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Pinyin and English Invented Spelling in Chinese-Speaking Students Who Speak English as a Second Language

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Abstract This study examined pinyin (the official phonetic system that transcribes the lexical tones and pronunciation of Chinese characters) invented spelling and English invented spelling in 72 Mandarin-speaking 6th graders who learned English as their second language. The pinyin invented spelling task measured segmental-level awareness including syllable and phoneme awareness, and suprasegmental-level awareness including lexical tones and tone sandhi in Chinese Mandarin. The English invented spelling task manipulated segmental-level awareness including syllable awareness and phoneme awareness, and suprasegmental-level awareness including word stress. This pinyin task outperformed a traditional phonological awareness task that only measured segmental-level awareness and may have optimal utility to measure unique phonological and linguistic features in Chinese reading. The pinyin invented spelling uniquely explained variance in Chinese conventional spelling and word reading in both languages. The English invented spelling uniquely explained variance in conventional spelling and word reading in both languages. Our findings appear to support the role of phonological activation in Chinese reading. Our experimental linguistic manipulations altered the phonological awareness item difficulties.

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Introduction

Different writing systems differ substantially in the approaches by which they encode the phonology of their language. The *universal phonological principle* postulates that readers in different writing systems activate phonology at multiple levels when printed words are presented to them (Perfetti and Zhang 1995; Perfetti et al. 1992). In other words, the phonological properties associated with printed words will be automatically activated once the readers have contact with words in any writing system. Based on the universal phonological principle, the phonological activation itself is general across writing systems, across elements of the writing system that correspond to the phonological objects in the language, and across individuals (e.g., low-achieving readers versus high-achieving readers), although the activation of phonological levels might vary depending on the specific features of the writing system. How could this principle be manifested in Chinese literacy acquisition? Lin et al. (2010) argued that phoneme-level processing is not directly required in Chinese reading because Chinese is essentially a logographic (character) language and there is a one-to-one correspondence between each Chinese character and its corresponding syllable. Thus, syllable awareness is relatively easy for Chinese children because of the natural separation between each Chinese character (syllable). Children in China receive systematic training on pinyin (the phonetic coding system to pronounce Chinese characters) and are proficient to manipulate onsets, rimes, and tones (People's Education Press 2013). As a result, phoneme awareness is also well mastered by Chinese children who receive pinyin instruction. Although there have been strong correlations between phonological awareness and Chinese literacy skills (e.g., McBride-Chang and Kail 2002; Tong and McBride-Chang 2010), the phonological awareness measures do not always predict Chinese reading independently (e.g., McBride-Chang et al. 2005a, b). The findings might not indicate that phonological awareness does not play the same important role in Chinese reading in comparison to its role in alphabetic languages. Instead, the findings might suggest that traditional phonological awareness tasks do not capture some unique linguistic features of Chinese that do not exist in Indoeuropean languages. Many traditional phonological awareness tasks (e.g., phoneme deletion or onset awareness) often emphasize syllable-level or phoneme-level processing (e.g., Bialystok et al. 2005b; McBride-Chang and Ho 2000; Shu et al. 2008), and it might not be the best approach to capture some unique linguistic features of Chinese. Therefore, the purpose of the present study was to examine the utility of a newly developed pinyin invented spelling task, which captures segmental-level (i.e., syllable and phoneme) and suprasegmental-level features (i.e., tonal changes and tone sandhi) of spoken Chinese, and the English invented spelling task in explaining word reading and conventional spelling skills in children who speak Chinese as a first language (L1) and English as a second language (L2).

Pinyin as the Phonetic Coding System for Mandarin Chinese

Since 1958, Pinyin has been the official phonetic coding system that uses the Latin alphabet to present the lexical tones and the sounds of Mandarin Chinese characters. The pinyin system consists of 21 onsets, 35 rimes, and four lexical tones. Suen (1979) postulated that only half of the combinations of all onsets and rimes (approximately 1200 syllables) are conventional in spoken Chinese, with consideration of tonal changes. As a logographic script, Chinese characters represent meaning instead of sounds. Pinyin instruction provides a unique tool for teachers to teach the association between print and sounds. In first grade, Chinese children spend considerable time in their first semester to learn, master, and become proficient with the pinyin system (Yin et al. 2011). All character pronunciations are explicitly printed with pinyin in their first-grade textbooks. In the first and second grades, the pinyin system is used consistently to foster children's character reading. By looking at the pinyin, the students are supposed to spell out the character. Through repetitive exposure to characters coupled with pinyin printed above characters, young readers gradually learn to be familiar with the associations between print and sounds (Cheung and Ng 2003).

Empirical studies involving Chinese children have consistently shown that pinyin facilitates phonological awareness (e.g., McBride-Chang and Ho 2000; Shu et al. 2008). Even for morpheme-syllabic script such as Chinese, the importance of phonological awareness is recognizable because matching phonetic representations of Chinese characters to their graphic representations require some involvement of the phonology of spoken Chinese (Hu and Catts 1998). However, there are notable differences in terms of the role of phonological awareness in reading Chinese and English. Chinese is a tonal language, whereas tone changes do not exist in English. In comparison to other aspects of phonological awareness in Chinese, the role of tone awareness for reading has received little attention.

In Mandarin Chinese, there are four standard tones and a flat tone, consisting of (a) high-level tone (e.g.,/bā/), (b) rising tone (e.g.,/bá/), (c) low-falling-rising tone (e.g.,/bǎ/), (d) high-falling tone (e.g.,/bà/), and (e) mid-flat tone (e.g.,/ba/). The meaning of a syllable can be dramatically altered by a change of the tone. Thus, tonal change plays a critical role in listening comprehension of spoken Chinese. To determine the meaning of a given Chinese syllable (e.g., 爸-father,/bà/), children have to differentiate the segments of the corresponding phonemes. As a meaning-bearing morpheme, the semantic value of a syllable is largely determined by the combination of the segments and tones, which are suprasegmental (Siok and Fletcher 2001).

Incorporation of Tone Awareness and Tone Sandhi in Pinyin Invented Spelling

McBride-Chang (1995) conducted four linguistic manipulations within three tasks that measured phonological awareness in English-speaking children and reported that all of the speech manipulations increased item discriminability. The linguistic manipulations included phoneme deletion, position analysis, and phoneme segmentation. We made an analogy to the pinyin invented spelling task, focusing on onsets, rimes, and tones of pinyin for examination. Common tasks used to measure phonological awareness in Chinese typically do not examine tone awareness. Because Chinese at the character level is essentially a mono-syllabic and tonal language, a phonological awareness task tapping into syllable awareness only is relatively simple for Chinese children because there is one-to-one correspondence between each Chinese character and its corresponding syllable. Chinese reading teachers systematically and explicitly teach children in Mainland China to identify, master, manipulate, and produce all onsets, rimes, and tones of each character taught. Thus, a task that measures phoneme-level manipulation, such as onset deletion, might be easy for those who have received systematic pinyin instruction (People's Education Press 2013).

Numerous findings have indicated that phonological awareness is a core contributor to reading performance in Chinese, at the segmental level such as syllable awareness (e.g., Chow et al. 2005; McBride-Chang and Ho 2000; McBride-Chang and Kail 2002) and phoneme awareness (e.g., McBride-Chang et al. 2006; Shu et al. 2008). However, relatively fewer studies have focused on the suprasegmental level of phonological awareness such as tone awareness in Chinese (e.g., Tong and McBride-Chang 2010; Tong et al. 2015). Tone awareness is believed to develop at the suprasegmental level because one cannot learn a tone of a character as an independent task, and children typically recognize and learn the tone within the context of a given syllable or rime (Dinneen 1967). A tone awareness task might tap into phonological sensitivity that is unique in Chinese because many alphabetic languages are non-tonal and multi-syllabic. Tone awareness was critical for Chinese word reading and Chinese sentence reading (Li and Ho 2011), tonal change played an important role in semantic activation in the process of speech input recognition (Zhou et al. 2004), and Chinese dyslexic children showed particular weakness in tone awareness (Li and Ho 2011). Thus, we anticipated that a pinyin invented spelling task that involved both segmental components and suprasegmental components (e.g., tones and tonal changes) might explain unique variance in reading skills in Chinese children, after taking into account other tasks that measured phonological awareness at the segmental level only (e.g., manipulation of onsets and syllables).

Tone sandhi is a unique linguistic feature of Mandarin Chinese. It is one type of phonological change existing in tonal languages. The pinyin invented spelling task embedded the component of tone sandhi, which received relatively little attention in previous studies. The pinyin invented spelling task required the participants to spell out the onsets, rimes, and tones of the given words (i.e., real words and nonreal words) regardless of the meanings of the given words (i.e., there are many homophones in Chinese). Tone sandhi is a phonological change unique for tonal language, in which some tones of individual words or morphemes are altered according to how the adjacent words are pronounced. In elementary reading textbooks in China, rules for tone sandhi are not explicitly spelled out, and teachers might introduce some rules alongside their pinyin instruction. There are some general rules applied to Mandarin Chinese tone sandhi. For example, when there are two 3rd tones side by side (老/lǎo/虎/hǔ/), the first third tone changes to a 2nd tone (老/láo/虎/hǔ/). However, instruction in tone sandhi in Mandarin Chinese is non-systematic. Thus, we anticipated that testing items involving tone sandhi rules might be more difficult to manipulate than those that did not involve tone sandhi.

To complicate the linguistic structure of pinyin invented spelling, we embedded both real and nonreal words. The tone sandhi rules in Chinese are applied according to how the adjacent words or morphemes are pronounced, not based on the meaning of the actual words. Tonal changes should also be applied to nonreal words as long as they meet the rules of tone sandhi. We used nonreal words to avoid memorization effects. If participants could demonstrate accurate tone sandhi in both real and nonreal words, it might demonstrate that children comprehend the tone sandhi rules even when they are encountering unfamiliar word structure. We anticipated that children might perform relatively better on real words than they do on nonreal words because of less exposure to nonreal words.

In the third grade of elementary school in China, Chinese children start to learn English as a school subject. Chinese children speak Mandarin Chinese and local dialects at home, and school instruction is offered in Mandarin Chinese except for the English language classes. We applied the term of second-language acquisition to describe the process by which Chinese children learned English as an L2 while Chinese is a well-established language (Bialystok et al. 2005b). Bilingualism is often used to describe bilingual individuals who are equally fluent in two languages. However, there are no definite boundaries between these two systems. If one considers bilingualism as a whole scale of language proficiency of two languages, then the terms of bilingual individuals versus second-language learners might be used to describe those who possess different levels of proficiency of both languages with specific linguistic and contextual features on the scale (Bialystok et al. 2005b).

Invented Spelling in Relation to Reading and Spelling

Invented spelling is typically described as children's spontaneous or self-directed efforts to represent words in print (Read 1971). Invented spelling could measure children's abilities to develop phonological acuity, knowledge of sound-letter correspondence, and understanding of conventional association between sounds and print (Bear and Templeton 1998). Spelling in young children often starts with representation of the first sound of a given word (e.g., spell A for apple), then moves to phonetic spelling (i.e., spell all the sounds they hear without closely following the conventional spelling rules), and finally reaches the conventional spelling (Gentry and Gillet 1993).

The association between invented spelling and phonological awareness has been demonstrated in numerous studies (Hecht and Close 2002; Ouellette and Sénéchal 2008). Although invented spelling was considered as an approximation of phonological awareness (McBride-Chang and Ho 2005), a series of studies by Ouellette, Sénéchal and colleagues supported the notion that invented spelling contributed to unique variance in reading and spelling performance that is beyond the well-known psycholinguistic variables such as phonological awareness and alphabetic knowledge. For example, Ouellette and Sénéchal (2008) recruited three groups of children, including an invented-spelling training group (experimental), a phonological awareness training group (comparison), and a control group. The experimental group outperformed the other two groups on a post-intervention learn-to-read task and an invented-spelling task, and the experimental group performed similarly to the comparison group in terms of phonological awareness. The conclusion was that invented spelling could be used as an early literacy task to improve the ability to read and such improvement was not due to improved phonological awareness or alphabetic knowledge. In a longitudinal study by Ouellette and Sénéchal (2017), invented spelling concurrently predicted reading, after taking account for phonological awareness and alphabetic knowledge. Along with alphabetic knowledge, invented spelling predicted subsequent reading and became a mediator between phonological awareness and early reading. Along with phonological awareness, invented spelling predicted subsequent conventional spelling and mediated the effects of alphabetic knowledge.

Invented Spelling in Learning Chinese as L1 and English as L2

There have been some studies examining the skill transfer between an alphabetic language and a logographic language, such as English and Chinese (Bialystok et al. 2005a; McBride-Chang and Ho 2005; McBride-Chang and Kail 2002). Many previous studies on phonological awareness in Chinese focused on syllable- or phoneme-level awareness, which can be considered as segmental-level examinations. The present study aimed to address invented spelling in Mandarin-speaking children who spoke English as an L2 at segmental and suprasegmental levels. Early studies have demonstrated that invented spellings in young children who spoke English tapped into the underlying phonological structures of words and invented spelling differed from standard spelling (Mann et al. 1987; Richgels 1995). McBride-Chang and Ho (2005) used an English invented spelling tool in Hong Kong Chinese children who spoke both Cantonese and English and found strong association between English invented spelling and reading in English. Similarly, we developed an English invented spelling tool to examine its relation to English reading skill and Chinese reading skill as well.

According to Taylor et al. (2011), children had more difficulties with nonreal word fluency in comparison to other measures of fluency. Thus, we hypothesized that participants might perform better on real words and perform worse on nonreal words. One of the speech manipulations was whether consonants possess differential difficulty levels for manipulation, contingent on their positions within a consonant string. Phoneme manipulations possessed differential difficulty levels depending on how many consonants were included in the consonant cluster (McBride-Chang 1995). In Mandarin Chinese, a syllable has a relatively simple phonological structure with no double consonants (e.g., such as the combination of “sk” in “desk”), although some syllables may have two syllable-ending consonants (e.g., bang). In the present study, we considered this issue by including spelling items in a consonant–vowel-consonant (CVC) order, a consonant–consonant–vowel-consonant (CCVC) order, or a consonant–vowel-consonant–consonant (CVCC) order. English does not possess the feature of tonal changes; thus, we considered syllable stress as an approximately parallel feature, which is at the suprasegmental level of phonological awareness. Goswami et al. (2013) found that children with dyslexia had perception deficits in syllable stress. Thus, we included words with and without syllable stress to compare the difference of item difficulty. Based on McBride-Chang (1995), we anticipated that experimental linguistic manipulations (e.g., alternating the number of consonants in order) would influence phonological awareness item difficulties.

To summarize, the aims of the present study were to examine (a) to what extent the manipulation of various linguistic features of the newly developed invented spelling tasks might lead to differential difficulty of the task items (e.g., tonal changes or no tonal changes, real words or nonreal words, English words with or without stressed syllables); (b) possible transfer of skill between Chinese and English; and (c) the utility of a pinyin invented spelling, which tapped into Chinese phonological awareness, tonal awareness, and tone sandhi, and an English invented spelling, which measured English syllable awareness, phoneme awareness, and word stress rules, for explaining unique variance in Chinese and English conventional spelling skills and Chinese and English word reading skills.

Method

Participants

We recruited 72 sixth graders (36 females and 36 males) from three classes in one elementary school in Mainland China. The children averaged 12.25 years old (SD = .54). They did not carry any official diagnosis of intellectual disabilities or other mental disorders. The study took place in an urban elementary school in Beijing. Starting in first grade, children received the Chinese reading curriculum, and standard English reading curriculum was introduced in the beginning of third grade. In daily life, these children spoke Mandarin. English was learned and taught as a school subject, and the participants typically did not use English for daily communication. Except for the English subject, all other subjects were delivered in Mandarin Chinese. Because of their limited proficiency and exposure to English, the participants were considered as second-language learners of English. Chinese children received systematic pinyin instruction during their first grade. For English, teachers relied on a phonics approach for teaching. By the time of testing, the participants had received English classes for 3 years.

Measures

Many of the tasks were constructed in a parallel format for both languages, including Chinese versus English word reading, Chinese pinyin versus English invented spelling, and Chinese versus English conventional spelling tasks. It is impossible to translate tasks word by word to ensure equivalence across languages. The main goal was to evaluate comparable concepts of skills in two languages. We used non-verbal intelligence, rapid naming (in Chinese), and Chinese phonological awareness as control variables given the fact that rapid naming and phonological awareness have shown to be two key predictors of early reading skills in children (e.g., Shu et al. 2003; Li et al. 2012). The participants were far more proficient in Chinese than in English, thus we administered rapid naming and phonological awareness tasks in these children's first language to ensure the sensitivity of these instruments.

Raven's Progressive Matrices

We used the Raven's progressive matrices as a measure of non-verbal intelligence (Raven et al. 1995) in which there were five sets of 12 items each. In total, there were 60 colorful pictures with a portion missing. The 60 pictures were divided into five sets with 12 items for each set. The participants were presented with matrices with missing portions. The participants were to choose the correct missing portion out of multiple choices. We recorded the raw scores.

Chinese Word Reading

We used a Chinese word reading task developed by Ho et al. (2000). There were 150 two-character Chinese words presented based on order of increasing difficulty. The original version of Chinese word reading in Ho et al. (2000) was printed in traditional Chinese characters, and we used simplified Chinese characters for our participants who learned simplified Chinese characters in their school. We consulted with elementary school teachers to examine the item appropriateness. We field tested this task with a few Chinese students to ensure the words were appropriate for Chinese elementary school students. This task had a split-half reliability greater than .90. The internal consistency in this independent sample was .78. The participants discontinued the task when they had 10 consecutive errors. The participants earned one point for each correct item. The maximum score was 150.

Chinese Conventional Spelling Task

We used the rules in the Spelling subtest of the *Wide Range Achievement Test–Revision 3* (WRAT-3; Wilkinson 1993) and developed the Chinese conventional spelling task. There were 15 pinyin items as basal items and 40 items of Chinese words in either one-syllable or two-syllable formats. These Chinese words were selected from a series of Chinese reading textbooks for Grades 1–6. This task was initially tested in Ding et al. (2010). The participants were given worksheets with item numbers printed and listened to the examiner who orally presented each Chinese word in order. The examiner would read the item number, the target word in isolation, and then the target word in a sentence. For example, the examiner would say "Item number 2, *tree*, they are planting *tree*. Spell the word *tree*." According to the examiner's direction, the participants spelled out each target word. If a participant failed five items consecutively, we considered that the participant reached the ceiling. The internal consistency for this task was .83. The participants earned one point for each correct item. The possible points were from 0 to 55.

Chinese Phonological Awareness Task

There were 29 syllable deletion items and 22 phoneme deletion items. The Chinese syllable awareness task was used in previous studies (McBride-Chang and Kail 2002; Shu et al. 2008).

The participants listened to three-syllable Mandarin phrases and were asked to delete one particular syllable, according to the examiner's direction. For example, 红 /hóng/ 苹 /píng/ 果 /guǒ/ became 红 /hóng/ 果 /guǒ/ after deleting the middle syllable. This task included both real and nonreal phrases. The phoneme deletion task was adopted from McBride-Chang et al. (2005). For example, 代 /dài/ without the initial phoneme would be/ài/. The testing items consisted of words of various lengths, including one-, two-, or three-syllable words. The participants were asked to delete a particular phoneme from a word, according to the examiner's direction. The internal consistency for this task was .76. The participants earned one point for each correct item. The participants could earn points from 0 to 51.

Pinyin Invented Spelling

Based on Lin et al. (2010), we designed a pinyin invented spelling task, which included 32 items. There are a few unique features of pinyin invented spelling. First, this task had two-syllable to four-syllable items, which expected children to identify syllables and segment one syllable from the others. Second, this task measured phoneme awareness by asking children to write out the onsets and rimes. Third, this task measured tone awareness by asking children to identify and write a lexical tone for each target character. For the 20 real words, we applied sandhi rules to eight items and did not apply sandhi rules to the remaining 12 items. Similarly, for the 12 nonreal words, we applied sandhi rules to eight items, but not to the remaining four items. We tried to design parallel items in real words and nonreal words involving tone sandhi. For example, item 4 represented tonal change in a real word that involved a third tone ([老]虎/lǎo//hǔ/→/láo//hǔ/) and item 21 represented tonal change in a nonreal word that involved a third tone ([主]马/zhǔ//mǎ/→/zhú//mǎ/). This task had an internal consistency (Cronbach's alpha) of .88. To ensure a parallel comparison, the manipulation of linguistic features for items 1–8 (sandhi rules were applied in real words) was similar to items 11–18 (sandhi rules were not applied to real words), and items 21–28 (sandhi rules were applied to nonreal words). We provide examples of item manipulations in Table 1. The pinyin invented spelling in Ding et al. (2015) was presented through the auditory modality. By orally presenting the Chinese syllables, including those with tone sandhi, it was difficult to tell whether children simply spelled pinyin based on exactly what they heard or whether they truly comprehended the tone sandhi. Thus, in the present study, all Chinese characters were presented on paper.

The scoring scheme for pinyin invented spelling was based on Lin et al. (2010). Each item could be scored from 0 to 12 points. There were four linguistic features we considered for the scoring scheme, consisting of onsets, rimes, tones, and order of the pinyin. We used a 5-point scale (0–4) for the onset and rime scoring, respectively (see Table 2). A 0–1 rating scale was used for the order of onset and rime. A 0–3 scale was used for the lexical tones. Another rater independently rated one-third of the data, and the inter-rater reliability was .98.

English Conventional Spelling Task

The design of the English conventional spelling task was based on the Spelling subtest of the *Wide Range Achievement Test–Revision 3* (WRAT-3; Wilkinson 1993). It included 15 letter items and 40 English vocabulary items. The 40 vocabulary items were presented in order of increasing difficulty and were selected from the elementary English reading textbooks (People's Education Press 2013). The examiner read each item out loud and the participants

Table 1 Design structure and samples for the Pinyin invented spelling task

Structure	Section	N	Example	Sample answer
Real words with tone sandhi (two-syllable)	Items 1–5	5	[一]律	/yī//lǜ/→/yí//lǜ/
Real words without tone sandhi (two-syllable)	Items 11–15	5	统一	/tǒng//yī/
Nonreal words with tone sandhi (two-syllable)	Items 21–25	5	[主]马	/zhǔ//mǎ/→/zhú//mǎ/
Real words with tone sandhi (three-syllable)	Items 6, 7	2	亮堂[堂]	/liàng//táng//táng/→/liàng//táng//tang/
Real words without tone sandhi (three-syllable)	Items 16, 17	2	大会堂	/dà//huì//táng/
Nonreal words with tone sandhi (three-syllable)	Items 26, 27	2	虎扑[扑]	/hǔ//pū//pū/→/hǔ//pū//pu/
Real words with tone sandhi (four-syllable)	Item 8	1	[一]走了之	/yī//zǒu//liǎo//zhī/→/yì//zǒu//liǎo//zhī/
Real words without tone sandhi (four-syllable)	Item 18	1	心口如一	/xīn//kǒu//rú//yī/
Nonreal words with tone sandhi (four-syllable)	Item 28	1	[一]挑匹肋	/yī//tiǎo//pǐ//lèi/→/yì//tiǎo//pǐ//lèi/
Real words without tone sandhi (four-syllable)	Items 9,10, 19,20	4	瞬息万变	/shùn//xī//wàn//biàn/
Nonreal words without tone sandhi (four-syllable)	Items 29,30,31,32	4	流能惠飞	/liú//néng//huì//fēi/

Tone sandhi is applied to characters in []

were asked to spell out each item. If a participant spelled incorrectly for five consecutive items, we considered that the participant had reached the ceiling. This task had an internal consistency of .95. The participants earned one point for each correct item and the possible points were from 0 to 55.

English Word Reading

This task was adopted from Tong and McBride-Chang (2010). There were 60 English words presented in order of increasing difficulty. The participants were asked to read each item in order. The participants earned one point for each correct item. This task had an internal consistency of .92, and the possible points were from 0 to 60.

English Invented Spelling

There were 14 real words and 14 nonreal words in this task. Among the 14 real words, we designed eight single-syllable words, four two-syllable words, and two three-syllable words. Within the eight single-syllable words, four followed a CVC order, two followed a CCVC order, and two followed a CVCC order. Within the four two-syllable words, two were stressed

Table 2 Samples of Pinyin invented coding scheme

Pinyin	Scores	Type (range of scores)			
		Onset (0–4)	Rhyme (0–4)	Tone (0–3)	Order (0–1)
/qían/潜水的潜	0	Nothing written, or character or picture was written			Incorrect order
	1	Random letter	Random letter	1, 3, 4	Correct order
	2	Letters including *j, q,* or *x*, and others	Letters including *i* or *an*, and others	*	–
	3	Letter of just *j or x*	Letters of just *i or an*	2	–
	4	Letter of just *q*	Letters of just *ian*	–	–

Table 3 Item number and examples for the English invented spelling task

Structure	Section	N	Examples
Real words with CVC structure (one-syllable)	Items 1–4	4	Map
Real words with CCVC structure (one-syllable)	Items 5–6	2	Flag
Real words with CVCC structure (one-syllable)	Items 7–8	2	Fast
Real words with 1st syllable stressed (two-syllable)	Items 9, 10	2	Butter
Real words with 2nd syllable stressed (two-syllable)	Items 11, 12	2	Compare
Real words with 3rd syllable stressed (three-syllable)	Items 13, 14	2	Kangaroo
Nonreal words with CVC structure (one-syllable)	Items 15–18	4	meb
Nonreal words with CCVC structure (one-syllable)	Items 19, 20	2	plig
Nonreal words with CVCC structure (one-syllable)	Items 21, 22	2	fept
Nonreal words with 1st syllable stressed (two-syllable)	Items 23, 24	2	binter
Nonreal words with 2nd syllable stressed (two-syllable)	Items 25, 26	2	haspare
Nonreal words with 3rd syllable stressed (three-syllable)	Items 27, 28	2	inmitarp

CVC Consonant–vowel-consonant, *CCVC* consonant–consonant–vowel-consonant, *CVCC* consonant–vowel-consonant–consonant

in the first syllable and the other two were stressed in the second syllable. The three-syllable words were stressed in the third syllable. The nonreal words were developed based on the same design. The examiner read all of the items aloud and the participants were instructed to spell out the English words that they heard. The examiner explicitly informed the participants that they would hear both real and nonreal words. The coding scheme was developed based on the design used by Ouellette and Sénéchal (2008). A 7-point scale (0–6 points) was used for each spelling (see "Appendix A"). Examples of manipulations are presented in Table 3.

Rapid Automatized Naming (RAN)

This Chinese RAN-character was designed according to Denckla and Rudel (1974). We used the characters of "尺," "衣," "风," "也," and "出", which are all high frequency characters in Chinese. These characters could be individual characters as stand-alone characters. They could also be morphemes that could make more complex characters such as 迟, 依, 枫, 池, and 础. Chinese children are taught to remember these basic characters as sight words. It was used successfully by Ding et al. (2010, 2013). The examiner recorded each participant's completion time and errors on RAN.

Procedure

The examiners were two graduate students majoring in psychology. The testing procedure took 1–1.5 h for each participant, and data collection was completed within 2 weeks.

Table 4 Descriptive statistics of all measures

Measures	M	SD	Skewness	Kurtosis	Cronbach's
Pinyin invented spelling (1104)	1060.00	28.00	− 2.63	1.92	.88
Chinese word reading (150)	140.65	4.86	− 1.57	3.00	.78
Chinese phonological awareness (51)	46.88	2.52	− 1.13	1.14	.76
Chinese conventional spelling (55)	26.68	6.09	.06	− .19	.83
English invented spelling (168)	123.06	26.49	− .55	.09	.92
English word reading (60)	42.55	9.28	− 1.07	1.46	.92
English conventional spelling (55)	22.62	10.32	− .19	− 1.05	.95
Raven's progressive matrices (60)	49.61	6.42	− 1.94	2.44	–
RAN character	20.60	3.22	.45	− .51	–

Numbers in parentheses = maximum points for each measure
Because Raven's progressive matrices is a standardized test, reliability was not provided

Results

Descriptive Statistics

We provide descriptive statistics in Table 4. The internal consistency coefficients for all measures were at least .76 or higher. The reliability coefficients for pinyin invented spelling and English invented spelling were .88 and .92, respectively. We examined all skewness and kurtosis indices, which did not indicate severe violation of normality assumptions (Tabachnick and Fidell 2001).

The phonological manipulations embedded in the pinyin invented spelling task were the key components for our descriptive analysis. Our first hypothesis was regarding the items with tone sandhi and those without it. Among the pinyin invented spelling task, we purposefully imposed parallel structure to items 1–8, items 11–18, and items 21–28. Three subgroups of testing items all had the maximum scores of 18 points and were presented with similar difficulty levels. Such item construction allowed the comparison of raw scores of different clusters of task items. Based on the data shown in Table 5, the participants performed worse on items for which tone sandhi was applied (items 1–8 and items 21–28) than they did on items for which tone sandhi was not applied (items 11–18). When we ran a paired-sample *t* test, the participants performed significantly worse on items 1–8 (real words with tone sandhi) then they did on items 11–18 (real words without tone sandhi; $t = -11.40$, $p = .000$). Similarly, the participants performed significantly worse on items 21–28 (nonreal words with tone sandhi) than they did on items 11–18 (real words without tone sandhi; $t = 17.84$, $p = .000$), which supported the hypothesis that tone sandhi made items more difficult to manipulate. The participants performed significantly worse on items 21–28 than they did on items 1–8 ($t = 9.99$, $p = .000$), which supported our hypothesis that real words were easier to manipulate than nonreal words when tone sandhi was applied to both conditions.

For the English invented spelling task, items 1–4 versus items 5–8, items 5–8 versus items 19–22, and items 9–14 versus items 23–28 had parallel structure and a comparable level of difficulty, with the same maximum raw scores. Comparison of absolute raw scores is feasible

Table 5 Means and standard deviations for subdomains of invented spelling measures

Invented spelling	Mean	SD	Paired sample *t* test (t/p)
1. PISTotal	1060.00	28.00	
2. PIS 1–8 (real words with tone sandhi)	229.13	4.01	2>3 (− 11.40/.000)
3. PIS 11–18 (real words without tone sandhi)	236.63	4.74	3>4 (17.84/.000)
4. PIS 21–28 (nonreal words with tone sandhi)	220.69	7.49	2>4 (9.99/.000)
5. EISTotal	123.06	26.49	
6. EIS 1–14 (real words)	68.30	11.17	
7. EIS 15–28 (nonreal words)	54.76	17.15	
8. EIS 1–4 (real words with CVC)	22.97	1.89	
9. EIS 15–18 (nonreal words with CVC)	14.04	5.70	8>9 (13.34/.000)
10. EIS 5–8 (real words with CCVC or CVCC)	19.24	4.39	
11. EIS 19–22 (nonreal word with CCVC or CVCC)	15.59	6.65	10>11 (5.14/.000)
12. EIS 9–14 (real words with stressed syllables)	26.09	7.29	
13. EIS 23–28 (nonreal words with stressed syllables)	25.13	7.89	12>13 (1.18/.244)

PIS Pinyin invented spelling, *EIS* English invented spelling, *CVC* consonant–vowel-consonant, *CCVC* consonant–consonant–vowel-consonant, *CVCC* consonant–vowel-consonant–consonant. Each word was rated against a 0–6 scale

for such structure of item design. Real words with CVC structure (items 1–4) were significantly easier to manipulate than nonreal words with CVC structure (items 15–18) (t = 13.34, $p = .000$). Real words with CCVC or CVCC structure (items 5–8) were significantly easier to manipulate than nonreal words with CCVC or CVCC structure (items 19–22) (t = 5.14, $p = .000$). Thus, it supported our hypothesis that it was easier to manipulate real words than nonreal words. Within multi-syllable words, real words with stressed syllables (items 9–14) were not significantly easier to manipulate in comparison to nonreal words with stressed syllables (items 23–28) (t = 1.18, $p = .244$). Thus, our hypothesis regarding the difficulty difference between real and nonreal words with or without syllable stress was not supported. To test item discrimination, we compared real words with CVC structure (items 1–4) and real words with CCVC or CVCC structure (items 5–8), and those with CVC structure were significantly easier to manipulate (t = 7.53, $p = .000$). Similarly, nonreal words with CVC structure (items 15–18) were significantly easier to manipulate than nonreal words with CCVC or CVCC structure (items 19–22) (t = − 2.28, $p = .026$). This indicates that the double-consonant structure was more difficult for Chinese children than the CVC structure.

Table 6 Second-order correlations between Chinese and English invented spelling, dictation, and word reading measures, with Chinese phonological awareness and RAN character partialed out

	PIS	Chinese conventional spelling	Chinese word reading
EIS	.20	.53***	.35***
English conventional spelling	.32*	.69***	.55***
English word reading	.27*	.23	.53***

PISTotal Pinyin invented spelling total score; *EISTotal* English invented spelling total score
* $p<.05$; ** $p<.01$; *** $p<.001$

Correlational Findings Among Chinese and English Measures

The second-order correlations among all measures were calculated by partialing out participants' performance in Chinese phonological awareness and RAN character (see Table 6). The correlation coefficients for the same tasks in the two languages are displayed on the diagonal. The correlation coefficients consistently indicated a statistically significant association between two same tasks presented in two languages (i.e., Chinese conventional spelling task versus English conventional spelling task, Chinese word reading versus English word reading). Among the same tasks, pinyin invented spelling did not show significant correlation with English invented spelling. Among the different tasks, Chinese conventional spelling task did not show significant correlation with English word reading.

Regression Analysis

We conducted separate hierarchical regression analyses to test whether invented spelling tasks explained unique variance on the Chinese conventional spelling task and English conventional spelling task (see Table 7). In order to control for nonverbal IQ, we entered it in the first block. We included RAN character in the second block and Chinese phonological awareness task in the third block because there have been rigorous empirical studies supporting the importance of RAN and phonological awareness for literacy development. In the fourth block, we entered Chinese word reading and English word reading given the importance of word reading (decoding) in relation to literacy skills. As shown in Table 7, nonverbal IQ did not explain unique variance in either Chinese conventional spelling or English conventional spelling, whereas RAN character explained unique variance in both Chinese conventional spelling and English conventional spelling. Interestingly, Chinese phonological awareness explained unique variance in English conventional spelling, but not in Chinese conventional spelling. Chinese word reading and English word reading together explained large variance in both Chinese conventional spelling (17.4%, $p=.001$) and English conventional spelling (31.5%, $p=.000$). Pinyin invented spelling in the fifth block explained unique variance in Chinese conventional spelling (5.1%, $p=.036$). English invented spelling in the sixth block explained unique variance in both Chinese conventional spelling (12.2%, $p=.001$) and English conventional spelling (6.9%, $p=.003$).

To examine whether the invented spelling tasks explained unique variance in both Chinese and English word reading, we conducted another set of hierarchical regression analyses (see Table 8). We included control measures of nonverbal IQ, RAN character, and Chinese phonological awareness in the first, second, and third blocks, respectively. Pinyin invented

Table 7 Hierarchical regression analyses explaining Chinese and English conventional spelling

Steps	Variables	Chinese conventional spelling				English conventional spelling			
		βeta	R^2	R^2 change	p	βeta	R^2	R^2 change	p
1	Raven's	−.018	.019	.019	.291	−.099	.001	.001	.801
2	RAN character	−.164	.131	.141**	.003	−.038	.118	.117**	.007
3	Chinese phonological awareness	−.107	.120	.003	.631	.107	.225	.107**	.007
4	Chinese word reading	.303	.278	.174**	.001	.249	.540	.315***	<.001
	English word reading	−.134				.293			
5	Pinyin invented spelling	.229	.322	.051*	.036	.076	.548	.008	.348
6	English invented spelling	.421	.446	.122**	.001	.314	.616	.069**	.003

* $p<.05$; ** $p<.01$; *** $p<.001$

spelling and English invented spelling were included in the fourth block and fifth block, respectively. Pinyin invented spelling contributed a unique 10.8% of the variance in Chinese word reading ($p = .030$) and 6.0% of the variance in English word reading ($p = .037$). Similarly, English invented spelling contributed a unique 6% of the variance in Chinese word reading ($p = .030$) and 7.2% of the variance in English word reading ($p = .018$).

Discussion

In the discussion, we focus on the three research aims that we mentioned early on, including (a) how the manipulation of linguistic features of the pinyin invented spelling tasks leads to differentiated performance on different task items; (b) possible transfer of skill between Chinese and English; and (c) the predictive utility of pinyin invented spelling in explaining performance in other Chinese and English reading measures.

The Linguistic Manipulation in Pinyin Invented Spelling Task

The idea of developing a pinyin invented spelling task was initiated by the pinyin task used in Lin et al. (2010). However, the task utilized in Lin et al. (2010) was designed for very young children (i.e., kindergartners) and contained only five one-syllable Chinese words. We extended the pinyin invented spelling task to 32 items (e.g., two-, three-, and four-syllable words) with a total of 92 characters that can be suitable for older elementary students. We included tone sandhi as a component of measure at the suprasegmental level, which was not addressed in Lin et al. (2010). The pinyin invented spelling task was validated in a study that involved both typical readers and readers with reading difficulties in Mandarin Chinese (Ding et al. 2015). However, the coding system used in Ding et al. (2015) relied on a 0–1 coding scheme, so the present study utilized a coding system that allowed separate examination of awareness in the aspects of onset, rime, lexical tone, and order. Children were to produce pinyin (i.e., onsets, rimes, and tones) based on printed compound words. Such administration allowed the opportunities to examine whether children truly comprehend tone sandhi and learn to manipulate tonal changes in familiar words and unfamiliar words. To avoid the situation in which the participants might not recognize the presented characters, the researchers examined the standard Chinese reading textbooks from Grade 1 to 6 to ensure that the characters selected for the pinyin invented spelling were already learned by the participants.

The pinyin invented spelling task was used to measure children's phonological awareness at the segmental (i.e., syllable and phoneme) and suprasegmental (i.e., tone) levels. Tone awareness, as a sub-concept under the larger concept of phonological awareness, has only been examined in a few studies such as Li and Ho (2011) and Yin et al. (2011). Lexical tone can be defined as the use of pitch in language to distinguish lexical or grammatical meaning. Lexical tone cannot be represented alone or be learned independent of a given word; it is typically presented through a syllable or rime (Dinneen 1967). Adequate lexical tone awareness might be an important metalinguistic skill contributing to successful reading in Chinese. Poor readers in Chinese Cantonese demonstrated more difficulty with tone discrimination than typical readers (Chan and Siegel 2001). In an independent sample that involved a Cantonese-speaking control group and dyslexic children, it was reported that a deficit in some areas of tone awareness was identified in over one-third of the dyslexic children (Li and Ho 2011). Siok and Fletcher (2001) reported a significant association between tone awareness and Chinese word reading in children who spoke Mandarin Chinese. In addition

Table 8 Hierarchical regression analyses explaining Chinese and English word reading

Steps	Variables	Chinese word reading				English word reading			
		βeta	R^2	R^2 change	*p*	βeta	R^2	R^2 change	*p*
1	Raven's	.079	.027	.027	.204	.055	.011	.011	.428
2	RAN character	−.140	.121	.094*	.015	.001	.065	.055	.068
3	Chinese phonological awareness	.040	.153	.032	.144	.245	.187	.121**	.005
4	Pinyin invented spelling	.296	.261	.108**	.006	.189	.247	.060*	.037
5	English invented spelling	.280	.321	.060*	.030	.309	.319	.072*	.018

* $p < .05$; ** $p < .01$; *** $p < .001$

to tone awareness, we measured tone sandhi as a fourth feature of this task. In short, our pinyin invented spelling task addressed phonological awareness at syllable, phoneme, and tonal levels, respectively.

It is important to produce the accurate lexical tone of a given character in order to make effective communication by using spoken Chinese. Because of the nonsystematic approach for Chinese children to learn tone sandhi, we hypothesized that tone sandhi made testing items more difficult to manipulate. The findings indicated that participants performed better on testing items that did not involve tone sandhi than they did on those items with tone sandhi. It supported our hypothesis. Chinese reading curriculum at the first-grade level explicitly and systematically addresses teaching of onsets, rimes, and tone assigned to each character (People's Education Press 2013). Characters involving tone sandhi in the textbook were directly marked with pinyin and tones that already reflected tone sandhi (e.g., 三/sān/个/gè/圈/quān/圈/quān/to 三/sān/个/gè/圈/quān/圈/quan/) without providing guidelines or rationales about why such tonal changes should occur. Tone sandhi in Chinese children is often learned through personal experiences, which is similar to how English-speaking children learn about syllable stress. As a linguist, Lin (1980) described two conventional tonal changes in Chinese Mandarin. One type is termed *allophonic variation*, which typically exists in words with a third tone. The second type is termed *morphophonemic variation,* which often occurs in one syllable that is adjacent to a syllable with an identical tone. However, such classification of tone sandhi is rarely introduced in pinyin instruction. A small number of studies have shown that tone awareness has demonstrated significant correlation to reading development in Chinese children (e.g., Yin et al. 2011; So and Siegel 1997; Shu et al. 2008) and children's phoneme onset awareness and tone awareness dramatically increased as the formal instruction was introduced (Shu et al. 2008). The findings supported our anticipation about the differences between real and nonreal words. Pinyin invented spelling was presented through the visual modality in the present study; thus, participants did not have opportunities to listen to how the examiners orally presented these words. Their judgment about the correct pronunciations and tones using pinyin might primarily rely on their prior exposure to words involving tone sandhi. In such testing conditions, it is not surprising that nonreal words were more difficult to manipulate because the participants were less familiar with nonreal words, concurring with Taylor et al. (2011).

We tried to design a parallel version of invented spelling in English by focusing on measures of similar concepts in two languages, rather than creating completely equivalent tasks for both langauges. The English invented spelling task tapped into syllable awareness, phoneme awareness, and stressed syllables, which involves phonological awareness at the suprasegmental level. The findings supported our hypothesis that real words are easier to manipulate than nonreal words. The CCVC or CVCC structure was more difficult for Chinese children to manipulate than the CVC structure, indicating that our experimental manipulations of linguistic features did influence item difficulties, concurring with McBride-Chang (1995). A plausible interpretation was that Chinese character pronunciation typically does not possess the consonant–consonant combination, and children might be less familiar with such linguistic manipulation.

Possible Transfer of Skill in Chinese and English

Disregarding somewhat controversial findings regarding how bilingualism plays a role in development of phonological awareness (e.g., Bialystok et al. 2003; Chen et al. 2004; Yelland et al. 1993), our findings suggested some transfer in same-task skills. Bialystok et al. (2005b) advocated that instead of examining bilingualism as a stand-alone concept, we need to examine the linguistic features of target languages and instructional contexts in which children become bilingual. In particular, the correlations of scores on the conventional spelling tasks and word reading tasks were at the .5 level or above, supporting some overlap of literacy skills in learning of Chinese and English, after partialing out Chinese phonological awareness and RAN character. Conventional spelling tasks used in Chinese schools are often coupled with rote memorization. A common classroom practice in Chinese schools is that the teacher reads a list of vocabulary out loud and the students are expected to dictate what they hear in writing format. Such conventional spelling practice is applied to both Chinese and English classes. It is likely that Chinese children heavily rely on rote memorization for dictating Chinese and English vocabulary in the written format.

As a logographic language (i.e., Chinese), the units of the written language generally correspond to morphemes, not speech segments (Perfetti et al. 1992). The Chinese writing system gives little cues to the phonology based on the graphic inputs. Word reading (decoding) skills in Chinese children are mostly developed through formal schooling and repetitive practice in order to make automatic mapping between the sounds and the print. After each reading lesson is introduced, there are a list of newly introduced vocabularies for children to memorize. Although English instruction in Chinese schools applies the phonics approach, English word reading is often trained through formal schooling that emphasizes rote memorization and repetitive practice. Children might develop their English word reading skills in relation to their strategy to learn Chinese word reading. Such findings are consistent with Bialystok et al. (2005a, b), indicating that Chinese children in this particular sample might use similar cognitive strategy and memory resources to learn word reading in Chinese and English, so the scores were highly related. In addition, the sixth graders recruited in the present study were native speakers of Chinese and they had learned English through formal schooling for only 3 years. They were far more advanced in Chinese reading and were merely at the early stage of English reading. They might not develop two different approaches to word reading in Chinese and English (Bialystok et al. 2005a, b), thus the two scores were highly correlated.

Pinyin invented spelling and English invented spelling were not significantly correlated, although the tasks both required invented spelling. There are two plausible explanations. In Chinese schools, pinyin instruction is explicitly taught in the beginning semester of first grade. Children are likely to develop a systematic and relatively independent cognitive strategy to approach pinyin of Chinese characters. The teaching of English in Chinese elementary school also applies a phonics approach. Teachers emphasize instruction on vowels, consonants, and phoneme-level processing. Because of the systematic approach to teach sounds of English letters and words, children might also develop a relatively independent cognitive strategy to approach sounds of English words and attempt to spell out the sounds of given words. Second, the pinyin invented spelling task required children to use pinyin as the phonetic system to spell out the onset, rimes, and tones of given Chinese characters, which did not require the spelling of the actual Chinese characters. The English invented spelling task required children to inventively spell out the given English real or nonreal words based on the phonics rules. In other words, these two invented spelling tasks are not equivalent in terms of what they attempted to measure.

Invented Spelling in Relation to Reading and Conventional Spelling Skills

A conventional phonological awareness task in Chinese often focuses on awareness of syllables and phonemes. However, it does not measure learners' abilities to produce phonological structures of a given character or word. Pinyin invented spelling compensates for the limitations in typical Chinese phonological awareness and taps into phonological structure. Theoretically, a measure of phonological awareness should move beyond the level of syllable and phoneme awareness and measure the awareness of phonological structure. Our pinyin invented spelling task not only captured children skills on phonological awareness, but also on phonological structure (i.e., spelling out onset, rime, and tone in order).

The pinyin invented spelling task was unique in its association with Chinese conventional spelling (i.e., exact spelling of Chinese characters). Indeed, even after taking into account the children's word reading and other measures including RAN character and Chinese phonological awareness, it still interpreted unique variance in Chinese conventional spelling. This task was uniquely associated with Chinese word reading and English word reading after taking into account RAN character and Chinese phonological awareness. In Shu et al. (2008), syllable deletion and tone detection uniquely explained variance in Chinese character recognition (similar to Chinese word reading in the present study). Our findings confirmed the association between the pinyin skills and Chinese word reading. The pinyin invented spelling tasks measured children's awareness at syllable, phoneme, and tonal levels. As a morphosyllabic and tonal language, it is not difficult to understand why the ability to detect and manipulate speech sounds at syllable, phoneme, and tonal levels might be important for Chinese word reading. In the early stage of reading (i.e., first grade), Chinese children use reading books that have Chinese words printed with pinyin on top of each character. To some degree, the format of the Chinese reading books forced the mapping between pinyin and Chinese character recognition. The association between pinyin invented spelling and Chinese conventional spelling might be related to instructional experiences that are unique for Chinese children. Many school exams test children's abilities to spell out pinyin based on given characters or vice versa. The expectation in their reading tests might reinforce such association. In terms of the association between pinyin and English word reading, a plausible interpretation might be the benefit of pinyin training. Bialystok et al. (2005a, b) reported that children in Hong Kong (i.e., they did not receive pinyin instruction) made no progress over time in phonological awareness at the phoneme level when there was no explicit training of phonics in place. Pinyin instruction was universally implemented in China and it largely and explicitly enhanced children's phoneme awareness, which is critical for English learning (Lin et al. 2010). The ability to use the phonics approach to attack sounds in one language appear to assist the word attack skills in another language (i.e., English word reading in this study). The pinyin invented spelling did not explain unique variance in the English conventional spelling task. The English conventional spelling task required the children to produce perfect conventional spelling of the vocabulary that they heard. Pinyin skills might help children to have better syllable and phoneme awareness in learning English. However, perfect conventional spelling in English not only requires phonics skills, but also other metalinguistic abilities, such as phonology-to-orthography mapping in English and recognition of sight words, which were beyond what pinyin invented spelling could capture.

Another interesting finding was that English invented spelling interpreted unique variance in both Chinese and English conventional spelling tasks. The results imply that sensitivity to English invented spelling might be important for developing phonology-to-orthography mapping (conventional spelling) in English as L2 (6.9% of the variance) and Chinese as L1 (12.2% of variance). The findings are relatively promising because the results still held after we statistically controlled for nonverbal intelligence, RAN, Chinese phonological awareness, and Chinese and English word reading skills. Read (1971, 1975) postulated that invented spelling in Children represented children's experiences to put words into print and over time they became more proficient on mapping the sounds they heard to the letters (or print). Over time, children improve the sophistication of their invented spelling, which gradually represents conventional spelling. Our findings were consistent with the evidence in Quellette and Sénéchal (2017) that invented spelling explained unique variance in subsequence conventional spelling, after taking account for phonological awareness. English invented spelling also interpreted unique variance in both Chinese and English word reading. The findings concurred with early investigation which indicated that children with more phonologically sophisticated invented spelling learned to read words more easily (Ehri and Wilce 1987; Richgels 1995). The findings supported the notion that invented spelling explained unique variance in reading of Chinese pinyin (Lin et al. 2010) and English literacy acquisition (Caravolas et al. 2001). Our findings appear to support the role of phonological activation in Chinese reading (Perfetti and Tan 1998; Perfetti et al. 1992).

Finally, Chinese phonological awareness explained unique variance in English word reading and conventional spelling, but not in Chinese word reading and conventional spelling. It is not surprising that phonological awareness continues to be an important predictor of English word reading and English conventional spelling, which has been validated in a large number of studies (e.g., Ball and Blachman 1991; Ehri et al. 2001; Ziegler and Goswami 2005). Our findings did not indicate that phonological awareness is not important for Chinese reading. One plausible interpretation is that the use of syllable-level and phoneme-level examination in the Chinese phonological awareness task in the present study does not capture some unique features of Chinese language as a mono-syllabic and tonal language. As a mono-syllabic language, each Chinese character corresponds to one syllable, thus syllable awareness is relatively easy to be established because there is natural space between each character (syllable). McBride-Chang et al. (2005a, b) argues that phoneme awareness is less frequently used to predict Chinese character recognition because Chinese script is not represented at the phoneme level. In other words, it is not necessary to rely on phonemic awareness to read Chinese character. The second plausible interpretation might be related to the age of the participants. McBride-Chang et al. (2005a, b) postulated that phonological awareness might not be a universal predictor of reading beyond its initiation. In Chinese children, mastery of syllable awareness (i.e., the primary unit of phonological awareness in Chinese reading) is obtained by early elementary school (e.g., Treiman and Zukowski 1991). According to McBride-Chang and Kail (2002), the importance of phonological awareness in Chinese reading might be time–limited due to the properties of the script. Our participants were sixth graders, so they might be well beyond the time-limited period to demonstrate the importance of phonological awareness in Chinese reading.

Limitations and Conclusion

We summarized a number of limitations for this study. First, this study was based on a modest sample size from one geographical location in China, which may limit the generalizability of the findings. Our study explored the acquisition of Chinese and English in a specific educational context. Curricula for teaching Chinese and English are highly homogeneous in China due to the mandatory guidelines required by the Ministry of Education. Such instructional and contextual features might not be seen in other regions where children speak both Chinese and English within different instructional and home-school environments (e.g., Hong Kong, Singapore, Taiwan). Second, the data presented were correlational by nature and we cannot explain causality among different variables. Third, for the English invented spelling, we originally planned to ask all participants to use the international phonetic alphabet to spell out the phonics and stress of given English real and nonreal words. For example, for the word of window, the phonics expressed through the international phonetic alphabet will be/’windəu/. During the testing, we found that this particular group of students did not receive instruction for the international phonetic alphabet. They might learn stress through implicit learning, but did not learn how to mark stress using standard symbols. Thus, we simply asked all participants to inventively spell out English words based on what they heard and we could only compare raw scores on items that involved stressed syllables (i.e., those were stressed in the second or third syllables) and those without it (e.g., single syllable). We did not have a mechanism to code recognition of stressed syllables as a stand-alone concept. This might be the reason that our hypothesis regarding the difficulty difference between real and nonreal words with or without syllable stress was not supported.

In summary, this is one of a few studies of invented spelling in children who speak Chinese as L1 and English as L2. In the pinyin invented spelling task, we measured phonological awareness both at the segmental (i.e., syllable and phone awareness) and suprasegmental levels (i.e., tones and tonal changes). In addition, we embedded tone sandhi in our design. We anticipated that tone awareness and tone sandhi might capture some unique linguistic features of Chinese Mandarin. Our findings highlight the importance of explicit training on phonics of Chinese characters, including syllable, phoneme, and tone awareness. Our findings revealed some transfer of skill in the same tasks across Chinese and English. There is not a simple transfer of ability in two languages. Children’s approach to learn in each language might be related to the formal instructional approaches they received at school in order to learn that particular language. The pinyin invented spelling task explained unique variance in Chinese conventional spelling, Chinese word reading, and English word reading, even after controlling for Raven’s, RAN character, and Chinese phonological awareness. The findings provide some support for the activation of phonological processing in Chinese reading. Pinyin skills appeared to benefit word reading in English. English invented spelling proved to be a promising instrument, accounting for unique variance in both Chinese conventional spelling and word reading, and English conventional spelling and word reading. The manipulation of linguistic features in invented spelling tools affected the item difficulties. If the pinyin invented spelling and English invented spelling tasks continue to demonstrate utility in longitudinal studies, researchers might consider incorporating such instruments into evaluation batteries to evaluate at-risk children who are biliterate in Chinese and English.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval This study closely followed all ethical standards established by Institutional Review Board at Fordham University and participating schools.

Appendix

See Table 9.

Table 9 Scoring Rubric for English invented spelling

Points	Description
0	A random sequence of letters was provided
1	A prominent part of the word was represented using a phonetically related letter
2	The correct spelling of the initial grapheme was provided
3	More than one phoneme was represented with a phonetically related or conventional letter in the correct order
4	All phonemes were represented with phonetically related or conventional letters
5	All consonant phonemes were represented with conventional letters and representation of vowel
6	A proper conventional spelling was provided

Note The coding was developed based on Ouellette and Senechal (2008)

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