chinese and English onset and rime skills are correlated with each other. The contrastive Chinese phonological property, tone, contributes unique variance to English pseudoword reading. Orthographic learning across the two different writing systems, on the other hand, may be language-specific with little facilitation from one to the other. In learning to read across different writing systems children can build on the shared phonological mechanism of the two spoken languages, but in the meantime acquire one orthographic system independent of the other.

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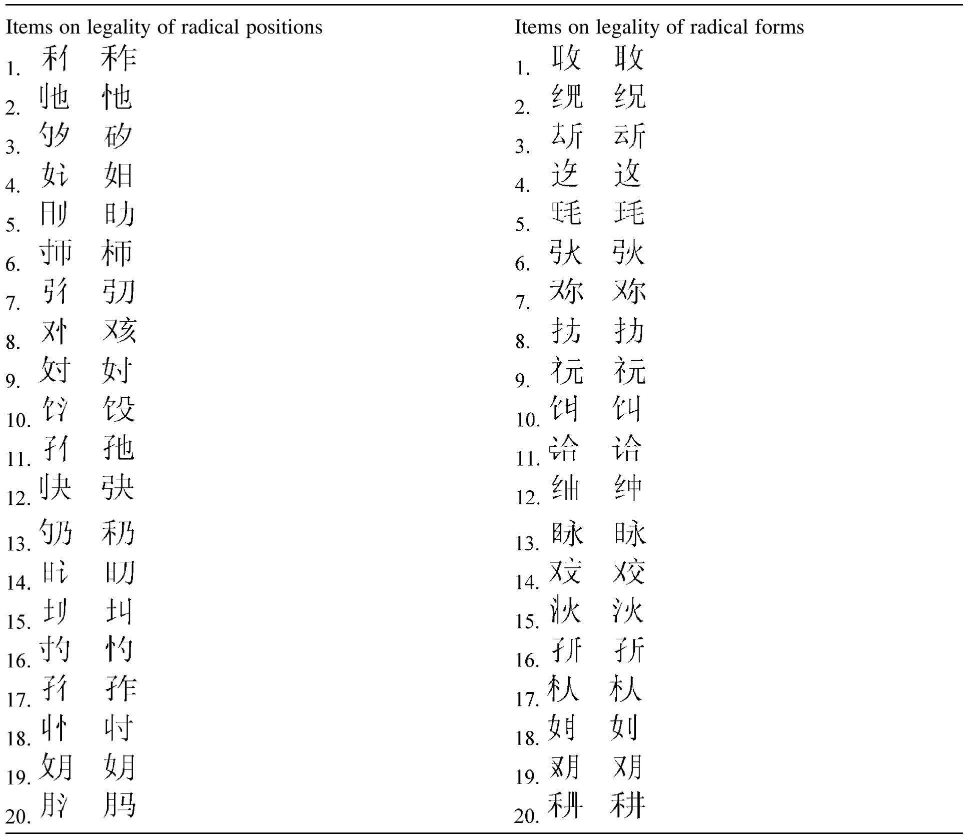
Appendix A. Chinese orthographic choice task materials



Appendix B. English orthographic choice task materials

1.	ffeb	beff
2.	dalled	ddaled
3.	yikk	yinn
4.	vayying	vadding
5.	dacker	ckader
6.	vaad	vadd
7.	munt	muun
8.	moyl	moil
9.	bei	bey
10.	daw	dau
11.	gri	gry
12.	chym	chim
13.	milg	miln
14.	vism	visn
15.	vosst	vost
16.	skap	sckap
17.	qoast	quoast
18.	phim	ffim

References

Adams, M. J. (1990). *Beginning to read: Thinking and learning about print*. Cambridge, MA: MIT Press.

Bertelson, P., de Gelder, B., Tfouni, L. V., & Morais, J. (1989). Metaphonological abilities of adult illiterates: New evidence of heterogeneity. *European Journal of Cognitive Psychology*, *1*(3), 239–250.

Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read: A causal connection. *Nature*, *301*, 419–421.

Bretherton, L., & Holmes, V. M. (2003). The relationship between auditory temporal processing, phonemic awareness, and reading disability. *Journal of Experimental Child Psychology*, *84*(3), 218–243.

Byrne, B., & Fielding-Barnsley, R. (1995). Evaluation of a program to teach phonemic awareness to young children: A 2- and 3-year follow-up and a new preschool trial. *Journal of Educational Psychology*, *87*(3), 488–503.

Chen, H. C., & Tzeng, O. J. L. (Eds.). (1992). *Language processing in Chinese*. Amsterdam: North-Holland.

Cheung, H., Chen, H.-C., Lai, C.-Y., Wong, O.-C., & Hills, M. (2001). The development of phonological awareness: Effects of spoken language experience and orthography. *Cognition*, *81*(3), 227–241.

Cisero, C. A., & Royer, J. M. (1995). The development of cross-language transfer of phonological awareness. *Contemporary Educational Psychology*, *20*, 275–303.

Comeau, L., Cormier, P., Grandmaison, E., & Lacroix, D. (1999). A longitudinal study of phonological processing skills in children learning to read in a second language. *Journal of Educational Psychology*, *91*(1), 29–43.

D'Angiulli, A., Siegel, L., & Serra, E. (2001). The development of reading in English and Italian in bilingual children. *Applied Psycholinguistics*, *22*, 479–507.

DeFrancis, J. (1989). *Visible speech: The diverse oneness of writing system*. Honolulu, HA: University of Hawaii.

de Gelder, B., Vroom, J., & Berleson, P. (1993). The effecs of alphabetic reading competence on language representation in bilingual Chinese subjects. *Psychological Research*, *55*(4), 315–321.

Durgunoglu, A. Y. (2002). Cross-linguistic transfer in literacy development and implication for language learners. *Annals of Dyslexia*, *52*, 189–204.

Durgunoglu, A. Y., Nagy, W. E., & Hancin-Bhatt, B. J. (1993). Cross-language transfer of phonological awarness. *Journal of Educational Psychology*, *85*, 453–465.

Feldman, L. B. (1987). Phonological and morphological analysis by skilled readers of Serbo-Croatian. In A. Allport, D. G. MacKay, W. Prinz, & G. Scheerer (Eds.), *Language perception and production* (pp. 197–210). London: Academic Press.

Frith, U., Wimmer, H., & Langerl, K. (1998). Differences in phonological recoding in German- and English-speaking children. *Scientific Studies of Reading*, *2*(1), 31–54.

Ganschow, L., & Sparks, R. (1995). Effects of direct instruction in Spanish phonology on the native-language skills and foreign-language aptitude of at-risk foreign-language learners. *Journal of Learning Disabilities*, *28*(2), 107–120.

Geudens, A., & Sandra, S. (2003). Beyond implicit phonological knowledge: No support for an onset-rime structure in children's explicit phonological awareness. *Journal of Memory and Language*, *49*, 157–182.

Geva, E., & Siegel, L. (2000). Orthographic and cognitive factors in the concurrent development of basic reading skills in two languages. *Reading and Writing: An Interdisciplinary Journal*, *12*(1/2), 1–30.

Goswami, U., Gombert, J., & Barrera, L. (1998). Children's orthographic representations and linguistic transparency: Nonsense word reading in English, French, and Spanish. *Applied Psycholinguistics*, *19*(1), 19–52.

Gottardo, A. (2002). The relationship between language and reading skills in bilingual Spanish–English speakers. *Topics in Language Disorders*, *23*, 42–66.

Gottardo, A., Yan, B., Siegel, L., & Wade-Woolley, L. (2001). Factors related to English reading performance in children with Chinese as a first language: More evidence of cross-language transfer of phonological processing. *Journal of Educational Psychology*, *93*(3), 530–542.

Hanley, J. R., Tzeng, O., & Huang, H.-S. (1999). Learning to read Chinese. In M. Harris, & G. Hatano (Eds.), *Learning to read and write: A cross-linguistic perspective* (pp. 173–195). Cambridge, UK: Cambridge University Press.

Ho, C. S.-H., & Bryant, P. (1997a). Development of phonological awareness of Chinese children in Hong Kong. *Journal of Psycholinguistic Research*, *26*, 109–126.

Ho, C. S.-H., & Bryant, P. (1997b). Learning to read Chinese beyond the logographic phase. *Reading Research Quarterly*, *32*, 276–289.

Ho, C. S.-H., & Bryant, P. (1997c). Phonological skills are important in learning to read Chinese. *Developmental Psychology*, *33*, 946–951.

Hu, C.-F., & Catts, H. W. (1998). The role of phonological processing in early reading ability: What we can learn from Chinese. *Scientific Studies of Reading*, *2*(1), 55–79.

Huang, H., & Hanley, R. (1994). Phonological awareness and visual skills in learning to read Chinese and English. *Cognition*, *54*, 73–98.

Hulme, C., Hatcher, P. J., Nation, K., Brown, A., Adams, J., & Stuart, G. (2002). Phoneme awareness is a better predictor of early reading skill than onset-rime awareness. *Journal of Experimental Child Psychology*, *82*(1), 2–28.

Jastak, J. R., & Jastak, S. R. (1984). *Wide range achievement test-revised*. Wilmington, DE: Guidance Associates.

Kubozono, H. (1996). Speech segmentation and phonological structure: Cross-linguistic studies. In T. Otake, & A. Cutler (Eds.), *Phonological structure and language processing* (pp. 77–94). Berlin: Mouton de Gruyter.

Leong, C. K., & Tamaoka, K., (Eds.). (1998). *Cognitive processing of the Chinese and the Japanese languages*: Special issue of Reading and Writing: An Interdisciplinary Journal, 10.

Liow, S. R. (1999). Reading skill development in bilingual Singaporean children. In M. Harris, & G. Hatano (Eds.), *Learning to read and write: A cross-linguistic perspective* (pp. 196–213). New York: Cambridge University Press.

Liow, S. J. R., & Poon, K. K. L. (1998). Phonological awareness in multilingual Chinese children. *Applied Psycholinguistics*, *19*(3), 339–362.

Liu, Y., & Perfetti, C. A. (2003). The time course of brain activity in reading English and Chinese: An ERP study of Chinese bilinguals. *Human Brain Mapping*, *18*(3), 167–175.

Lundberg, I., Frost, J., & Petersen, O.-P. (1988). Effects of an extensive program for stimulating phonological awareness in preschool children. *Reading Research Quarterly*, *23*, 263–284.

Mattingly, I. G. (1992). Linguistic awareness and orthographic form. In R. Frost, & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 11–26). Amsterdam: Elsevier Science Publishers, 11–26.

McBride-Chang, C., & Ho, C. S.-H. (2000). Developmental issues in Chinese children's character acquisition. *Journal of Educational Psychology*, *92*(1), 50–55.

Muter, V., Hulme, C., Snowling, M., & Taylor, S. (1998). Segmentation, not rhyming, predicts early progress in learning to read: Erratum. *Journal of Experimental Child Psychology*, *71*(1), 3–27.

Naglieri, J. (1985). *Matrix analogies test: expanded form*. London, UK: The Psychological Corporation: Harcourt Brace Jovanovich Inc.

Peng, D.-L., Li, Y.-P., & Yang, H. (1997). Orthographic processing in the identification of Chinese characters. In H. C. Chen (Ed.), *Cognitive processing of Chinese and related Asian languages* (pp. 86–108). Hong Kong: The Chinese University Press.

Perfetti, C. A. (1992). The representation problem in reading acquisition. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading Acquisition* (pp. 145–174). Hillsdale, NJ: Lawrence Erlbaum Associates.

Perfetti, C. A. (1999). Comprehending written language: A blueprint of the reader. In C. Brown, & P. Hagoot (Eds.), *The neurocognition of language* (pp. 167–208). New York: Oxford University Press.

Perfetti, C.A., Liu, Y., & Tan, L.H. (2005). The lexical constituency model: Some implications of research on Chinese for general theories of reading. *Psychological Review*.

Perfetti, C. A., Zhang, S., & Berent, I. (1992). Reading in English and Chinese: Evidence for a 'universal' phonological principle. In R. Frost, & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 227–248). Amsterdam: North-Holland.

Reed, M. A. (1989). Speech perception and the discrimination of brief auditory cues in reading disabled children. *Journal of Experimental Child Psychology*, *48*(2), 270–292.

Share, D. L. J., Maclean, A. F., & Russell, R. M. (2002). Temporal processing and reading disability. *Reading and Writing*, *15*(1/2), 151–178.

Shu, H., & Anderson, R. C. (1999). Learning to read Chinese: The development of metalinguistic awareness. In J. Wang, A. W. Inhoff, & H. C. Chen (Eds.), *Reading Chinese script: A cognitive analysis* (pp. 1–18). Mahwah, NJ: Lawrence Erlbaum.

Shu, H., Anderson, R. C., & Wu, N. N. (2000). Phonetic awareness: Knowledge of orthography-phonology relationships in the character acquisition of Chinese children. *Journal of Educational Psychology*, *92*(1), 56–62.

Siegel, L. S., Share, D., & Geva, E. (1995). Evidence for superior orthographic skills in dyslexics. *Psychological Science*, *6*(4), 250–254.

Stanovich, K. E., Cunningham, A. E., & Cramer, B. B. (1984). Assessing phonological awareness in kindergarten children: Issues of task comparability. *Journal of Experimental Child Psychology*, *38*(2), 175–190.

Taft, M., Zhu, X., & Peng, D. (1999). Positional specificity of radicals in Chinese character recognition. *Journal of Memory and Language*, *40*(4), 498–519.

Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children. *Brain and Language*, *9*(2), 182–198.

Tan, L. H., Liu, H.-L., Perfetti, C. A., Spinks, J. A., Fox, P. T., & Cao, J.-H. (2001). The neural system underlying Chinese logographic reading. *NeuroImage*, *13*, 836–846.

Tan, L. H., Spinks, J. A., Feng, C. M., Siok, W. T., Perfetti, C. A., Xiong, J., Fox, P., & Gao, J. H. (2003). Neural systems of second language reading are shaped by native language. *Human Brain Mapping*, *18*(3), 158–166.

Taylor, I., & Taylor, M. M. (1995). *Writing and literacy in Chinese, Korean, and Japanese*. Philadelphia: John Benjamins.

Treiman, R. (1993). *Beginning to spell*. New York: Oxford University Press.

Wade-Woolley, L. (1999). First language influences on second language word reading: All roads lead to Rome. *Language Learning*, *49*, 447–471.

Wang, M., & Geva, E. (2003). Spelling performance of Chinese ESL children: Lexical and visual-orthographic processes. *Applied Psycholinguistics*, *24*, 1–25.

Wang, M., Koda, K., & Perfetti, C. A. (2003). Alphabetic and non-alphabetic L1 effects in English word identification: A comparison of Korean and Chinese English L2 learners. *Cognition*, *87*, 129–149.

Wang, M., Liu, Y., & Perfetti, C. A. (2004). The implicit and explicit learning of orthographic structure and function of a new writing system. *Scientific Studies in Reading, 8*(4), 357–379.

Wang, M., Perfetti, C. A., & Liu, Y. (2003). Alphabetic readers quickly acquire orthographic structure in learning to read Chinese. *Scientific Studies in Reading*, *72*(2), 183–207.

Woodcock, R. C. (1987). *Woodcock Reading Mastery Test*. Circle Press, MN: American Guidance Service.

Wydell, T. N., & Butterworth, B. (1999). A case study of an English–Japanese bilingual with monolingual dyslexia. *Cognition*, *70*(3), 273–305.

Yoon, H. K., Bolger, D. J., & Perfetti, C. A. (2002). Sublexical processes in learning to read: A difference between Korean and English. In L. Vehoeven, C. Elbro, & P. Reisman (Eds.), *Precursors of functional literacy* (pp. 139–163). Amsterdam/Philadelphia: John Benjamins.