SPELLING ENGLISH WORDS:

CONTRIBUTIONS OF PHONOLOGICAL, MORPHOLOGICAL AND ORTHOGRAPHIC KNOWLEDGE IN SPEAKERS OF ENGLISH AND CHINESE

A Dissertation

by

JING ZHAO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2011

Major Subject: Curriculum and Instruction

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Approved by:

Chair of Committee,	R. Malatesha Joshi
Committee Members,	L. Quentin Dixon
	Bruce Thompson
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ABSTRACT

Spelling English Words: Contributions of Phonological, Morphological and Orthographic Knowledge in Speakers of English and Chinese.

(May 2011)

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A growing body of literature has provided evidence of the contribution of various metalinguistic skills to children's English literacy development; however, most of the studies focused on reading outcomes while spelling outcomes have been under-researched. Further, very few studies have been conducted to investigate if the results based on native English speakers can be generalized to speakers of other languages who are learning to read and spell in English.

In this study, the simultaneous influence of phonological, morphological and orthographic knowledge that may impact English spelling acquisition, among Chinese students learning English as a foreign language in Grade 8 (n = 339) in mainland China and native English-speaking students in Grade 3 (n = 166) in the United States, was investigated. Measures in English tapping into the three aspects of metalinguistic skills—phonological awareness (PA), morphological awareness (MA) and orthographic awareness (OA)—were administered to both groups. Multi-group structural equation models were used to compare models between the Chinese and the American group.

Results showed that 1) the overall model of metalinguistic skills predicting spelling outcome was highly similar between the American and the Chinese groups; 2) metalinguistic skills were correlated and worked in concert to compose the linguistic repertoire construct which concurrently predicted the spelling outcome; 3) MA was the major component, compared to PA and OA, of Linguistic Repertoire (LING) across the two groups. Linguistic repertoire explained 64.1% and 40.2% of the total variance in the spelling outcome for the American and the Chinese groups, respectively; and 4) the contribution of OA was greater in the Chinese group than it was in the American group, whereas the contribution of PA was greater in the American group than it was in the Chinese group.

This study highlights the important contribution of MA to literacy development among both the American students and the Chinese students. It also sheds light on the influence of first language (L1) orthography on English literacy acquisition. That OA contributed more than PA to the LING construct may reflect that the English learners with L1-Chinese background have enhanced visual-orthographic processing skills. This study challenges phase models of literacy development that claim MA only contributes to literacy acquisition late in the process and offers some empirical evidence to support the emerging “linguistic repertoire” theory of literacy development.

DEDICATION

To Dr. Leo Casey and Ms. Glenn Scott,

dedicated educators, world travelers, and my dear friends.

I hope you get well soon.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Spelling is closely correlated with writing and reading skills (Ehri, 1997, 2000; Perfetti, 1997). Compared to reading, spelling performance might be a better indicator of an individual's knowledge of alphabetic principle, which is the key to literacy in alphabetic orthographies (Joshi, Hoien, Feng, Chengappa, & Boulware-Gooden, 2006). Spelling requires complete retrieval of the correct letter strings that are stored in the orthographic memory and is more difficult than "pure recognition of orthographic representations as required in reading" (Moll & Landerl, 2009, p. 306).

The globalization of English has resulted in the need to understand the process of English literacy acquisition for English language learners in different contexts (Crystal, 1997). Examining the effect of bilingualism on spelling performance is gaining popularity and has been investigated qualitatively (e.g., Fashola, Drum, Mayer, & Kang, 1996; Sun-Alperin & Wang, 2008) and quantitatively (e.g., Holm & Dodd, 1996; Rickard Liow & Lau, 2006). Figueredo (2006) systematically reviewed the literature of cross-linguistic influence on spelling skills and found that a bilingual's first language (L1) has both positive and negative influence on his or her English spelling and second language (L2) spelling mechanisms vary according to two variables: L1 language proficiency and the typological distance between L1 and L2.

This dissertation follows the style of *Reading and Writing: An Interdisciplinary Journal*.

Children learning to read and write in English must process information from the writing system at different levels, namely, phonological, morphological, semantic and syntactic levels (e.g., Nagy, Berninger & Abbot, 2006). The role of phonological awareness (PA) is well established in English literacy research (Adams, 1990; Snow, Burns, & Griffin, 1998). It is considered the general driving force for literacy outcomes in readers and spellers in early stages of learning to read and write. Increasing evidence supports the importance of orthographic awareness (OA), which is one's knowledge of word spelling regularities and permissible letter sequence in a word. In the past decade, interest in the role of morphological awareness (MA) has been elevated. According to Carlisle (1995), MA is children's "conscious awareness of the morphemic structure of words and their ability to reflect on and manipulate that structure" (p. 194). This study was designed to determine the relationships among PA, MA and OA when examined simultaneously and their joint contribution to spelling performance in the American and the Chinese groups.

Related Theoretical Models

The examination of the theoretical models for how PA, MA and OA relate among native English speakers requires the examination of several models of reading and spelling development that have been proposed. Detailed discussion is presented for four major models: the Phase Model, the Lexical Quality Hypothesis, the Dual-Foundation Model of Orthographic Development and the Repertoire Theory model. Because the current study included a Chinese-English bilingual sample, another important theory—

Orthographic Depth Hypothesis—is presented to account for L1 influence on L2 spelling development.

The Phase Model

One of the most cited models of word reading and spelling development is the Phase Model (Ehri, 1995, 2005). The phase model includes description and distinction of four phases: “prealphabetic”, “partial alphabetic”, “full alphabetic” and “consolidated alphabetic” phases. In this model, the initial stage is characterized by children’s heavy utilization of phonological skills; however, increasing exposure to print allows children to recognize and use orthographic skills in addition to phonological skills (Arab-Moghaddam & Sénéchal, 2001). PA and OA are therefore regarded as the main components in the model. Ehri (2005) argues that orthographic knowledge is a device that forms “connections between graphemes and phonemes to bond spellings of the words to their pronunciations and meanings in memory” (p.167) and it is “enabled by phonemic awareness and by knowledge of the alphabetic system, which functions as a powerful mnemonic to secure spellings in memory” (p. 167).

Share’s (1995, 1999) self-teaching hypothesis resembles Ehri’s phase model in that PA and OA are core skills and are related to each other. Share (1995) argues that through phonological recoding of print lexicon, children gradually learn the regularities of the grapheme-phoneme correspondences. During this process, children’s orthographic knowledge system develops as “lexical constraints” including “morphemic constraints” (p. 156) are imposed on the child’s knowledge of basic letter-sound relationships The self-teaching hypothesis considers PA the primary contributor and OA the secondary contributor to word reading.

In both the phase model and the self-teaching hypothesis, the role of MA is not emphasized in early stages of literacy acquisition. The phase model suggests that MA emerges in the fourth phase (consolidated alphabetic phase) and is grouped together with orthographic knowledge. Share's model regards morphemic units as parts of the orthographic regularity. Therefore, it is not clear whether MA makes a unique contribution to word reading and spelling apart from OA and PA, according to the phase model.

Lexical Quality Hypothesis

The next model to consider is Perfetti's (2002) Lexical Quality Hypothesis. In this model, Perfetti (1991) argues that the lexical representation has high quality when the lexical entry is composed of both phonetic and semantic information, so that the lexical information can be fetched efficiently from one's mental lexicon. The hypothesis can be expressed through the theory of lexical specificity and redundancy (Perfetti, 1991, 1992). Lexical specificity or lexical precision refers to the fact that a lexical representation has to have a specified orthographic representation, usually in the form of a conventionally correct spelling of a word. Lexical redundancy means that phonological representations from both spoken language and from grapheme-phoneme mappings have to be available for the lexical representation to be high in quality. Perfetti and Hart (2002) illustrated that the retrieval of lexical representation was likely to have high quality if it was both orthographically specific and phonologically redundant. They proposed a graphic representation of a specific lexical entry which consisted of three components (orthographic, phonological and semantic information) in a triangle framework. A connection of the three integrated components for a word was likely to be established if one encountered a specific word repeatedly for multiple times.

Orthography is defined as “the graphemic patterns of a written language and their mapping onto phonology, morphology, and meaning” (Henderson, 1984, p. 1)., Relating orthography to the writing system and the spoken language, Perfetti (1997) states that spoken languages provide multi-level units in phonology which includes phonemes, syllables, onsets, rimes and morphemic units. Written system principles underline converting these multilayered language units into basic graphic units. Orthography places a system of constraints on the graphic units.

In this model of lexical quality, orthographic rules constrain phonology. Orthographic and phonological skills are therefore highly related. From this perspective, lexical quality hypothesis is similar to Share’s self-teaching hypothesis. The lexical quality model implicitly includes a role for morphology while emphasizing semantics, which includes grammatical and meaning information that is often demonstrated by morphemic units. In the case of English, homography, homophony, and polysemy[1] challenges one-on-one orthographic to phonological relations, and therefore, the quality of lexical representation.

[1] Homography, homophony, and polysemy are three common lexical phenomena in English. Homography can be understood as having the same spelling but different pronunciations (e.g., *lead* pronounced as /led/as a noun means “a kind of metallic element” and pronounced as /li: d/ as a verb means “guide”); Homophony refers to words that share the same pronunciations but different spellings and different meanings (e.g., *see* and *sea* have the same pronunciation but different meaning); and polysemy refers to lexical ambiguity caused by the same word means differently in different context (e.g., *book* in “She is reading a book” and “Did you book the hotel?” has different meaning).

The Dual Foundation Model of Orthographic Development

Another prominent model of reading and spelling is the Dual-Foundation Model of Orthographic Development (Seymour, 1997, 2006; Seymour, Aro, & Erskine, 2003). In this model, a distinction is made between *logographic* and *alphabetic* foundations. A logographic foundation enables children to read familiar words. In this system, symbols represent whole words or concepts, whereas the alphabetic foundation enables children to read phonologically, for example, sound out simple unfamiliar consonant-vowel-consonant (CVC) words or non-words. In the alphabetic process, component sounds are represented to reflect lexical identities, word derivations and morphological structure. Basic foundational components (including small units such as phonemes) are acquired in early phase and larger units such as rimes and syllables included in more complex orthographic structures are acquired later phases.

Seymour (1997) distinguished the two kinds of PA: 1) preliterate PA, which is referred to as meta-phonology in his model and 2) phonemic awareness, which is only acquired through an alphabetic method of literacy instruction. Seymour's concept of meta-phonology is analogous to the phonological aspect of Goswami's (2006) Psycholinguistic Grain-Size Theory (PGST), in which she argues that some phonemic information (at the syllable and onset levels) is represented by children before literacy. PA and OA constitute the foundations of this model proposed by Seymour. MA is an additional component to accommodate the need to deal with words that have a complex morphemic structure. Frith (1985), in line with the phase theory, suggests that the mastery of these morphemic aspects of written language is the key feature of the advanced levels of development. Among all three models that are examined the dual-foundation model addresses the question of how PA, OA and MA related in L1 English children and how these factors together contribute to literacy acquisition. However, because it is based on the phase model, an early influence of morphology is not specified in this model.

Repertoire Theory

An emerging theory that does incorporate the early influence of MA is the “repertoire theory” of spelling development (Apel, Masterson, & Hart, 2004; Apel, Masterson, & Niessen, 2004). The major argument of this theory is that children, even at an early age, utilize multiple linguistic resources and processes in their reading and spelling development (Wolter, Wood, & D’zatko, 2009). The “repertoire theory” portrays spelling as a linguistic skill and supports the idea that good spellers are able to “use their explicit awareness of all of these areas including phonology, orthography, morphemes, and meanings of words, as well specific mental images of words” (Masterson & Apel, 2010, p. 186). Because the repertoire theory is based on children’s spelling samples obtained in instruction and assessment settings in schools, repertoire researchers were able to count the number of the linguistic resources that a child actually used in his or her reading and spelling development. The growth of the number has been used to account for the change in children’s reading and spelling development over time. The “repertoire theory” is the most related theoretical framework for this study because it addresses the issue of the contributions of PA, OA and MA in a balanced way, compensating for the potential weaknesses of the three major models mentioned earlier.

The Effect of L1 Orthography on English Spelling

Orthographic Depth Hypothesis (ODH)

Orthographies have different degrees of phoneme-grapheme correspondence, some more complex than others. According to the Orthographic Depth Hypothesis (ODH) (Katz & Frost, 1992), at one side of the orthography continuum, there are transparent orthographies, such as Spanish and Italian, which have almost one-to-one grapheme/phoneme correspondence (GPC). At the other side of the continuum are opaque orthographies, such as Chinese, which has a morphosyllabic writing system with an unreliable relationship between written units and speech units. English orthography is somewhere in between, being quite deep for an alphabetic script, and is relatively unsymmetrical in sound-to-print correspondence (Venezky, 2006). For example, the phoneme /i:/ has many possible corresponding graphemes as in *heal*, *delete*, *either, machine*, and *green*. The consonant /k/ could be represented by *k, c, ck, que,* or *ch.* At the same time, the same grapheme could represent different phonemes, for example, *c* is pronounced as /s/ in *receive, cider* and *cycle* and as/k/ in *cat, caught*, and *lilac*. Most cross-linguistic studies examining L1 influence on L2 literacy acquisition have focused on PA and reading-related tasks (Joshi et al., 2006); however, spelling may be a better indicator of individual's alphabet knowledge and awareness of intra-word structure.

Bilingual spellers are influenced by the knowledge of their first language and represent a complex and intriguing case for studying English spelling. Bilingual spellers of an alphabetic L1 with a reliable GPC, such as Italian or Portuguese, often outperform monolingual spellers in real word English spelling. For instance, D'Angiulli, Siegel, and

Serra (2001) studied 81 English-Italian bilingual children aged from 9 to 13 years old in Canada and found that advanced bilingual Italian children outperformed monolingual English children (matched on age) on English spelling (Hedge's g = 1.18) and reading. Similarly, Da Fontoura and Siegel (1995) compared bilingual Portuguese-English children (n = 37; 9-12 years) with a comparison group of monolingual English children and found that Portuguese-English bilingual children scored higher on the English spelling task (Hedge's g = 0.42).

In contrast, spellers with a non-alphabetic L1 seem to perform differently in English spelling than alphabetic L1 spellers. Wang and Geva (2003a) examined the spelling performance of 33 monolingual English speaking children and 30 Cantonese-speaking bilingual children in Canada (Grade 2). The authors found that there was no statistically significant difference in real word spelling between the two groups (Hedge's g = -.04, result favoring monolingual group), but monolingual English-speaking children performed better than Cantonese-English bilingual children on pseudoword spelling (Hedge's g = -0.88). The Chinese-English bilingual children in their study had no previous experience with Pinyin, an alphabetic representation of Chinese characters. In another study, Jackson, Holm, and Dodd (1998) compared a group of Cantonese-speaking school-aged children with matched English monolingual children and found that monolingual English children outperformed Chinese-English bilingual children on phonological tasks and non-word spelling (Hedge's g = -0.49). They, therefore, concluded that superior phonological awareness reported in previous research of two phonologically similar languages (such as French and English) may not apply to Chinese-English bilinguals.

Mandarin Chinese: A Primer

In order to investigate the influence of L1 orthography on English spelling and the underlying cognitive components, a primer on Chinese phonology, morphology and orthography is presented. I shall be referring in all cases in this study to Mandarin Chinese, transcribed using the Pinyin system of phonetic representation and represented using simplified Chinese characters. Mandarin Chinese is the official language in mainland China both in its written form and spoken form (often referred to as Putonghua). In many of the Chinese-English biliteracy studies—for example, McBride-Chang et al. (2006)—participants are speakers of Cantonese which is a variety of Chinese used in southern China around Guangdong area, Hong Kong and Macau. Spoken Mandarin and Cantonese are not mutually intelligible; however, most written characters in formal Cantonese are the same as Mandarin and can be understood by Mandarin readers.

Phonology. Most Chinese characters have only one syllable with one initial (sheng1 mu3: consonant) followed by one final (yun4 mu3: rhyming elements). The properties of the initials are similar to English consonants. Some initials (e.g., *b, d, p, t,* and *k)* are pronounced like the English consonants. The finals are more complicated than the initials. Most of the Chinese characters are open syllables that can be expressed with Consonant-Vowel (CV) and Vowel (V) structure and occasionally CVC (with /m/ or /n/ ending). CCVC or CVCC structures with consonant clusters do not exist in the Mandarin phonological system. It is important to note that, unlike English, Mandarin Chinese is a tonal language with four tones. The same pronunciation with different tones indicates different meaning, for example, ma1 (妈)-mother, ma2-flax (麻), ma3-horse (马), ma4-scold (骂) (1, 2, 3, 4 are tone markers). Spoken Mandarin contains many homophones and specific meanings of words are accessed through relative contextual cues. A number of studies has investigated the relationship between PA and Chinese reading and found that PA is a primary predictor for early Chinese reading (Ho & Bryant, 1997; Huang & Hanley, 1995; McBride-Chang & Ho, 2000). Particular aspects of Chinese PA, such as Chinese rhyme deletion, predicts English word reading as well (Chow, McBride-Chang, & Burgess, 2005; Gottardo, Yan, Siegel, & Wade-Woolley, 2001).

Morphology. In Chinese, many of the single-syllable characters can stand alone as individual meaning indicators, but they also serve as morphemes to form multi-syllabic compounds, known as the western notion of words. Lexical compounding is an important feature of Chinese morphology, which makes Chinese an orthography which is relatively transparent semantically. A Chinese word can consist of one character-morpheme or more. In the words, 排球 (pai2 qiu2), 篮球 (lan2 qiu2) and 垒球 (lei3 qiu2), the second character-qiu2-is a morpheme that indicates that it is some kind of a ball. The three words mean volleyball, basketball, and baseball, respectively. MA has shown to be highly predictive of Chinese character reading (McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003). A detailed discussion of Chinese morphology is available in Packard (2000).

Orthography. Mandarin Chinese is basically morphosyllabic in nature (Perfetti & Zhang, 1995). The Chinese reading and writing system is often regarded as iconic (Luk & Bialystok, 2005); for example, the Chinese character 国 [guo2], *country*, has two semantic components, one from the outside 口 symbolizing the border of a country and the inside one 玉 which means *jade* on its own referring to the authoritative figure of a country. In such characters, there is no phonetic component. However, a high proportion (80%) of Chinese characters contains both a semantic component and a phonetic component which aid the Chinese readers in character reading (Hanley, 2005). For example, the character 城 [cheng2], *city* contains the semantic component, 土 *earth, soil* and the phonetic component 成 [cheng2], meaning *succeed, win, finish,* or *become*.

The alphabetic sequential computations do not seem to apply to reading and writing in Chinese. However, in the current study, all of the Chinese-English participants have been exposed to Pinyin, which is a rendition of Chinese into the Roman alphabet. Pinyin instruction is widely encouraged in Mainland China. It is used to introduce new characters for the first two years of Chinese reading instruction. The processing mechanisms involved in Pinyin reading and spelling is similar to alphabetic reading and spelling. For example, the word 树林, *woods*, which consists of two characters, is spelled as *shu4 lin2* in Pinyin. In *shu*, *sh* is the initial and *u* is the final. Pinyin is a highly shallow/transparent orthography; it has an almost one-to-one phoneme-grapheme correspondence. It is hypothesized that Pinyin experience will familiarize the Chinese-English bilinguals included in this study with the alphabetic principle and strengthen their ability to spell phonologically.

Definitions of the Three Metalinguistic Skills

Phonological Awareness (PA)

Many studies have demonstrated that certain aspects of PA transfer across English and Chinese in reading, two very different orthographies. Wang, Perfetti, and Liu (2005) found that Chinese tone processing was a significant predictor of English pseudoword reading among a group of 8-year-old Chinese-English bilinguals in the United States. Gottardo, Yan, Siegel, and Wade-Woolley (2001) administered a series of standardized measures among 65 children whose L1 was Cantonese and found that PA, including scores in rhyme detection, phoneme detection, and phoneme deletion in English, and rhyme detection and phoneme detection in Chinese, were highly correlated. Luk and Bialystok (2008) also reported that English PA and Chinese PA were significantly correlated to each other for 6-year-old Chinese-English bilinguals born and raised in Canada.

Tan, Laird, Li and Fox (2005) in a meta-analysis of phonological possessing in Chinese and English from biological and neurocognitive perspectives concluded that brain activation for Chinese readers and English readers was significantly different, due to the fundamental differences in the phonological structure of the two languages and the learning strategies associated with learning these two different languages. Tan et al. (2005) stated that “Chinese characters map onto phonology at the (mono-) syllable level” (p.84). The phonological processing was constrained in the neural system by such a phonological structure. Will this constraint affect their performance in English spelling?

Wang and Geva (2003b) analyzed spelling errors made by Chinese-English bilinguals on English spelling tasks. They found that Chinese children have difficulty in spelling phonemes that do not exist in Chinese phonological system, such as /*θ*/ and /ʃ/. These children also performed poorly in an auditory discrimination task in their study. Developmentally, however, this negative influence of Chinese did not persist across time for their sample. In other words, after one year of immersion in English instruction, Chinese-English bilingual and English native speakers performed at about the same level in terms of phonological spelling. There might be a biological adaption as the Chinese children are exposed to more and more English.

Conflicting results concerning PA development have been shown by Joshi et al. (2006), who studied English spelling performance of students from the United States, Norway, India and China. They found that American third graders performed better than Norwegian fifth graders, Indian seventh graders and Chinese fifth graders on real word spelling. There was no difference among Norwegian, Indian and Chinese students when they were exposed to formal English instruction for three years. However, as they proceeded to the fourth year of English instruction, Norwegian and Indian students performed better than Chinese students. As for phonological spelling, the Chinese group also scored lower than the comparable groups from Norway and India. When Chinese students did not know the correct spelling, they tended to either skip the entire word or use a known real word as a substitute (e.g., *nice, light, nine* for *night*), whereas Norwegian and Indian students tended to make phonetic approximations of the target word (e.g., *nait, nte, nnet* for *night*). The different results might have been caused by the different settings of the two studies. Bilingual students in Wang and Geva (2003b) were in an English as a second language (ESL) setting—a country within which L2 learners of English are immersed in a majority English L1 society, whereas the bilingual students in Joshi et al. (2006) were in an English as a foreign language (EFL) setting—a country within which L2 learners of English are surrounded by a majority who speaks their same L1, with little exposure to L1 speakers of English. In addition, the effect of age was not controlled in Joshi et al. (2006).

Concurring with Joshi et al. (2006), Rickard Liow and Lau (2006) investigated 80 children (average age = 6 years) with three language backgrounds (English L1 and Mandarin L2, Mandarin L1 and English L2, Malay L1 and English L2) in Singapore. They found all three groups used some PA for spelling but the children with Malay background (which uses a highly transparent orthography) were more dependent on PA, whereas Chinese children seem to rely more on whole word processing. Also in the Singaporean context, Dixon, Zhao and Joshi (2010), through examination of spelling errors made by kindergartners with different ethnic language backgrounds who were learning English, found that the Chinese-English spellers made more real-word substitution errors than Malay-English and Tamil-English spellers with age statistically controlled.

Chinese students' English spelling also seems to be influenced by previous Pinyin experience. Holm and Dodd (1996) included 40 university students from China, Hong Kong, Vietnam and Australia in their study and they found that these students did not differ in real word reading and spelling tasks; however, Hong Kong students who had no previous experience in Pinyin had difficulty processing non-words. This pattern did not emerge for Mainland Chinese students who had studied Pinyin.

McBride-Chang, Cheung, Chow, Chow, and Choi (2006), in a study of 217 Hong Kong Chinese kindergarten children learning English as a second language, found that PA in English explained unique variance in English vocabulary knowledge. The partial correlation coefficient of English vocabulary, measured by the Peabody Picture Vocabulary Test (PPVT), and English syllable detection was 0.35 ($p < 0.001$). The partial correlation coefficient of PPVT and English phoneme onset deletion was 0.44 ($p < 0.001$) with age statistically controlled. From this study we do not know if PA was uniquely associated with English spelling among these Hong Kong bilingual children.

Morphological Awareness (MA)

A growing body of literature indicates that MA is important in monolingual reading and spelling development across many writing systems (McBride-Chang et al., 2008; Tong, McBride-Chang, Shu, & Wong, 2009). Siegel (2008) found that MA had a stronger correlation with word reading and spelling measures than PA tasks among 1,238 English monolinguals and English language learners in Grade 6. No specific correlations were reported for English language learners separately in this study.

There are controversial findings regarding Chinese students’ ability to analyze and manipulate morphological structures in L2 English. Koda (2000) compared Chinese and Korean students on English MA tasks and found that Chinese learners performed more poorly than Korean learners in analyzing intra-word structures, but they did not lack the ability to integrate morphological and contextual information when processing sentences. Jiang (2004) found that Chinese learners of English were not sensitive to number morphemes in sentence processing experiments involving stimuli such as "The key to the *cabinet was rusty* from many years of disuse" and "The key to the *cabinets was rusty* from many years of disuse." Both studies were conducted with adult ESL learners.

Orthographic Awareness (OA)

OA is defined as learners' awareness of conventional rules in structuring English words (Treiman & Cassar, 1997); one of the core ability of OA is the sensitivity to permissible letter sequences (Pacton, Perruchet, Fayol, & Cleeremans, 2001; Treiman, 1993). From a developmental perspective, OA is only acquired after one is more experienced with print materials after the initial phase of learning phoneme-grapheme conversion rules according to the phase theory of spelling (Frith, 1985). Recent empirical studies demonstrated that sensitivity to graphotactic conventions develops in English-speaking kindergarten children before the skill of encoding full phonological structure develops (Cassar & Treiman, 1997; Treiman, 1993). Caravolas, Kessler, Hulme, and Snowling (2005) studied vowel spelling among 78 British children (age = 5;7) at one point in time and six months later and found that at both times, knowledge of sound-letter correspondence, unconventional consistency of vowel spelling in particular, affected children's spelling. Unconventional consistency of vowel spelling indicates all of the possible vowel spellings for a certain vowel sound, for example, /ɛ/ can be represented by *e, a* and *ea*; however, it is defined to be spelled as *ea* with a coda /d/ , for example, *head*, and this is conventional consistency of vowel spelling.

Orthographic knowledge also includes “extraction of phonological and morphological information from a printed word” (Koda, 2007, p. 4). Ehri (1998) stated that orthographic knowledge “provides powerful mnemonic system that bonds the written forms of specific words to their pronunciation in memory” (p. 15). It is therefore particularly important in deep orthographies which do not have reliable relationships between spelling and pronunciation. English and Chinese are two examples of this type of writing system.

Sun-Alperin and Wang (2009) found the predictive power of OA within English was significant in Spanish-English bilinguals. An English homophone choice task accounted for an additional 28% of the variance in English real word spelling after controlling for age, receptive vocabulary and PA. However, whether orthographic knowledge is language specific or language general is still debatable. Even though Spanish and English are both alphabetic *and* use the same alphabet, Sun-Alperin and Wang (2009) found that Spanish orthographic processing skills could not predict English real word and pseudoword spelling, which indicated that orthographic knowledge might not be transferable across these two orthographies. In contrast, an orthographic transfer effect was seen in Deacon, Wade-Woolley, and Kirby (2009) among English native speakers learning French in an immersion program.

In Wang and Geva (2003a), Chinese ESL children scored higher than their L1 counterparts in a confrontation spelling task, which required the ability to distinguish orthographically legitimate and illegitimate letter combinations. The authors attributed this finding to Chinese children’s advantage in spelling visually presented materials.

Akamatsu (1999) used different methods of word distortion (e.g., cAsEaLtErNaTiOn) to examine the influence of L1 orthographic characteristics on English word recognition. Participants with Chinese-, Japanese and Persian-L1 backgrounds responded to stimulus items presented on a computer screen. Response errors and reaction time were recorded. The results suggested that the Chinese and Japanese participants whose L1 was not alphabetic were more likely to be influenced by the case alternations in a naming task than the Iranian participants whose L1 was alphabetic. This finding suggests that "the first language orthographic features affect the orthographic coding mechanisms (e.g., word recognition mechanism) in a second language" (p.381).

Predictors of English Spelling for Speakers of English

Previous psycholinguistic research on monolingual English children has identified a number of factors that are closely related to spelling development, among which the ability to identify, distinguish and manipulate the smallest units of sound (phonemes) seems to be critical (Gentry, 1982; Henderson & Beers, 1980; Landerl & Wimmer, 2008; Treiman, 1993). Developmental spelling errors show that monolingual English-speaking children who are somewhat aware of phonological subunits make the effort to try to represent in spelling the sounds that stand out the most when pronouncing it, for example, *wrk* for *work*, which led Treiman (1993) to conclude that children's early spelling is a window to their phonological representation ability.

Another important skill in spelling development in alphabetic languages with deeper orthographies (e.g., English) is the understanding of morphological structures (Bryant, Nunes, & Bindman, 1997). Aside from phonological knowledge, children also attend to meaning relations in learning to spell (Carlisle, 1995; Treiman, Cassar, & Zukowski, 1994). For example, children made fewer mistakes in the flaps in words like *dirty* than in *city*, because those children in the 1st grade have already noticed that *dirt* is a morphemic unit. MA is defined by Carlisle (1995) as the ability to recognize, distinguish, segment and construct meaning subunits. Thirdly, the knowledge of orthographic representation poses a special demand for children learning to spell in English, where phoneme-grapheme correspondence is not highly predictable.

Recent empirical studies confirm the importance of these cognitive components to English spelling among English monolingual children. Caravolas, Hulme, and Snowling (2001), in a longitudinal study of 153 five-year-old children in Britain, found that receptive vocabulary and non-verbal intelligence were associated with spelling and phonological spelling, but the correlation coefficients were not among the highest. Verbal span was associated with both spelling and phonological spelling; however, visual span was only associated with phonological spelling.

Spelling production is sometimes assessed both for conventional accuracy and for phonological plausibility. The scoring of real word spelling emphasizes the accuracy of lexical representation as a whole; whereas the scoring of phonological spelling evaluates the phonological representation of only each part of the word or pseudoword. Spelling is assessed at a lexical level and phonological spelling is assessed at sub-lexical level.

Interrelation of PA, OA and MA for Speakers of English

An increasing number of empirical studies have investigated the three cognitive factors (PA, OA and MA) in pairs or altogether. PA and MA may share some common processes and three kinds of evidence are available for this argument. The first kind of evidence is from intervention studies, where crossover effects have been observed. The crossover effect means PA training causes improvement in MA and MA training causes increases in PA scores (e.g., Richards, Berninger, Nagy, Parsons, Field, & Richards, 2005). Besides English, the cross-over effect has been observed for other alphabetic languages. For example, Casalis and Cole (2009) conducted an experimental study with French-speaking monolingual kindergartners (30 in PA training, 30 in MA training and 30 in control). The reciprocal influence analysis was performed and the results indicated that MA training improved children's phonological sensitivity, and PA training helped children to segment morphemes; however, MA training did not improve phoneme manipulation, and PA training did not improve derived words. The results indicated that PA and MA shared some common processing skills but each of them had their unique properties that were independent from the other.

The second kind of evidence draws on the distinction between the relationship of morphological construction with phonological change (*five-fifth*) and without phonological change (*dark-darkness*). It is already quite established that PA and reading comprehension are highly related. The logic is if morpheme manipulation performance on items with phonological change is more highly associated with reading comprehension than the manipulation performance on items without phonological change, PA is facilitating or impeding the relationship between MA and reading comprehension. Fowler and Liberman (1995) investigated the interdependence of MA, PA and orthographic knowledge in 48 children (age 7.5-9.5 years) and found that reader group (good/poor) differences were most pronounced in performing MA tasks on items with phonological change. The results suggested that the MA effect was impeded by phonological deficits.

The third kind of evidence that helps to explain the relationship between PA and MA is to see whether they make independent contributions to literacy outcomes. In a longitudinal study, Deacon and Kirby (2004) followed a group of students from Grade 2 (n = 143) to Grade 5 (n = 103) in Canada and measured PA and MA in Grade 2 and reading outcomes in the subsequent grades. They found that MA measured by a sentence analogy task predicted later reading comprehension scores with PA measured by a sound oddity task, and IQ statistically controlled. PA and MA in Grade 2 were statistically significantly correlated (r = .567). The results of the study suggested that MA's contribution was comparable to that of PA and continued to have an effect after three years.

Nagy, Berninger and Abbott (2006) used structural equation modeling to examine whether MA explained any unique variance in literacy outcomes when PA was controlled. The participants were Grade 4-9 students from the US. MA was measured by a Suffix Choice Test and a Morphological Relatedness Test. Spelling was measured by the Spelling Test of the Wechsler Individual Achievement Test (2^{nd} ed.). They found that the MA factor was a unique predictor of spelling skills for students of all grade levels (with correlations ranging from 0.60-0.85). As expected, PA was also a significant predictor of spelling skills for all groups of students (with correlations ranging from 0.71-0.80). They concluded that the contribution of MA to literacy outcomes was more consistent in upper elementary grades and middle school. Nagy, Berninger and Abbott (2006) further argued that:

> Although morphological awareness is not the largest contributor to success in learning to read, it is not necessarily an insignificant one. Nor should one assume that the variance shared by phonological and morphological awareness is exclusively phonological. Some of the shared variance between these two construct may be metalinguistic in a more general sense rather than tied specifically to morphology or phonology. (p.137)

In contrast to Nagy, Berninger and Abbott's (2006) assertion of a later MA influence, Carlisle and Nomanbhoy (1993) studied English monolingual students in Grade 1 and found a statistically significant correlation between PA measured by syllable and phoneme deletion tasks and MA measured by a word relation judgment (e.g., *moth* and *mother*) (r = .30, $p < 0.01$) and by a morpheme production task (e.g., *Farm, My uncle is a* ___. *[farmer]*) (r = .51, $p < 0.001$). In an hierarchical regression analysis, when MA was entered after PA, it only accounted for 4% of the variance.

Another study supporting the early influence of MA on literacy development (spelling, in particular) of 1st graders (n = 47) is Wolter, Wood and D'zatko (2009), in which they measured PA (CTOPP Elison task), MA (oral morphology production task), reading and spelling (Test of Written Spelling) and found that PA and MA together accounted for 42% of the variance in spelling and MA accounted for 7.4% of the variance in spelling over and above PA. Deacon, Kirby and Casselman-Bell (2009) measured MA and a variety of control variables that could be possible confounding factors, which included verbal and non-verbal intelligence, rapid automatized naming, verbal short term memory, and PA, among a group of 115 children with English as their first language at age seven. Spelling was measured two years later. They found that after controlling for all of the variables mentioned above, MA still made an independent contribution to spelling (explaining an additional 4-10% variance). They, thus, concluded that MA is of robust and long-lasting utility to spelling. This study conducted in a lower elementary grade is complimentary to the previous finding by Nagy et al. (2006) of the independent contribution of MA from PA in upper elementary grades. The weakness of this study, however, is that the reliability index for the MA measure was low (Cronbach's $\alpha = .64$) and only past tense morphological construction was assessed. These pieces of evidence together support the view that MA makes a smaller (compared to PA), but significant, contribution to reading and spelling development, even in the early grades.

Kuo and Anderson (2006) conducted a research synthesis of the effect that MA had on literacy skills. They came to the conclusion that MA was closely associated with other aspects of metalinguistic awareness, namely, PA, syntactic awareness, and vocabulary knowledge. Their final comment on the existing literature of MA and literacy outcomes was the lack of satisfactory control of the covariates. Recent empirical studies have started to attend to this problem (e.g., Deacon, Kirby, & Casselman-Bell, 2009).

It is concluded from the previous literature that the contribution of PA and MA to literacy outcomes also depend on three other factors, besides grade level: (1) the task that is given to measure PA and MA (perception or production); (2) the nature of the outcome measures (reading or spelling); and (3) the developmental stage of the participants. MA may be more important in spelling than in word reading (e.g., Deacon, Kirby, & Casselman-Bell, 2009). According to the phase model and the dual language foundation model, understanding the alphabetic principle is the first step, followed by phonological decoding and encoding. Insights into morphological aspects of the orthography may develop at a later stage. However, according to the "repertoire theory," reading and spelling are best explained by the range and richness of the linguistic resources children use. Children who attend to morphological units of the words at an earlier grade might also be better readers or better spellers. Empirical evidence is needed to support this view.

Further, MA and OA were also correlated, because both relate to recognition and ability to manipulate word segments. OA needs to be investigated simultaneously to distinguish the effect. In addition, MA, PA and OA are preferably assessed concurrently in order to illustrate the inter-correlations among them. A couple of empirical studies investigated the concurrent contributions of all three factors.

Nagy, Berninger, Abbott, Vaughan, and Vermeulen (2003) used structural equation modeling to examine the contributions of phonological, orthographic, and morphological factors to English word spelling and other literacy outcomes in 2nd-grade at-risk readers (n=98) and 4th-grade at-risk writers (n=97). For 2^{nd-}grade children, the

MA factor was significantly correlated with the PA factor (correlation value = .26, $p < .05$), but not with the OA factor. PA and OA were correlated with a correlation value of .43. In this study, the correlation between PA and OA was higher than that between PA and MA. It is also important to note that in this study, OA was the only statistically significant predictor of the spelling outcome for the 2nd-graders with the overall model fit being satisfactory ($\chi^2_{(19)} = 28.21$, CFI = .96, RMSEA = .07). For 4th -grade at-risk writers, the MA factor was strongly correlated with the other two factors PA ($r = .67$), and OA ($r = .58$). OA again was the only statistically significant predictor of the 4th-grade spelling outcome with excellent model fit ($\chi^2_{(19)} = 23.32$, CFI = .99, RMSEA = .05). Structural equation modeling is a large sample method but the sample size was comparatively small in this study with a total number of less than 200.

Ouellette and Sénéchal (2008) studied 115 English monolingual children (age = 5 years) and found that in predicting invented spelling performance, OA, measured by legal character and permissible sequence, explained approximately an additional 10% in R-squared in the hierarchical regression analysis after PA was controlled. PA (measured by CTOPP subtests of Sound Matching, Blending Words and Elision) alone explained 40.5% of the variability in invented spelling and made a unique contribution of 30.8 % in the variance accounted for after parental education and analytic intelligence were controlled. In this study, MA (measured by an auditory comprehension test of morphemes; participants are asked to indicate the correct picture of a farm animal, a farm and a farmer when they hear “The farmer is big”) made a unique contribution to invented spelling of 4% after PA is controlled. OA made an additional 10% unique contribution over and beyond PA and MA. It is important to note that in this study, the authors found that the inclusion of the control variables in the regression models may have masked the true relevance of MA in invented spelling. PA and OA withstood the inclusion of control variables. The MA measure was associated with the PA measure, combining raw scores of the three subtests, and the Legal Character measure of the OA construct after age, parent education, and analytical intelligence were statistically controlled. The partial correlation matrix showed that the Permissible Sequences measure was not correlated with the PA and MA measures and not even with the Legal Letter measure.

The results of the Ouellette and Sénéchal (2008) study were complemented by a recent study focusing on word reading by Roman, Kirby, Parrila, Wade-Woolley and Deacon (2009). In this study, the authors investigated four factors concurrently among 92 children in Grades 4, 6 and 8 from seven rural schools in Canada. These four factors were PA (measured by the CTOPP Elision subtest), naming speed, OA (measured by Olson's orthographic choice task), and MA (measured by a morpheme production task with syntactic cues and a word analogy task). PA was related with OA ($r = .266$, $p < 0.05$) and with MA ($r = .483$, $p < 0.01$). MA and OA were also statistically significantly correlated ($r = .609$, $p < .001$). MA and OA were more highly correlated than other predictors in this study. In predicting real word reading, when entered together into the multiple regression analysis in one step, age, PA ($\beta = .204$, $p < .01$), OA ($\beta = .411$, $p < .001$) and MA ($\beta = .274$, $p < .01$) were all statistically significant predictors, whereas rapid naming was not. OA, measured by an orthographic choice task, was the strongest predictor of the three. In predicting pseudoword reading, rapid naming again failed to be a statistically significant predictor. The relative strength of PA, MA and OA in predicting the reading outcome changed as well. PA became the strongest predictor for pseudoword reading ($\beta = .289$, $p < .001$), followed by MA ($\beta = .283$, $p < .05$), and then OA ($\beta = .255$, $p < .05$).

Taken together, it is reasonable to argue that PA, OA and MA are inter-correlated factors and each makes a unique contribution to literacy outcomes. It is clearly demonstrated by the three theoretical models that an emphasis on PA is a common theme in theories of literacy acquisition. The results offered by empirical studies, however, are highly consistent with the "repertoire theory" that emphasizes an interwoven relationship among phonological, morphological, and orthographic knowledge and skills. The phase model and the dual foundation model (that is based on the phase model) may be called into question by empirical studies regarding when MA emerges; however, by and large, these two models are reliable in interpreting the relationships among PA, OA and MA.

Interrelation of PA, OA and MA for Speakers of Chinese

Theoretically, models of cognitive components and literacy outcomes for English-speaking children have developed tremendously (Arab-Moghaddam & Sénéchal, 2001). However, little work has been done to model the L2 English literacy acquisition of children with different L1s, in this case, Chinese. Will models created for monolingual English-speaking children also be able to describe L2 English-learning children's literacy acquisition?

Predictors for monolingual English learners' spelling acquisition may differ from predictors for ESL learners in predicting spelling performance. Jongejan, Verhoeven, and Siegel (2007) measured the basic literacy skills and related cognitive processes of 212 ESL children and English monolingual children from 1^{st} to 4^{th} grade in Canada and found that predictors for spelling abilities for native English-speaking children, such as verbal working memory and syntactic awareness, did not contribute to the word spelling abilities of ESL children. The most important predictor for spelling abilities for L2 learners in lower grades was PA in English, which explained 24% of the variance in ESL spelling ability. In upper grades, PA continued to be a significant predictor of ESL spelling ability.

As mentioned in the English L1 models, PA, OA, and MA develop after a certain amount of exposure to print. Chinese L1 children with 3 or 4 years of English instruction should develop these processing skills reasonably well even without being explicitly taught word analysis strategies in English. From a developmental point of view, Yin, Anderson and Zhu (2007) investigated 118 Chinese children learning English as a foreign language in 2^{nd}, 4^{th} and 6^{th} grades in mainland China and found that Chinese children follow stages of pre-alphabetic, partial alphabetic and full alphabetic like those of English monolingual children in English word reading. They also found that Chinese children more readily made onset-vowel analogies than vowel-coda analogies. The results indicated that although L1 Chinese L2 English children followed a similar trajectory of English monolingual children in reading English, their performance on certain aspects of reading was influenced by their L1 experience.

To what extent the relationship among the linguistic resources, such as PA, MA, and OA, changes in the Chinese-English model because of the L1 influence deserves serious consideration. Rickard Liow (1999) argued that L1-Chinese L2English-speaking children who had no explicit phonemic awareness training may have adopted visual (logographic) strategies for an extended period because such processing did not rely on a good auditory vocabulary, nor on an understanding of the relationship between spoken and written forms. She also suggested that with an enhanced vocabulary in English, and more exposure to an alphabetic script, Chinese-English bilingual children's PA in English would increase eventually.

Wang, Cheng and Chen (2006) studied a group of Chinese-English bilingual children (n = 67) in Grades 1-5 in a weekend Chinese school in the US and measured their MA and reading-related outcomes. Among these children, 47% reported Chinese as their first language and 31% learned English and Chinese simultaneously. Pinyin instruction was available in the Chinese school they attended. School-aged children are routinely taught Pinyin as they are learning to read Chinese in China but in heritage language programs in the US, Pinyin instruction is a curricular decision of the specific program. The results showed that PA and MA in English were correlated. The Pearson *r* correlation coefficient between phoneme deletion and compound morphology was 0.49 ($p < 0.001$). The correlation between phoneme deletion and derivational morphology (extract the base type measure) was 0.50 ($p < 0.001$). The correlation between compound morphology and derivational morphology was 0.63 ($p < 0.001$). In predicting English word reading, English phoneme deletion uniquely explained 13% of the variance in R^2

change ($p < 0.001$) after age, grade level and English oral vocabulary were statistically controlled. English derivational morphology entered after English phoneme deletion in the hierarchical regression analysis accounted for another 10% in R^2 change ($p < 0.01$). The relationship of PA and MA in this Chinese-English bilingual sample was quite similar with that of English L1 models, except that PA accounted for a smaller amount of variance in word reading. This result might be attributable to the fact that these Chinese children attend English schools during weekdays so their English L2 skills increased rapidly with English instruction.

In another study, when PA, MA and OA were investigated simultaneously among Chinese-English bilingual children in the US (age = 6.8 years), Wang, Yang and Cheng (2009) found that OA (measured by orthographic choice task, e.g., *beff* or *ffeb*) and PA (measured by phoneme deletion) were statistically significantly correlated ($r = .27$, $p < .05$). MA (measured by compound structure) was only statistically significantly correlated with PA ($r = .40$, $p < 0.01$) but not with OA. The strength of association between PA and real word reading and non-word reading were the same ($rs = .34$, $p < 0.01$). Both MA and OA were statistically significantly correlated with reading outcomes. All of the correlation coefficients were calculated with age was controlled. In multiple linear regression analyses, OA was the strongest predictor of real word reading outcome compared with PA and MA in this sample. PA and OA each added unique contributions to nonword reading. MA failed to do so, which might be because of the measure selected has inherent limitations (only measured compounding skills).

The modification of the model for L1 Chinese and L2 English children would mainly be on the strength of the association among PA, OA and MA and between PA, OA and MA and literacy outcomes. All three factors should be important and contributing independently to the new model. It is hypothesized that the predictive strength of OA was stronger for the Chinese-English bilingual group than it was for the native English-speaking group, because of the enhanced visual orthographic processing skills developed in their L1 Chinese. As for MA, previous literature has shown that Chinese readers depend heavily on morphological information in order to read Chinese. Chinese-English bilinguals in 8^{th} grade should be able to rely on this skill when learning to read and spell in English. Together with PA and OA, they should all be contributing to the spelling outcome.

Taking into consideration the cognitive processes of English spelling and given that these processes are influenced by the nature of orthography, English learners with Chinese language background are hypothesized to process spelling differently than native English spellers. The question of how these cognitive components work together and separately for the two groups deserves serious consideration. The study was framed through two research questions:

Research Questions:

1. Are the factorial structures of the three constructs (OA, MA and PA) equivalent across the American and the Chinese group? If not, how do they differ?

2. How are the regression paths from the latent variables (OA, MA and PA) to English spelling scores (as measured by Test of Written Spelling) different across the American and the Chinese groups?

CHAPTER II

METHOD

Participants

The Chinese participants (N = 537) were recruited from nine intact classes in a secondary school in a northeastern city in China. To participate in this study, participants' parents were asked to sign a consent form approved by the Human Subjects' Protection Program at Texas A&M University. The participants were screened for history of receipt of special educational services. Fifty one and one-tenths percent (51.1%) of the Chinese participants were female. According to government statistics (Ministry of Education of the People's Republic of China, 2009), among all students in regular junior secondary schools, 47.32% were female. All of the Chinese participants were 8^{th} graders with an average age of 14 years and 2 months (*SD* = 6 months).Years of education completed by parents ranged from 2 to 24 years. Mean years of education for mother (*M* = 11.89, *SD* = 2.69) were less than that for fathers (*M* = 13.16, *SD* = 2.86). For mothers, 3.1% had completed elementary school; 23.9% had completed middle school (also called junior secondary school) and 43.8% finished high school; and 29.2% had some kind of tertiary education. For fathers, 1.4% had completed elementary school; 43.2% had completed middle school and high school; and 55.4% had some kind of tertiary education.

Family income ranged from less than ¥10,000 (RMB, the official currency of the People's Republic of China) per year (approximately US $1428.00) to over ¥1, 000,000 per year (approximately US $ 142,857.00).The median annual family income for this sample was from ¥50,000 to 80, 000. Seven and six-tenths percent (7.6%) of the families in the sample reported earning less than ¥10,000; 21.7 % reported earning an annual income from ¥50,000 to 80, 000; 21.4% earned from ¥80,000 to 150, 000; and 3.8% of the families had an income over 1, 000, 000 RMB per year.

At home, about 57.6% of the parents are not able to help their child learn English and 42.4% of the parents are able to help their child learn English. Thirty eight percent of the Chinese sample sought extra English tutoring/classes in addition to the English instruction at school. Most of the students had never been to any English-speaking countries; only 3.4% had been to an English-speaking country. Their stay in the English-speaking country ranged from 3 days to 6 months.

Chinese-English students in Grade 8 were chosen for the following reasons:

1) At the junior high (middle) school level, a majority of schools adopt the required textbooks of the national curriculum. English instruction as a required school subject starts as early as 1st grade and no later than 3rd grade. All Chinese provinces, other than some metropolitan cities such as Beijing and Shanghai, have adopted a national curriculum in English instruction. However, in primary schools, textbooks used for English instruction vary.
2) Chinese EFL students have limited exposure to English input (auditory or visual input). Students in primary schools receive two hours of instruction in English each week. From Grade 7, they receive one hour of English instruction each day for five days a week and 16-18 weeks per semester. Teachers usually have a bachelor’s degree or a teaching credential from universities and typically do not

speak English very well. Many children seek extra English tutoring from commercial English training institutions or take small classes in individual teachers' homes. Parents are not able to provide much assistance in English unless they are highly educated.

3) Some of the measures that are selected contain lexical-grammatical cues that students in lower grades probably would not understand. For example, in the morphological analogy task, participants should have knowledge about tense (e.g., past, progressive and present) to make the analogy. Tense markers are taught in Grade 7 and 8 but not usually at primary level.

American students of Grade 3 in the United States were recruited as the comparison group. Grade 3 was decided through comparisons of text readability. Ten excerpts from the textbook used by the Chinese-English bilingual participants were analyzed for readability levels and according to Flesch-Kincaid formula, the Grade Level was found to be 3.19.

The American participants (N = 183) were recruited from two states, Minnesota and Texas. The average age was 9; 5 (*SD* = 0; 6). The Minnesota sample came from one public elementary school, of which 94.9% of the 3rd grade participated. According to the School NCLB Data Report available from the Minnesota Department of Education (2010), the 3rd grade students were mostly White (96.97%). Of the entire grade level (n =99), 11 (11.11%) qualified for free and/or reduced price lunch (FRP). The FRP rate of 3rd graders was higher than that of the overall school rate (6%) but lower than the overall state rate (36%). FRP is often regarded as an indicator of socio-economic status (SES).

In this case, the participants from Minnesota were from either mid- or high SES background. Table 1 provides the reported demographic information for the Minnesota data. Five students who either did not attend school on the testing day or missing the entire spelling test were excluded from the sample, resulting in a number of 94 participants from Minnesota. Among the 94, participants, 48 (51.1%) were boys. Eighty nine and one tenths percent (89.1%) knew only English and 10.9% knew a language other than English.

Table 1 Minnesota participant information obtained from 2010 School NCLB Data Report (n = 99)

		Percentage	Frequency
Ethnicity	American Indian	1.01%	1
	Asian/Pacific Islander	1.01%	1
	Black	0.00%	--
	Hispanic	1.01%	1
	White	96.97%	96
Gender	Male	55.56%	55
	Female	44.44%	44
Other	Special	25.25%	25
	FRP	11.11%	11
	LEP	0.00%	--

Note: Special = Special Education; FRP = Free and reduced price lunch; LEP = Limited English Proficiency

The Texas sample was obtained from two public schools in Houston ISD, with a combined number of 89 participants. Of the entire Texas group of children, 53.9% of the participants were boys. Compared to the Minnesota sample, the ethnicity composition for the Texas sample demonstrated more diversity: 17.9% are Asian/Pacific Islander; 11.9% are Black; 25.0% are Hispanic and 45.2% are White.

A subsample of 166 American participants and 339 Chinese participants were selected to include in the final analyses according to the completeness of their testing data. The average age of the Chinese participants in the final sample was 14; 2 (*SD* = 0; 5) and the average age of the American participants in the final sample was 9; 5 (*SD* = 0; 6). Fifty three percent (53%) of the American participants and 41% of the Chinese participants were boys. Figure 1 provides information on parents' levels of education for the Chinese participants. The median for mother's level of education was high school (47.3%) and the median for father's level of education was bachelor's degree (43.0%). On average, fathers received more years of education (*M* = 13.27, *SD* = 2.78, valid n = 228) than mothers (*M* = 12.02, *SD* = 2.63, valid n = 237).

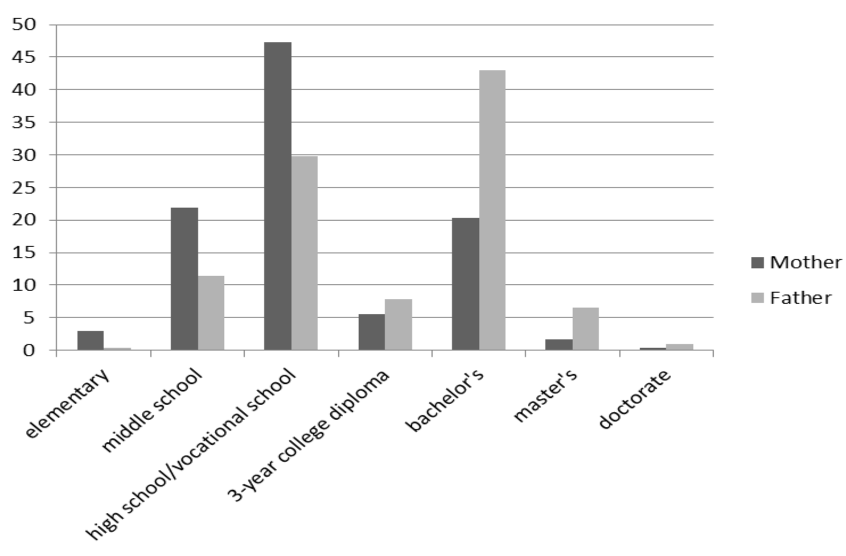

Fig. 1 Percentage of Chinese parents' levels of education (n = 339)

The median annual family income for the final Chinese sample was still from ¥50,000 to 80,000. Eight percent of the families in the sample reported earning less than ¥ 10,000; 19.6 % reported earning an annual income from ¥50,000 to 80, 000; and 20.5% earned from ¥80,000 to 150,000; 2.7% of the families had an income over 1,000,000 RMB per year. Figure 2 shows the annual family income distribution in Renminbi of the Chinese participants.

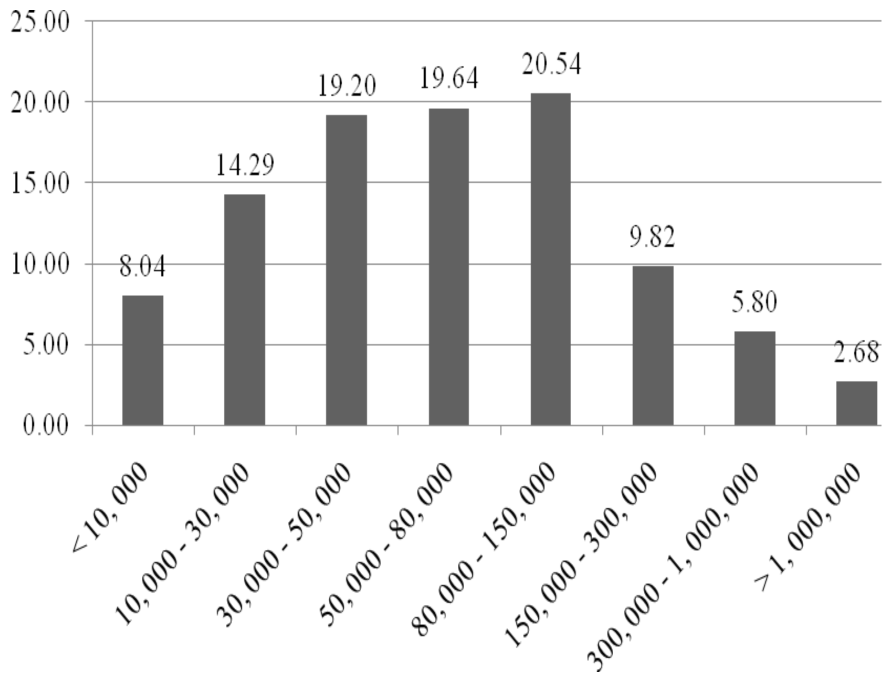

Fig. 2 Percentages of annual family income for the Chinese sample
(n = 339, valid n = 224)

Demographic information was not available at individual child level for the Minnesota data. The ethnicity composition of the Texas participants included in the final sample represented that of the initial sample (See Figure 3 for details).

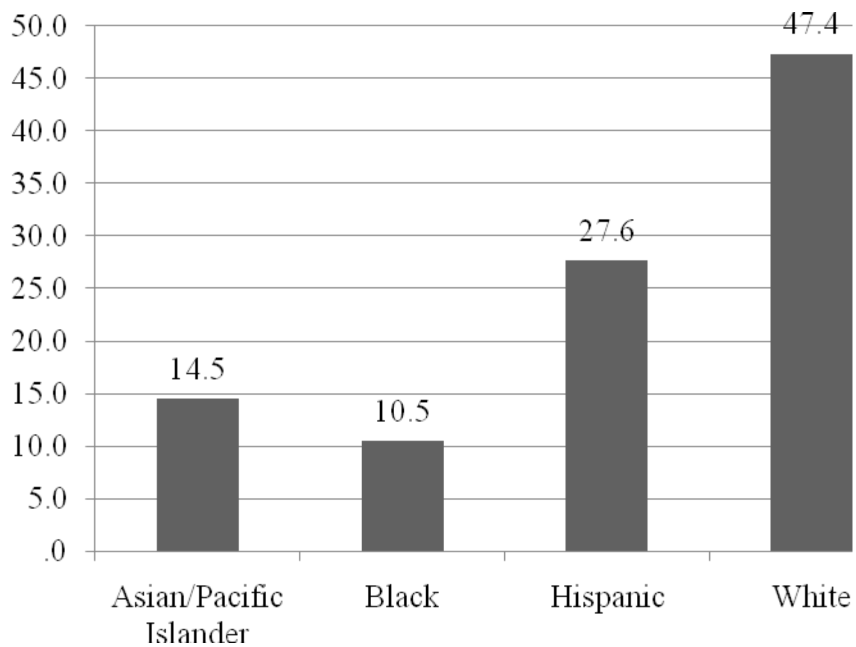

Fig. 3 Ethnicity composition of the American participants from Texas (n = 81)

Data Collection

Data collection took place during the summer of 2010, from May to September. Testing for the Chinese group was carried out in classrooms and an auditorium during the self-study period, which was from 4:00-5:00 p.m. during school days. The test stimuli were pre-recorded and played to the students. Tests were administered by the researcher with the help of English teachers. Students were informed prior to the testing that these tests would not affect their academic standing or their relationship with the teachers and their school. Parent consent forms and student assent forms were obtained prior to data collection. The entire testing session lasted about 60 minutes. For the American group[2], tests were administered by the researcher with the assistance of the classroom teachers. Test items were pre-recorded and played to the participants but in some cases, the classroom teacher read the items and instructions to the participants. The testing time and the order in which the tests were given were the same for both groups.

Instruments

Both groups were tested with the following measures and the reliability coefficients of the test scores of each test were calculated based on the Cronbach alpha method.

Word Spelling

Real Word Spelling. Test of Written Spelling (TWS) IV-Form A (Larsen, Hammill, & Moates, 1999) was used to assess word spelling ability in this study. The task consisted of 50 words that varied in length from two to eleven letters, for example *us, strong, institution, spend, district,* and *agriculture*. The participants first heard the target word and then the target word in a sentence. They heard the target word again at

[2] In this record of study, the terms “American group” or “American model” were used loosely to refer to English-speaking students in Grade 3 in the United States. With full understanding that America includes North America and South America and North America also include Canada, no better term is available to contrast with the “Chinese group” or “Chinese model”, which includes only the sample drawn from mainland China.

the end. A female voice reading the test was recorded and played to the participants in China using audio equipment. The research assistants and classroom teachers who were trained to administer this task read the words on the test and the corresponding sentences to the participants in the US. This spelling test measured word-specific knowledge stored in the mental lexicon. The responses were scored as correct or incorrect. No standard spelling score was available for Chinese-English bilingual students; therefore, only the raw scores of this test were used in the analyses. Participants were instructed to write only the target word and not the sentence and they were encouraged to attempt even when they did not know surely how to spell the target word. The reported test-retest reliability coefficient for TWS is 0.96 for the normed sample. The test scores of the current study had a high reliability of 0.91 in the American sample and a median reliability of 0.76 in the Chinese sample.

Testing Procedures. For the Chinese sample, all of the spelling stimuli were read by a middle-aged female whose native language was English and were recorded using the computer program Audacity and played to the participants using a compact disk (CD) player. The purpose of this was to ensure consistent pronunciations across multiple administration of the test. The participants were instructed that they would need to follow the pace of the audio tape and the entire testing time was approximately 13 minutes. For the American sample, spelling stimuli were read to the participants by their classroom teachers and by experienced research assistants who were trained to administer this test battery. The entire testing time for this task ranged from 12 to 15 minutes.

Orthographic Knowledge

Orthographic Choice-A (OCA). The task consisted of 40 groups of three words that were selected from an orthographic processing test developed by Aaron, Joshi and Williams (1999). This task is a variation of an orthographic or homophone choice task (*rain* vs. *rane*; Cunningham, Perry, & Stanovich, 2001; Olson, Frosberg, Wise, & Rack, 1994). It was used to assess children's word-specific orthographic knowledge while controlling for phonology. In this task, participants were asked to identify among three words that were pronounced the same one word that was not a real English word. Participants were asked to circle the one that was not an English word on the test answer sheet. For example, in each of the following rows, circle the one that is NOT an English word, *see sea cee*. Which one is not an English word, *see, sea* and *cee? Cee* is not an English word, circle *cee*. Two practice items were provided for the participants to understand the test (see Appendix A for a complete list of items and answer key). The test scores of OCA in the current study had an acceptable reliability of 0.75 in the American sample and 0.77 in the Chinese sample.

Orthographic Choice-B (OCB). This measure was initially developed by Cassar and Treiman (1997) and was modified and used by Wang, Perfetti, and Liu (2005). The measure contained 18 items that "tapped into children's sensitivity to various orthographic patterns in English" (Wang et al, 2005, p. 75), such as permissible positions for certain graphic units (e.g. *Which one looks like a real English word, beff or ffeb*?). The test scores on 18 items for the Chinese sample of the current study had a reliability coefficient (Cronbach α) of 0.72 and for the American sample a Cronbach α of 0.71.

Morphological Awareness

Word Form Exercise (Real Word) (WFE). The Word Form Exercise (Real Word) task also called Extract the Base (August et al., 2001) was developed by researchers at Center for Applied Linguistics based on Anglin (1993) and Carlisle (1988). It is designed to assess children's knowledge grammatical roles and knowledge of the word parts. The tests require the participant to extract the base from a derived word. Derived morphology is usually more difficult than the inflected morphology. For example: a. farmer. My uncle works on a ___. (farm). A total of 28 test items plus six practice items represent four kinds of morphological transformations. The reliability coefficient was 0.98 for scores of this test in the CAL pilot study (August et al., 2001). In the current study, the test scores of WFW had a very satisfactory reliability of 0.93 in the American sample and 0.92 in the Chinese sample. Appendix A shows a detailed scoring rubric with examples from both groups.

Word Form Exercise (Non Word) (WFENW). This task was adopted from Nunes, Bryant and Bindman (1997). In this task, participants had to read a written scenario of a person doing something in which the verb, noun or adjective was described with a pseudoword. The pseudoword always appeared twice and in two forms in the written stimuli, and the participant was required to produce inflectional morphemes including plural and past tense for the pseudowords to fill in the blank or to find the base for the pseudoword after having seen the word with affixes. For example, this is a *wug*. Now there is another one. There are two _____(wugs). The scoring was based on a scale of 0-2. See Appendix A for a detailed scoring rubric. The test scores of WFENW in the current study had an acceptable reliability of 0.82 in the American sample and 0.79 in the Chinese sample.

Phonological Awareness

Speech Sound/Syllable Counting (SSSC). This task was developed by the researcher and was composed of two parts: Part A-speech sound counting and Part B-syllable counting. Each part had 15 items. In Part A, participants were asked to count “how many speech sounds are there in the following words”. For example, the word “cat” has three speech sounds, /k/, /æ/ and /t/. The participant heard the target word twice and then wrote the number 3 in the corresponding space on the answer sheet. In Part B, participants were asked to count "how many speech syllables are there in the following words". For example, the word “together” has three syllables, /tə/, /ge/ and /ðə/. In the current study, the test scores of SSSC had a medium reliability of 0.77 in the American sample and a reliability of 0.83 in the Chinese sample. The entire test and corresponding item analysis are presented in Appendix A.

Sound Oddity Task (SOT). Adopted from James (2006), this task has a total of 30 items, including initial, final and middle phoneme judgment (see Appendix A). Each subtest on first sound different, end sound different and middle sound different has 10 items. Two practice items for each subtest were given to ensure that participants understood the test. In this task, participants read on the test paper the four words with the corresponding graphemes of the tested phonemes removed while hearing the words from an audio CD. They were then asked to circle the one with a different first or end or middle phoneme. For example, in the first condition (initial phoneme), they would read _ot, _od, _ock, _ox in a row, while listening to a CD or to the tester, rot, rod, rock, box, and then they would circle _ox for the correct answer. By doing this, the influence of orthographic knowledge was removed by removing the first grapheme. To lessen the memory load for the participants, remaining graphemes that were not focused were represented in writing. The reliability (cronbach α) was 0.89 based on the test scores of the American group and 0.82 based on the test scores of the Chinese group in the current study (Item analyses are presented in Appendix B).

Demographic variables were obtained from the Literacy Background Questionnaire that filled out by the students themselves before the first testing session were conducted. The Chinese version of the Literacy Background Questionnaire consists of demographic information (e.g. name, gender, date of birth, class, school, maternal education level, maternal occupation, paternal education level and paternal occupation and family income), English language resources (e.g., number of English textbooks, number of non-textbooks at home, knowledge of other languages besides Chinese and English, hours of outside English Tutoring per week, age of first English class, experience of visiting a native English-speaking country) and if there is Chinese reading difficulty identified (confirmed by Chinese teacher at school). The length of formal English instruction was computed by subtracting age of first English class from chronological age. The English version of the Literacy Background Questionnaire consists of demographic information (e.g. name, gender, date of birth, class, school, if a language other than English is spoken at home and if there is documented impairments in visual, speech and language). The questionnaire was completed by the participants with the help of classroom teachers.

The entire test battery and the questionnaire were administered in a one hour testing session. Chinese participants in groups of 60 to 70 and the American participants in groups of 20 to 30 were given these measures by trained researchers or classroom teachers who have practiced prior to giving the tests. The participants were told that the tests would not count for class credit and would not be reported.

CHAPTER III

RESULTS

Descriptive Statistics

Table 2 shows the means, standard deviations, maximum and minimum scores, skewness and kurtosis for all measures included in the study for both groups.

Table 2 Ranges, means, standard deviations, skewness and kurtosis for all measures

			American (N =166)					
Measure	Min.	Max.	M	SD	Skewness	S.E.	Kurtosis	S.E.
TWS	1	39	19.95	6.87	-0.06	0.19	0.13	0.37
OCA	17	40	34.11	3.92	-1.64	0.19	3.73	0.37
OCB	1	18	15.03	2.62	-2.53	0.19	8.18	0.37
WFE	0	83	63.56	13.86	-1.63	0.19	3.84	0.37
WFENW	0	20	9.69	5.17	-0.39	0.19	-0.79	0.37
SSSC	1	27	16.23	4.69	-0.25	0.19	0.18	0.37
SOT	6	30	24.96	5.22	-1.58	0.19	2.32	0.37
			Chinese (N=339)					
TWS	2	22	10.64	3.16	0.68	0.13	0.59	0.26
OCA	9	36	27.86	4.13	-1.03	0.13	2.04	0.26
OCB	1	18	13.52	3.02	-1.72	0.13	3.39	0.26
WFE	0	63	36.80	16.29	-0.49	0.13	-0.69	0.26
WFENW	0	19	9.14	4.99	-0.21	0.13	-0.87	0.26
SSSC	0	28	13.53	5.70	0.52	0.13	-0.37	0.26
SOT	7	30	24.80	3.77	-1.99	0.13	5.88	0.26

The Chinese group scored lower than the American group on all seven measures. Independent sample t-test was calculated for all seven measures for both groups (see Table 3). The t-test results indicated statistical significance for all but two tasks: Word Form Exercise Non Word (WEFNW) and Sound Oddity Task (SOT). These two tasks measure lexical analytical skills by removing the effect of vocabulary size. WFENW uses non words in a sentence context with fairly simple syntactical structures. SOT included stimuli which have simple three-phoneme structures; to complete this task, no semantic information is needed. Therefore, controlling for syntactical and semantic ability, the two groups are comparable on their performance.

Table 3 Results of independent sample t-test

	American (N=166)		Chinese (N=339)			
Measure	*M*	*SD*	*M*	*SD*	t	*p*
TWS	19.95	6.87	10.64	3.16	16.62	-
OCA	34.11	3.92	27.86	4.13	16.53	-
OCB	15.03	2.63	13.52	3.02	5.77	-
WFE	63.56	13.86	36.80	16.29	19.22	-
WFENW	9.69	5.17	9.14	4.99	1.15	0.25
SSSC	16.23	4.69	13.53	5.70	5.65	-
SOT	24.96	5.22	24.80	3.78	0.36	0.72

Note: t-test equal variance is not assumed

As for the performance on TWS, the score range of the Chinese group (20.00) was smaller than that of the American group (38.00). The Chinese group generally had less variability in their scores on the measures as revealed by smaller standard deviations, except for Word Form Exercise. The *SD* of TWS was 3.16 for the Chinese groups and 6.87 for the American group. The fact that the Chinese group is learning to spell mainly from textbooks may explain this high level of homogeneity in the spelling scores. The *SD* of WFE was larger for the Chinese group than the American group, which indicated that Chinese students demonstrated more individual variation in the morphological task. These variations may be caused by different learning strategies and the effect of pedagogy and instruction.

Table 4 shows zero-order correlations among all measured variables. A close examination of the table revealed that the correlations between TWS and the two MA measures (WFE, $r = 0.63$, $p < .01$ and WFENW, $r = 0.60$, $p < .01$) were the two highest for the American group. For the Chinese group, the correlation coefficient between TWS and WFENW was also the largest among all of the correlations, $r = 0.40$, $p < .01$. Third, TWS also closely correlated with OCA for both groups, $r = 0.59$, $p < .01$ (American) and $r = 0.32$, $p < .01$ (Chinese).

Table 4 Intercorrelations among all measured variables

Measure	1	2	3	4	5	6	7
1.TWS	__	.59**	.17*	.63**	.60**	.36**	.47**
2.OCA	.32**	__	.45**	.63**	.38**	.23**	.41**
3.OCB	.23**	.23**	__	.25**	0.15	0.01	.26**
4.WFE	.27**	.28**	0.1	__	.58**	.36**	.51**
5.WFENW	.40**	.30**	.22**	.37**	__	.43**	.40**
6.SSSC	.30**	.25**	.16**	.24**	.32**	__	.36**
7.SOT	.27**	.12*	.15**	0.1	.26**	.33**	__

Note: Intercorrelations for American participants (*n* = 166) are presented above the diagonal and intercorrelations for Chinese participants (*n* = 339) are presented below the diagonal. * p< .05; ** p < .01.

Model Testing

All of the participants who had complete data (N_{Total} = 505, $N_{American}$ = 166, and $N_{Chinese}$ = 339) were included in the subsequent model testing procedures to examine the three factor (OA, MA and PA) CFA model and the structural model with the endogenous variable—spelling (measured by TWS). The data were analyzed using multiple group structural equation modeling, the general aim of which was to determine whether the factorial structures and the casual structures were invariant across the American and the Chinese groups.

All structural equation modeling was performed with Mplus and/or AMOS. I followed the procedures of testing for multigroup invariance described in Byrne (2010). The first step was to test the equality of covariance matrices across the two groups of interest, with a null hypothesis (H_0), expressed as ∑American = ∑Chinese. In this hypothesis, ∑ is the population variance-covariance matrix. Rejection of the null hypothesis suggests that the groups may not be equivalent; however, failing to reject the null hypothesis suggests that the groups are likely to have invariant covariance matrices. χ^2 is often used to determine if the null hypothesis is rejected or not. However, χ^2 is sample size sensitive. As mentioned before, SEM is a large sample method, and with a large sample, the *p* value of the χ^2 statistic is often small and the null is always rejected (Thompson, 2000).

Determining the Baseline CFA Model

The first step is to determine the baseline model, separately, for each group. To establish the baseline model, the hypothesized model presented in Figure 4 was evaluated separately for the American and the Chinese group.

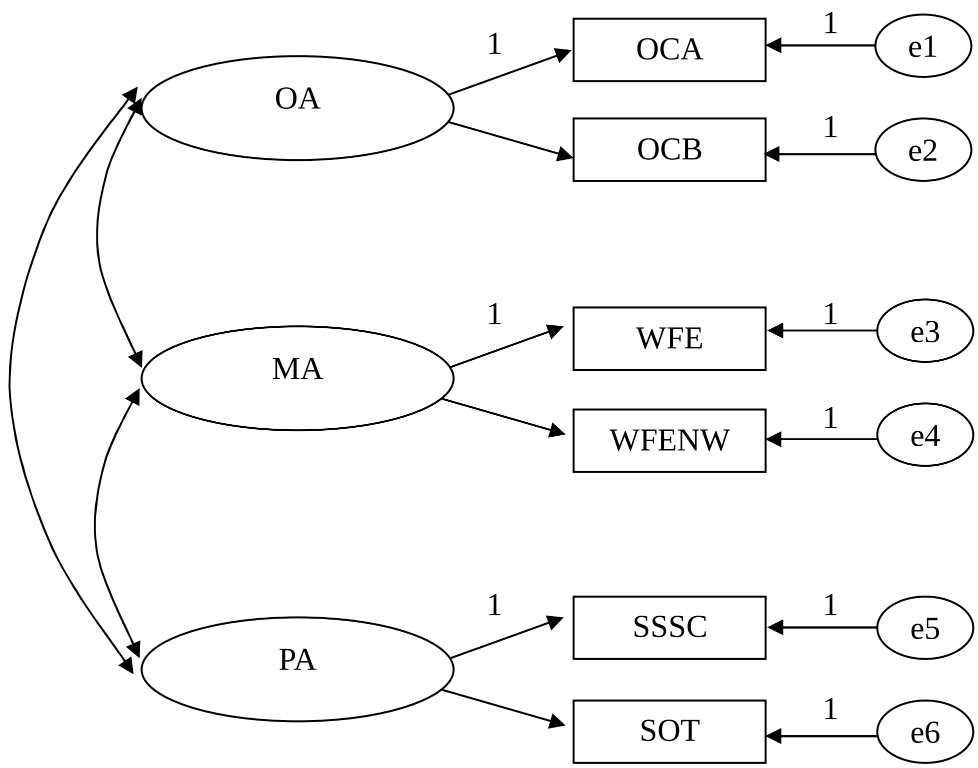

Fig. 4 Initially hypothesized model of a three factor structure (PA, MA and OA) for both groups

Note: The oval shapes represent the latent constructs of Orthographic Awareness (OA), Morphological Awareness (MA), Phonological Awareness (PA) and e1 to e6 represent measurement errors associated with each task. The rectangles represent observed variables of orthographic choice A (OCA), orthographic choice B (legal letter sequences) (OCB), word form exercise (extract the base) (WEF), word form exercise (non-word) (WFWNW), speech sound and syllable counting (SSSC), and sound oddity task (SOT).

Because of the limitation of the χ^2 statistic, several other model fix indices need to be used to evaluate the overall fit of the models to the data. The Comparative Fit Index (CFI) is an incremental index that ranges from 0 to 1. The number closer to 1.00 indicates a better fit of the model to the data. Hu and Bentler (1999) set the benchmark value of CFI to 0.95 to indicate reasonably good fit. The Root Mean Square Error of Approximation (RMSEA) focuses on estimated population fit (Thompson, 2000) and is a measure of error of approximation. It is also a function of the complexity of the model. A value approaching zero is desired and a value less than .08 indicates a good fit (Browne & Cudeck, 1993). Confidence interval for this model fit index needs to be reported. RMSEA is also the index that is most sample-size sensitive among others. When sample size is small, RMSEA tends to be large. The Standard Root Mean Square Residual (SRMR) is “a measure of the mean absolute correlation residual, the overall difference between the observed and predicted correlations values of the SRMR less than .10 are generally considered favorable” (Kline, 2005, p. 141).

The hypothesized model in Figure 4 was fitted to the correlation matrices of Table 3 separately for the two groups using Mplus (Muthén & Muthén, 2007). For the American group, the values of selected indexes indicate moderate overall fit of the three-factor CFA model: $\chi^2_{(6)} = 17.789$, $p < .01$, CFI = .958, RMSEA = .109 with the 90% confidence interval .052 - .169, and SRMR = .045. The solution was not admissible, because the unstandardized residual variance for OCA was negative (-1.265, $p > .05$). In order to obtain an admissible solution, indicator, OCA’s residual variance needed to be fixed to 0.01 in the subsequent model testing procedure. The model modification index suggested that SSSC should correlate with WFENW, with an M.I. of 10.448, EPC = 4.626. If the model was modified, according to the modification index, with correlating the error terms of SSSC and WFENW, it yielded a better fitted model for the American group: $\chi^2_{(5)} = 7.454$, $p > .05$, CFI = .991, RMSEA = .054 with the 90% confidence interval 0.000 - 0.130, and SRMR = 0.031. However, because there was no theoretical support for this relationship, this model modification was not implemented (Thompson, 2000).

For the Chinese group, a converged, admissible solution was obtained, and the values of selected indexes indicated very good overall fit of the three-factor CFA model: $\chi^2_{(6)} = 8.704$, $p > .05$, CFI = 0.987, RMSEA = 0.036 with the 90% confidence interval 0.000 - 0.085, and SRMR = 0.023. The standardized factor loadings of OCB on OA (0.384) and SOT on PA (0.470) were quite low compared to other factor loadings. The standardized factor loading of WFENW on MA was high, 0.709, $p < 0.01$, which meant that when the MA factor increased by 1 standard deviation, the score on WFENW increased by 0.709 standard deviations. No modification index was provided for the Chinese group.

R-square statistics indicated that MA factor was better manifested through WFE among the American participants but through WFENW among the Chinese participants. Interestingly, PA was better manifested through SOT among the American group but through SSSC among the Chinese group. As for the OA factor, OCA was a better indicator for both groups.

The correlation coefficients among the three factors for the Chinese groups were 0.756 (MA with OA), 0.581 (PA with OA), and 0.650 (PA with MA). The correlation between OA and MA was the highest among all three correlations. The correlation coefficients between PA and OA across the two groups were very similar, 0.581 for the Chinese and 0.528 for the American. All standardized parameter estimates for the two groups are summarized in Table 5.

Table 5 Summary of parameters in the initially hypothesized CFA models

Parameter	American		Chinese	
	Standardized	SE	Standardized	SE
Factor loading				
OA BY OCA	1.041***	0.111	0.589***	0.085
OA BY OCB	0.429***	0.078	0.384***	0.069
MA BY WFE	0.893***	0.046	0.525***	0.059
MA BY WFENW	0.652***	0.055	0.709***	0.065
PA BY SSSC	0.519***	0.075	0.698***	0.08
PA BY SOT	0.697***	0.077	0.47***	0.066
Correlation				
MA ∪ OA	0.656***	0.088	0.756***	0.117
PA ∪ OA	0.528***	0.104	0.581***	0.12
PA ∪ MA	0.831***	0.098	0.65***	0.093

Parameter	American		Chinese	
	Standardized	SE	Standardized	SE
R-square				
OCA	undefined		0.347**	0.101
OCB	0.184**	0.067	0.148**	0.053
WFE	0.797***	0.082	0.276***	0.062
WFENW	0.425***	0.071	0.502***	0.092
SSSC	0.269**	0.078	0.487***	0.112
SOT	0.486***	0.108	0.221***	0.062

** p< .01, *** p < .001

Research Q1. Are the factorial structures of the three constructs (OA, MA and PA) equivalent across the American and the Chinese group? If not, how do they differ?

The Configural CFA Model

Based on results of the model testing in the first step, only one modification was made. That was, the residual variance for OCA, which was not positive definite, was fixed to 0.01 for the American group and only for the American group. The modified model was named the configural CFA model. The fit of the configural model provided the baseline value for further model comparison.

Presented in Figure 5a and 5b are the standardized estimates of the configural model for the American and the Chinese group. With 6 indicators, there were (6*7)/2 = 21 observations for each group, so the total available degrees of freedom for the two groups were 42. With the first indicator as the marker variable for each factor (regression weight from the factor to the indicator was fixed to 1.00), this model had 29 parameters to be estimated, including 6 error variances, 3 factor loadings, 3 factor variances and 3 factor correlations for the Chinese group, and 5 error variances, 3 factor loadings and 3 factor variances and 3 factor correlations for the American group. The degrees of freedom equaled to 13 (= 42-29). Multiple group CFA model was tested using AMOS 16.0 (Arbuckle, 2007). A converged, admissible solution was obtained, and the values of selected indexes indicated good overall fit of the three-factor CFA model: $\chi^2_{(13)} = 26.514$, $p = 0.14$, CFI = 0.972, RMSEA = 0.045 with the 90% confidence interval 0.020 - 0.070, AIC = 84.514.

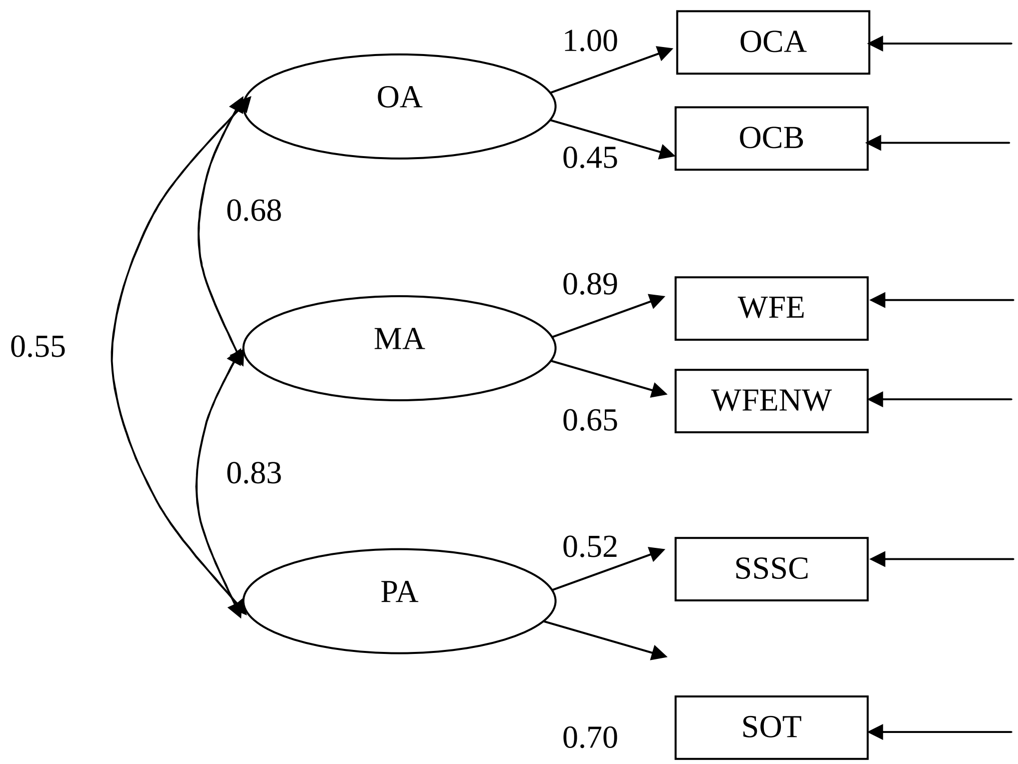

Fig. 5a Standardized estimates of the configural CFA model (American)

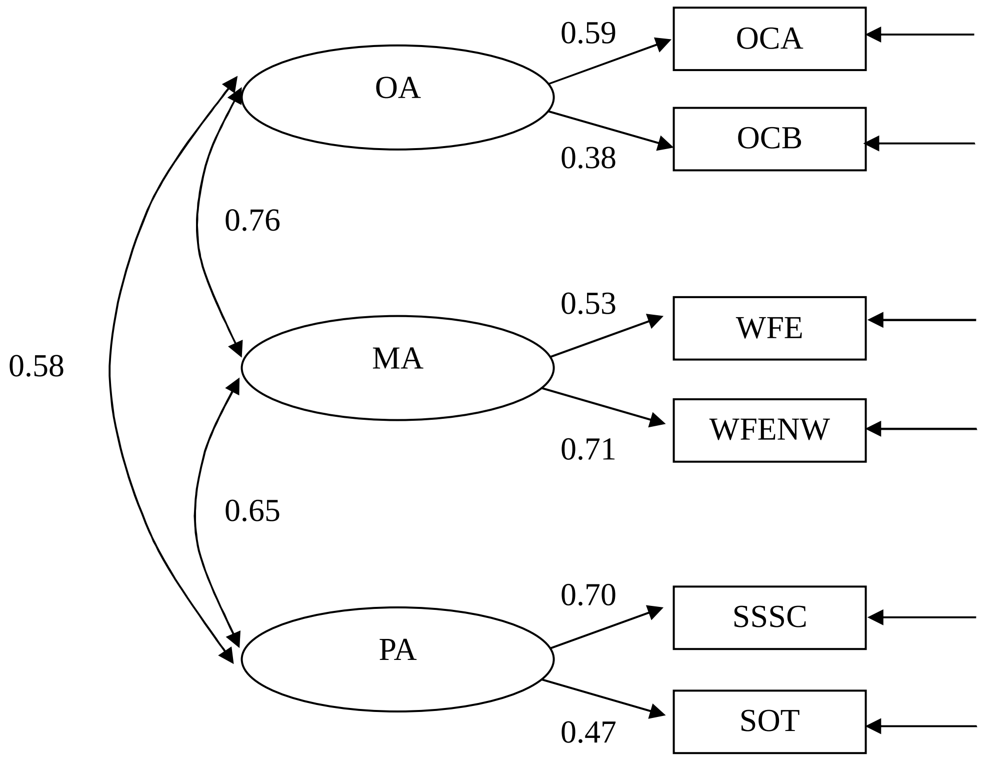

Fig. 5b Standardized estimates of the configural CFA model (Chinese)

Akaike Information Criterion (AIC) is penalized-likelihood criteria (Kline, 2005). Like RMSEA, AIC is influenced by model complexity. A smaller AIC is desired because represents the distance between the fitted model and the reality of the data.

Table 6 shows the results of the configural CFA model for the American and the Chinese groups. For the American group, the standardized factor loading from WFE to MA was higher than WFENW to MA. When MA increased by 1 standard deviation, WFE went up by 0.893 standard deviations and WFENW only went up by 0.651 standard deviations. The standardized factor loading from SOT to PA (i.e., 0.699) was higher than that from SSSC to PA (i.e., 0.518). When PA increased by 1 standard deviation, SOT went by 0.699 standard deviations and SSSC only went up by 0.518 standard deviations. The correlation coefficients among the three factors for the American group were 0.682 (MA with OA), 0.552 (PA with OA), and 0.829 (PA with MA). PA and MA were highly correlated among the American participants.

Table 6 Summary of parameters in the configural CFA models

Parameter	American		Chinese	
	Standardized	*p*	Standardized	*p*
Factor loading				
OA BY OCA	1.000		0.589	
OA BY OCB	0.447	***	0.384	***
MA BY WFE	0.893		0.525	
MA BY WFENW	0.651	***	0.709	***
PA BY SSSC	0.518		0.698	
PA BY SOT	0.699	***	0.470	***
Correlation				
MA ∪ OA	0.682	***	0.756	***
PA ∪ OA	0.552	***	0.581	***
PA ∪ MA	0.829	***	0.650	***
R-square				
OCA	0.999		0.347	
OCB	0.200		0.148	
WFE	0.797		0.276	
WFENW	0.424		0.502	
SSSC	0.268		0.487	
SOT	0.488		0.221	

** $p < .01$, *** $p < .001$

For the Chinese group, contrary to the American group, the standardized factor loading from WFENW to MA was higher than that from WFE to MA. When MA went up by 1 standard deviation, WFENW went up by 0.709 standard deviations and WFE only went up by 0.525 standard deviations. The standardized factor loading from SSSC to PA was higher than that from SOT to PA. When PA went up by 1 standard deviation, SSSC went by 0.698 standard deviations and SOT only went up by 0.470 standard deviations. The correlation coefficients among the three factors for the Chinese group were 0.756 (MA with OA), 0.581 (PA with OA), and 0.650 (PA with MA). Instead of PA and MA, MA and OA were highly correlated among the Chinese participants.

Table 7a and 7b show the implied correlation matrices for the American group and the Chinese group. For a saturated model, the implied correlation coefficient (also called structure coefficient) is the same as the sample correlation. For an overidentified model (one with positive degrees of freedom), the implied correlation between two measured variables can be different from the sample correlation. In that case, if the model is correct the implied correlation is a better estimate of the population correlation than the sample correlation is (Arbuckle, 2007). Graham, Guthrie and Thompson (2003) argued that in CFA reports involving correlated factors, both factor pattern and factor structure coefficients should be reported and interpreted, because the CFA "pattern and structure coefficients are equal if and only if factors are perfectly uncorrelated" (p. 144).

Table 7a Implied correlations for all variables in the CFA model (American)

	Measure	1	2	3	4	5	6	7	8	9
1	PA	_								
2	MA	0.83	_							
3	OA	0.55	0.68	_						
4	SOT	<u>0.70</u>	<u>0.58</u>	<u>0.39</u>	_					
5	SSSC	<u>0.52</u>	<u>0.43</u>	<u>0.29</u>	0.36	_				
6	WFENW	<u>0.54</u>	<u>0.65</u>	<u>0.44</u>	0.38	0.28	_			
7	WFE	<u>0.74</u>	<u>0.89</u>	<u>0.61</u>	0.52	0.38	0.58	_		
8	OCB	<u>0.25</u>	<u>0.31</u>	<u>0.45</u>	0.17	0.13	0.20	0.27	_	
9	OCA	<u>0.55</u>	<u>0.68</u>	<u>1.00</u>	0.39	0.29	0.44	0.61	0.45	_

Note: Factor structure coefficients are underlined.

Table 7b Implied correlations for all variables in the CFA model (Chinese)

	Measure	1	2	3	4	5	6	7	8	9
1	PA	_								
2	MA	0.65	_							
3	OA	0.58	0.76	_						
4	SOT	<u>0.47</u>	<u>0.31</u>	<u>0.27</u>	_					
5	SSSC	<u>0.70</u>	<u>0.45</u>	<u>0.41</u>	0.33	_				
6	WFENW	<u>0.46</u>	<u>0.71</u>	<u>0.54</u>	0.22	0.32	_			
7	WFE	<u>0.34</u>	<u>0.53</u>	<u>0.40</u>	0.16	0.24	0.37	_		
8	OCB	<u>0.22</u>	<u>0.29</u>	<u>0.38</u>	0.11	0.16	0.21	0.15	_	
9	OCA	<u>0.34</u>	<u>0.45</u>	<u>0.59</u>	0.16	0.24	0.32	0.23	0.23	_

Note: Factor structure coefficients are underlined.

The Constrained CFA Model

The implied correlations between the factors PA and OA were highly similar between the two groups: 0.55 (American) and 0.58 (Chinese). With constraining the covariance between two factors, PA and OA, to be equal between the two groups, the constrained CFA model (see Figure 6) was submitted under estimation. A converged, admissible solution was obtained, and the values of selected indexes indicated slightly better overall fit of the three-factor CFA model: $\chi^2_{(13)} = 26.563$, $p = 0.022$, CFI = 0.974, RMSEA = 0.042 with the 90% confidence interval 0.016 - 0.067, and AIC = 82.563.

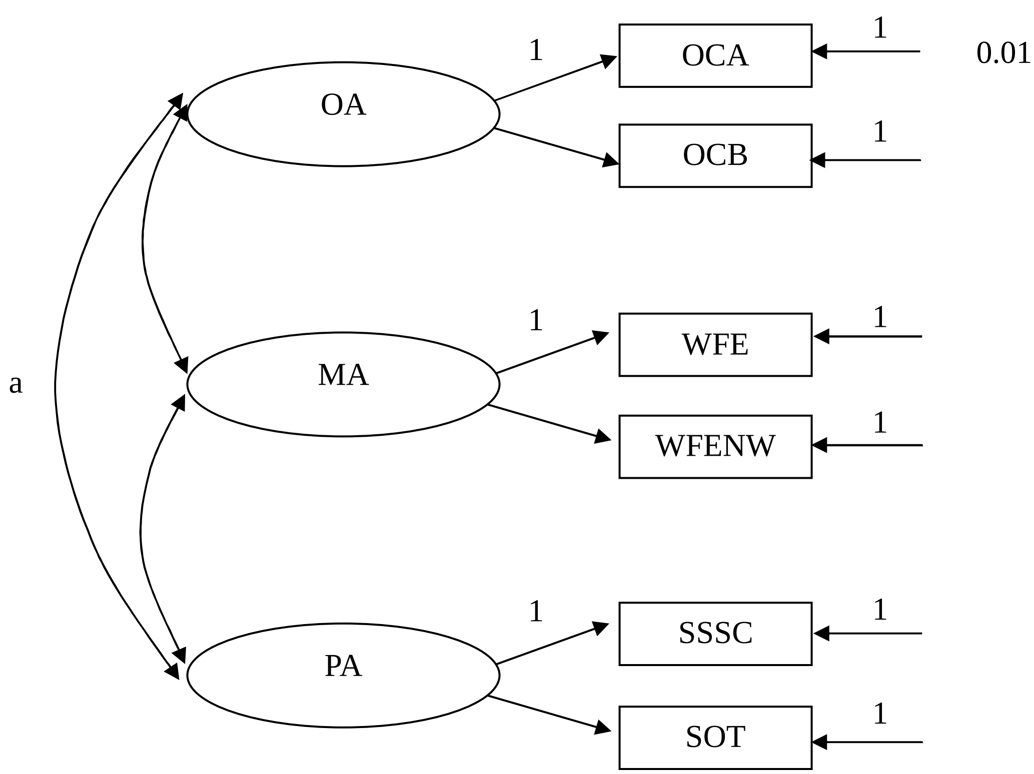

Fig. 6 Constrained CFA model

Research Q2. How are the regression paths from the latent variables (OA, MA and PA) to English spelling scores (as measured by Test of Written Spelling) different across the American and the Chinese groups?

Baseline Structural Model

To test the contributions of the phonological, morphological and orthographic factors to the prediction of the Test of Written Spelling (TWS) scores, I used latent variable structural equation modeling (SEM) of the covariance matrices of the American and Chinese groups. The analyses were conducted using the AMOS program. Figure 7 presents the hypothesized baseline structural model. In this model the error variance of OCA was fixed to 0.01 for the American group and the covariance of PA and OA were constrained to be the same across the two groups. Three correlated factors PA, MA, and OA predicted TWS individually. The overall model fit was favorable, $\chi^2_{(20)} = 39.940$, $p = 0.005$, CFI = 0.972, RMSEA = 0.045 with the 90% confidence interval 0.024 - 0.065, and AIC = 111.940. However, the regression weights between the three factors and the observed exogenous variable TWS were not statistically significant for both groups. These results pointed to the premise that the data matrices were better represented by a hierarchical factorial structure. In other words, the first-order factors might be explained by a higher order structure. In the case of the metalinguistic skills (i.e., PA, MA, OA), the single second-order factor, according to an emerging theory, was “linguistic repertoire” (LING) of literacy development.

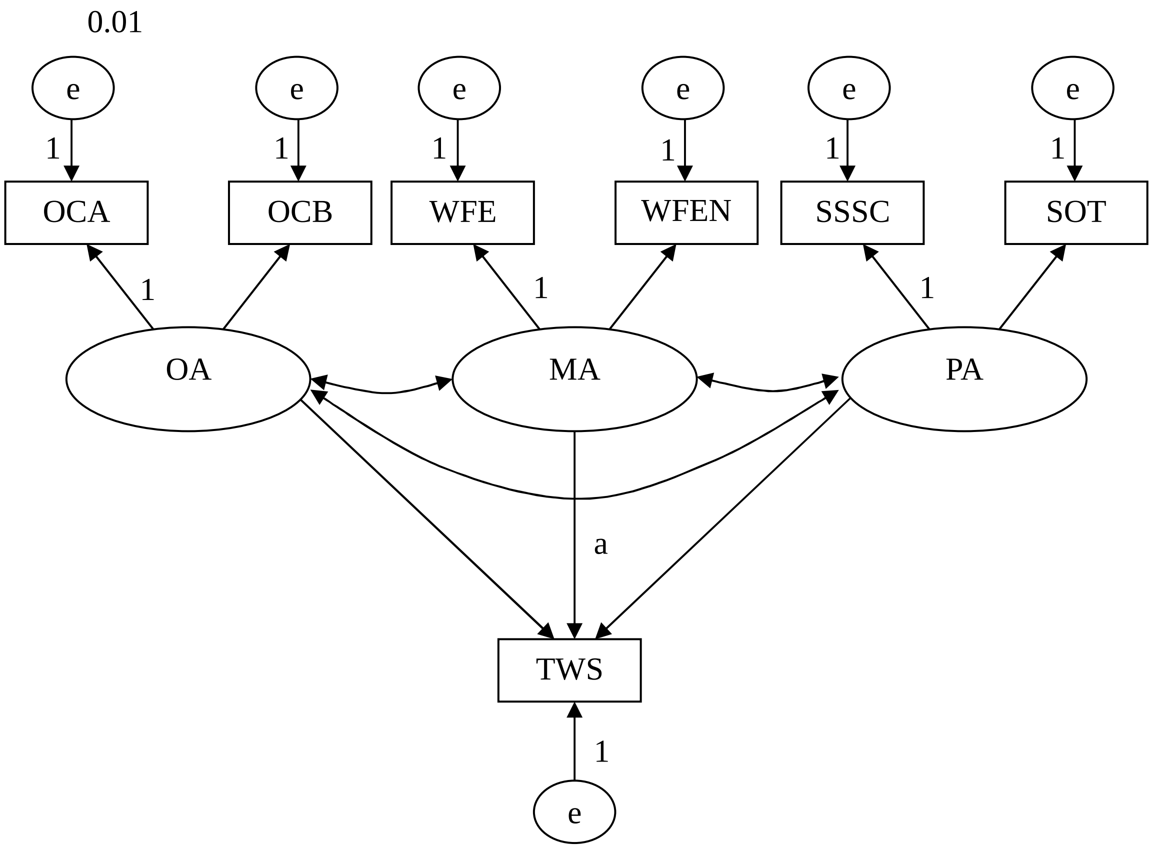

Fig. 7 Hypothesized baseline structural equation model

Second-Order Factor Model and the Structural Model

The structural model to be tested therefore met the following presumptions as required in Byrne (2010): 1) individual indicators (or measures) could be explained by three first-order factors (PA, OA and MA) and one second-order factor (LING); 2) each indicator had a non-zero loading on the first order factor which it should be indicating and a zero loading on the ones that it should not be indicating; 3) error variances associated with each indicator were uncorrelated and 4) the covariation among the three first-order factors was explained fully by their regression on the second-order factor. A graphic representation of this second-order factor model is presented in Figure 8. The second-order factor, LING was standardized (variance was fixed to 1.00) for the purpose of model-identification, because no marker variable was specified for the factor LING in the model.

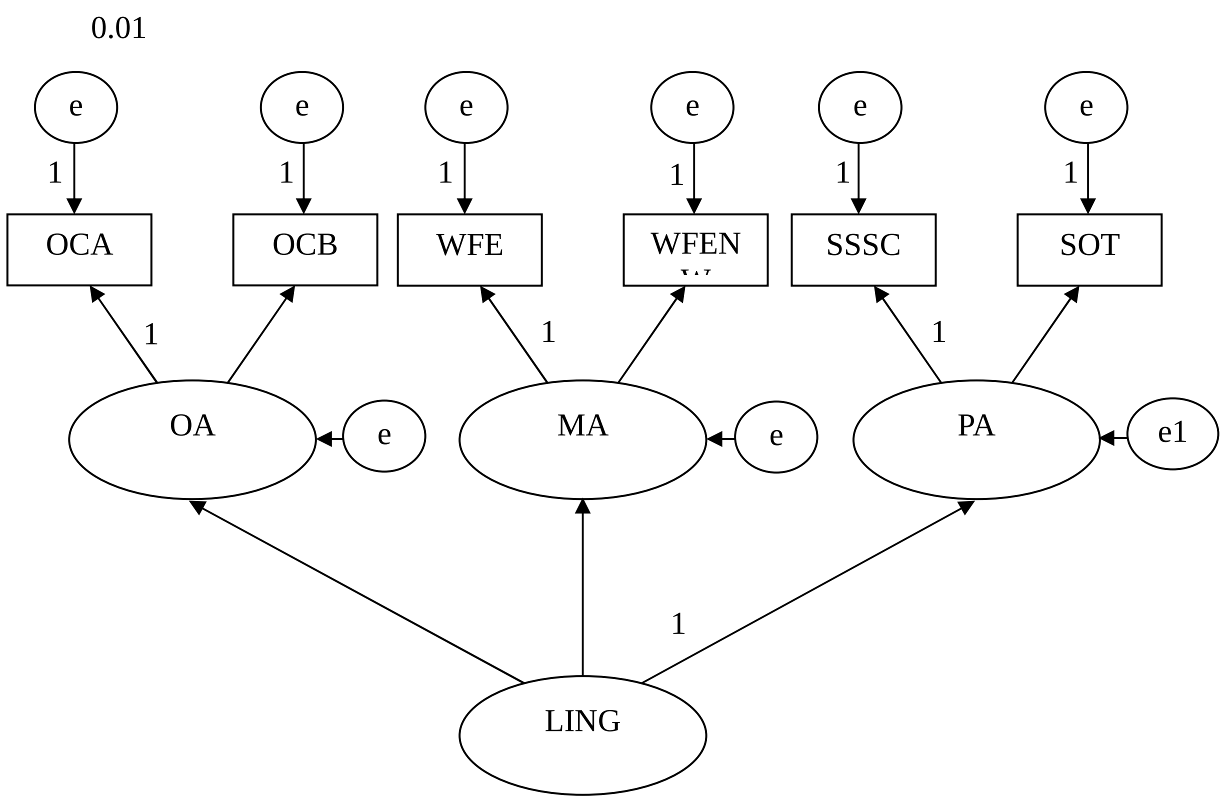

Fig. 8 Second-order factor model

The exogenous variable TWS was then added to the second-order factor model and structural model estimation yielded the following overall model fix indices: $\chi^2_{(23)}$ = 42.431, p = 0.008, CFI = 0.973, RMSEA = 0.041 with the 90% confidence interval 0.021 - 0.060, and AIC = 108.413. For the American group, the factor loadings of the three factors (OA, MA, PA) to the second-order factor (LING) were 0.702, 0.990, and 0.858, respectively. The MA factor was most representative of the LING factor. The PA factor was secondary followed by the OA factor. The standardized regression weight from LING to TWS was 0.801 (See Figure 9a).

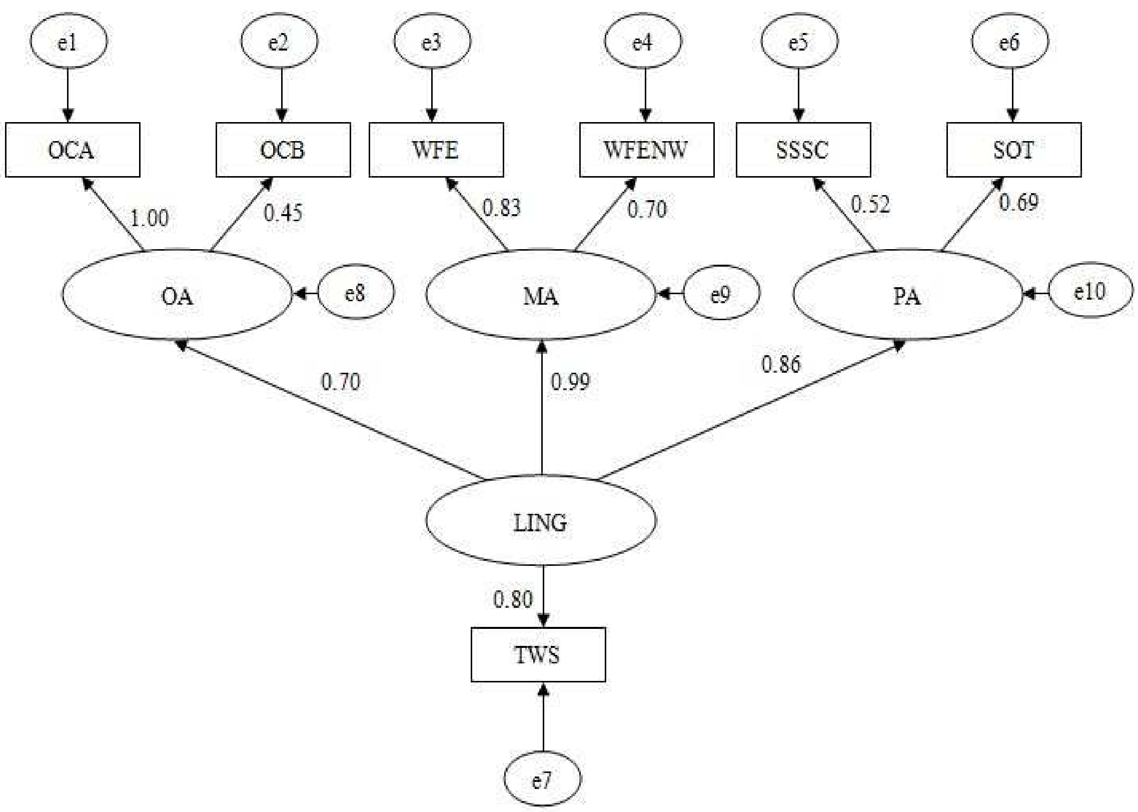

Fig. 9a Standardized estimates of the structural model (American)

For the Chinese group, the factor loadings of the three factors (OA, MA, PA) to the second-order factor (LING) were 0.856, 0.871, and 0.746, respectively. Similar to the American group, the MA factor was most representative of the LING factor; however, the OA factor was a stronger representative than the PA factor. Whereas for the American group, it was the opposite: the PA factor was a stronger representative than the OA factor. The standardized regression weight from LING to TWS was 0.634 (See Figure 9b). Results of the estimated model parameters are summarized in Table 8.

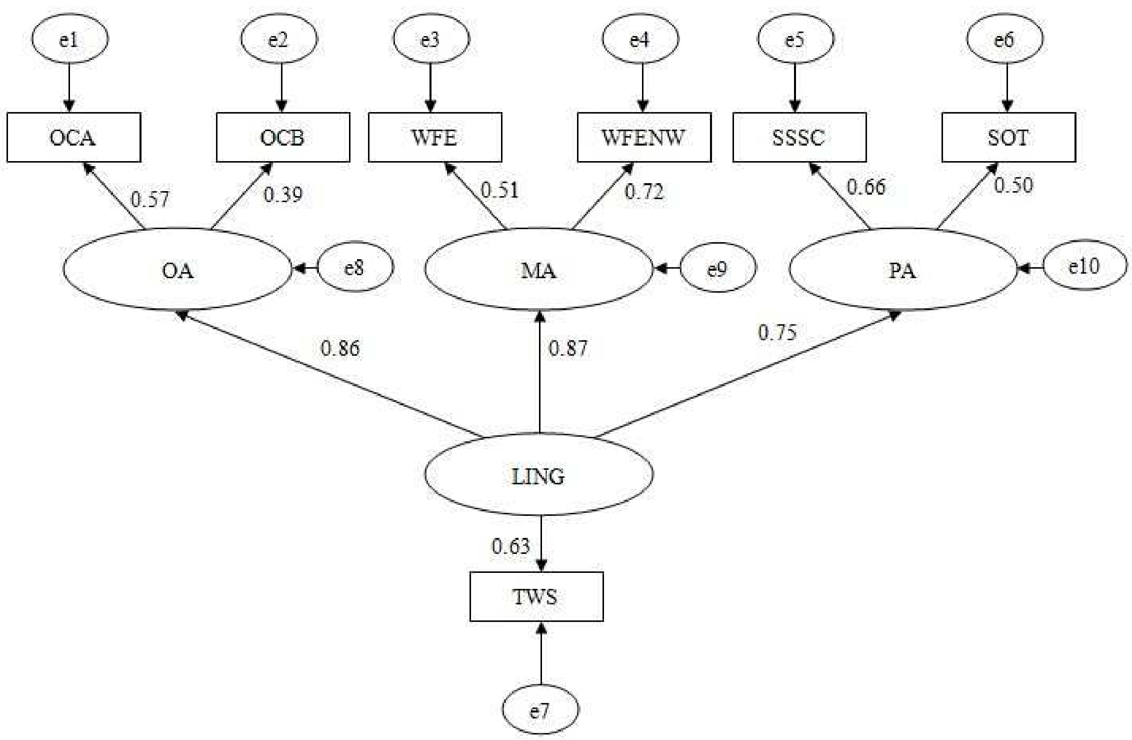

Fig. 9b Standardized estimates of the structural model (Chinese)

Table 8 Summary of parameters in the final structural models

Parameter	American		Chinese	
	Standardized	SE	Standardized	SE
Regression Weights				
LING BY OA	0.702***	0.048	0.856***	0.107
LING BY MA	0.990***	0.044	0.871***	0.074
LING BY PA	0.858***	0.081	0.746***	0.080
OA BY OCA	1.000	0.000	0.575	0.078
OA BY OCB	0.447***	0.062	0.394***	0.066
MA BY WFE	0.832	0.040	0.514	0.055
MA BY WFENW	0.699***	0.048	0.725***	0.058
PA BY SSSC	0.524	0.073	0.660	0.069
PA BY SOT	0.691***	0.073	0.497***	0.062
LING ON TWS	0.801***	0.040	0.634***	0.050
R-square				
TWS	0.641***	0.064	0.402***	0.064
OCA	0.999***	0.000	0.330***	0.089
OCB	0.200***	0.056	0.155**	0.052
WFE	0.693***	0.067	0.264***	0.056
WFENW	0.488***	0.067	0.525***	0.085
SSSC	0.274***	0.076	0.435***	0.090
SOT	0.447***	0.101	0.247***	0.061
OA	0.493***	0.068	0.732***	0.183
MA	0.981***	0.086	0.758***	0.128
PA	0.736***	0.139	0.557***	0.119

** $p < .01$, *** $p < .001$

Implied correlations indicated that TWS was most strongly associated with MA (0.793) for the American group and also with MA (0.552) for the Chinese group. The MA effect was larger for the American group than for the Chinese group.

For the American group, in addition to the TWS outcome, the MA factor was most strongly associated with WFE (0.832) and WFENW (0.699). Interestingly, the OA factor was also strongly associated with WFE (0.579) and WFENW (0.486). The implied correlation between OCB and the OA factor (0.447) was larger than the correlation between OA and the two indicators for PA but smaller than OA with the two indicators of MA. PA was correlated with MA (0.850) and OA (0.602) and MA was correlated with OA (0.696). MA was most strongly associated with PA for the American group. Implied correlation matrix for the American group is presented in Table 9a.

Table 9a Implied correlations for all variables in the structural model (American)

	Measure	1	2	3	4	5	6	7	8	9	10	11
1	LING	_										
2	PA	0.86	_									
3	MA	0.99	0.85	_								
4	OA	0.70	0.60	0.70	_							
5	TWS	0.80	0.69	0.79	0.56	_						
6	SOT	0.59	0.69	0.59	0.42	0.48	_					
7	SSSC	0.45	0.52	0.45	0.32	0.36	0.36	_				
8	WFENW	0.69	0.59	0.70	0.49	0.55	0.41	0.31	_			
9	WFE	0.82	0.71	0.83	0.58	0.66	0.49	0.37	0.58	_		
10	OCB	0.31	0.27	0.31	0.45	0.25	0.19	0.14	0.22	0.26	_	
11	OCA	0.70	0.60	0.70	1.00	0.56	0.42	0.32	0.49	0.58	0.45	_

For the Chinese group, in addition to the TWS outcome, the MA factor was most strongly associated with WFENW (0.725) and WFE (0.514). Contrary to the American group, WFENW was a better indicator for the MA factor in the Chinese group. A complex pattern was found for the association of measures with the OA factor. OA was most strongly correlated with OCA (0.575). It was also strongly correlated with WFENW (0.540) followed by the correlation with OCB (0.394). The implied correlations between PA and two indicators, SSSC (0.660), and SOT (0.497) were higher than the correlations of PA with other measures. PA was correlated with MA (0.650) and OA (0.639) and MA was correlated with OA (0.745). MA was most strongly correlated with OA for the Chinese group. Implied correlation matrix for the Chinese group is presented in Table 9b.

Table 9b Implied correlations for all variables in the structural model (Chinese)

		1	2	3	4	5	6	7	8	9	10	11
1	LING	_										
2	PA	0.75	_									
3	MA	0.87	0.65	_								
4	OA	0.86	0.64	0.75	_							
5	TWS	0.63	0.47	0.55	0.54	_						
6	SOT	0.37	0.50	0.32	0.32	0.24	_					
7	SSSC	0.49	0.66	0.43	0.42	0.31	0.33	_				
8	WFENW	0.63	0.47	0.73	0.54	0.40	0.23	0.31	_			
9	WFE	0.45	0.33	0.51	0.38	0.28	0.17	0.22	0.37	_		
10	OCB	0.34	0.25	0.29	0.39	0.21	0.13	0.17	0.21	0.15	_	
11	OCA	0.49	0.37	0.43	0.58	0.31	0.18	0.24	0.31	0.22	0.23	_

CHAPTER IV

DISCUSSION AND CONCLUSIONS

Discussion

In this study, I simultaneously examined the contribution of PA, MA and OA to English word spelling among two different groups: American native-English speaking children and Chinese-English bilingual students. Each metalinguistic construct was assessed with two different measures, taking into consideration the multi-dimensionality of metalinguistic awareness. The overall model of metalinguistic skills predicting the spelling outcome was highly similar between the American and the Chinese groups, although the regression weights were somewhat different.

The findings of this study added to the correlational studies with native English speakers which have shown that phonological, morphological, and orthographic awareness are highly intercorrelated (Carlisle, 1995; Fowler & Liberman, 1995; Juel, Griffith, & Gough, 1986). The factors PA and MA for the American group were highly correlated with a correlation of 0.83. PA and OA were moderately correlated with a correlation of 0.53. MA and OA had a strong correlation of 0.66. These correlations suggested that while PA, MA and OA share common features, each domain has its unique processes. In the morphological tests administered in this study, many items include phonological shifts, for example, the *c* in *publicity* pronounced as /s/ was changed to /k/ in *public*.

It is noteworthy that in the American measurement model, the strongest correlation among the three metalinguistic skills was the correlation between PA and MA

(0.83); however, in the Chinese CFA model, the strongest correlation was between OA and MA (0.76). This finding is not entirely surprising because in the Chinese writing system the grapheme-morpheme relationship seems to be more fundamental than the morpheme-phoneme relationship. Moreover, phonological awareness in Chinese is constrained at the syllable or onset rime level and not at the phonemic level (Wang et al., 2009). Morphological awareness in Chinese is considered as the core cognitive construct for Chinese character reading and for distinguishing normal and at-risk readers (Shu, McBride, Wu, & Liu, 2006).

The finding that phonological awareness and morphological awareness were correlated in the American model was consistent with some previous studies (Carlisle & Nomanbhoy, 1993; Deacon & Kirby, 2004). Phonological awareness is the most researched aspect of metalinguistic skill (Koda, 2005). In recent years, the study of morphological awareness has attracted increasing attention; however, the study of orthographic awareness has just started.

Due to the complexity of each of these three components of linguistic repertoire, different measures for these constructs were used across different studies by different researchers. Further, many correlation coefficients were calculated on single measures (for example, using sound oddity task to indicate phonological awareness) instead of factors, which are multidimensional and are able to encompass different aspects of the definition. Therefore, the results were not directly comparable. Furthermore, the correlation reported was often zero-order correlations (e.g., Pearson correlation between

PA and MA without controlling for the influence of the other two relationships: PA and OA, and OA and MA).

This study extended the previous findings of correlations among PA, MA and OA to Chinese speakers learning English as a foreign language. Previous research of Chinese-English language learners indicated that the three constructs were correlated. For example, Wang, Cheng and Chen (2006) with Chinese English bilingual students in elementary grades in the US found that phonological awareness (indicated by a single measure phoneme deletion) was correlated with morphological awareness (indicated by two measures --compound morphology and derivational morphology). The two measures of morphological awareness were also correlated. However, concurrent investigation of the three was rare, except for Wang, Yang and Cheng (2009) which investigated the joint contribution of PA, OA, and MA to English word reading in 1st grade Chinese-English bilinguals in Washington D. C. area. The focus of the study was cross-linguistic transfer of the three metalinguistic skills, which was different from the current study. Even though the research questions of the Wang et al. (2009) study were very different from the current study and the learning context of the Chinese-English bilinguals was also different, the findings provided useful information to the bigger question-- how languages of bilinguals interact with each other. Wang et al. (2009) made a claim based on their data that transfer effect from Chinese to English and vice versa was observable only at the phonological level and morphological level, and not at orthographic level. In other words, knowledge of orthography is language specific but knowledge of phonology and morphology may be language general which transfers across languages. Chinese tone awareness counted as an additional 14% of the variance in English word reading after age and all English measures were controlled. Their data also revealed that within language correlations were stronger than across language correlations.

Leong, Tan, Cheng and Hau (2005) investigated the relationship between PA and OA using structural equation modeling among Hong Kong students who are learning English as a second language. This study did not include any of the morphological awareness measures; however, similar to the findings of the current study, Leong et al.(2005) found that the PA and OA factors were highly correlated with each other and both factors together contribute to the literacy factor indicated by English word reading and spelling skills. More importantly, Leong et al (2005) also found that "orthographic, word specific knowledge" was a stronger predictor to English word spelling and reading compared with phonological awareness. The standardized estimation of the path from orthographic and lexical knowledge to literacy factor (0.83) quadrupled that from phonological knowledge to literacy factor (0.20). In the current study the predictive value of the orthographic awareness factor was also greater than the phonological awareness, which was consistent with Leong et al. (2005).

Theoretically, the results of the current study support an emergent theory, the “Linguistic Repertoire” theory, which argues that PA, MA and OA develop simultaneously and work in concert to form a linguistic repertoire from early grades for monolingual English children. The statement that MA only develops in later grades among native English speakers as proposed in the Phase Theory (Ehri, 2005) was challenged, because morphological awareness was found to be an important component of the linguistic repertoire construct in the current study. The linguistic repertoire theory, derived from a plethora of classroom observations and instructional practice, argues that from a developmental point of view, OA, PA and MA develop together and are all components for the pool of linguistic skills that a child processes. The idea of linguistic repertoire is similar to what Koda (2005) proposed: the concept of intra-word awareness (IA). IA refers to the "generalized metalinugistic insights" pertaining to "the perception of a word's internal structure, as well as to an understanding of how a spoken word's internal elements relate to units of graphic symbols" (p. 74). Components of linguistic repertoire including PA, MA and OA involve identifying and manipulating words' internal structure and functional elements representing phonology, morphology and meaning.

When using individual PA, MA and OA factors to predict the scores of Test of Written Spelling in the structural model, the parameters were not statistically significant; however, with the second order factor, "linguistic repertoire", which subsumed all three initial factors, the path became statistically significant and the overall model fit indices indicated excellent fit. The data from the current study also extend the empirical support of the "Repertoire Theory" from monolingual English speakers to Chinese-English bilinguals speakers.

Linguistic repertoire explained 64.1% and 40.2% of the total variance in the spelling outcome for the American and the Chinese groups. Linguistic repertoire explaining more variance in the spelling outcome for the American group suggests two plausible explanations: one from theoretical perspective and the other from socio-contextual perspective. Theoretically, the three predicting factors are deduced from observation and evaluation of native English-speaking children's literacy acquisition processes. It is plausible that they work better together to explain the total variance in the American model. The linguistic repertoire factor explained less total variance in the Chinese model and this might be attributed to the fact that there are other socio-cognitive factors that should be included in the Chinese model besides the three metalinguistc factors. These other factors might include length of English instruction, exposure to original English input both in oral and written form, opportunities to travel to English-speaking countries and even motivation to learn English.

The result that the morphological factor was significantly correlated with both the phonological factor and the orthographic factor amongtypically developing readers in the 3rd grade in the US and Chinese-speaking students in the 8th grade was consistent with the findings for at-risk 4th grade writers in Nagy et al. (2003). In Nagy et al. (2003), the morphological factor was significantly correlated with phonological factors, but not with an orthographic factor in the 2nd grade at-risk readers' model. Nagy et al. (2003) attributed this finding to the lack of linkage between morphological awareness and written language at that particular stage of reading development. This might also be because that the morphological measures used in Nagy et al. (2003) were all receptive measures (e.g., multiple choice and analogy tests). Productive morphology was not measured in their study.

There are many common features between the Nagy et al. (2003) study and the current study. Both studies used structural equation modeling with measurement models embedded in the structural models. Both studies included phonological, morphological and orthographic factors as predictors and word spelling skill as one of the outcomes. In the current study, English word spelling measured by a standardized written spelling test was the only outcome measure; whereas in Nagy et al. (2003), researchers also included measures of other basic literacy skills such as oral vocabulary, word identification, decoding, and reading comprehension.

One fundamental difference between the current study and Nagy et al. (2003) study is Nagy and colleagues included students who were at risk for meeting specific reading and writing criteria and the current study included typically developing readers. The purpose of the Nagy et al. (2003) study was to find out, through the relationships between orthography, morphology, phonology and literacy skills, how to improve students' achievement so that they could score above the population mean. The current study shares this purpose of Nagy et al. (2003), and in addition, through comparing the monolingual and bilingual models, the current study set out to examine the effect of L1 orthography on the relationships between orthography, morphology, phonology and English word spelling. The current study did not aim at distinguishing good readers and poor readers or generalizing the findings to students with specific learning disabilities.

In the current study, none of the three metalinguistic factors uniquely contribute to the spelling outcome. Jointly, through the linguistic repertoire construct, they predicted 64.1% of the total variance in word spelling for the American group and 40.2%

of the variance for the Chinese group. In Nagy et al. (2003) study, the orthographic factor, indicated by two measures, was found to be a statistically significant predictor that made a unique contribution to spelling outcome measured by WRAT-III spelling subtest for both the 2nd and 4th grade models. The other two factors did not make any unique contribution to word spelling outcome. The 1st indicator of the orthographic factor in Nagy et al. (2003) was *Process Assessment of the Learner (PAL) Receptive Coding*. This measure requires the participant to make a judgment if the second stimuli presented to them have matching letter sequences, or letter clusters or a letter to the first stimuli item that is presented to them one second ago. This test measures children's noticing the whole word or parts of the word but also requires strong short-term memory. This measure was very different from the measures used in the current study, because neither measure included in the current study required instant recall of features of the presented letters of letter sequences. The second indicator of the orthographic factor in Nagy et al. (2003) was PAL Word Choice, similar to the 1st indicator of the current study—OCA. In this test, participants were asked to select one real word that is correctly spelled out of three words or pseudowords that share similar or exactly the same pronunciation. The only difference was that in Nagy et al. (2003) the test was timed and the scores were calculated on the number of correct answers in two minutes.

The findings on the predictive value of each predictor factors mirror the L1 effects on second language spelling. MA was found to be the major component, compared to PA and OA, of Linguistic Repertoire (LING) in both American and Chinese models. In the Chinese model, the orthographic factor contributed equally as the morphological factor to word spelling. Coming from a morphosyllabic literacy background, Chinese learners may draw on orthographic and morphological processing more than phonological processing strategies.

The importance of orthographic awareness to English literacy acquisition as revealed by the data from the current study supports that Chinese learners of English may have enhanced visual-orthographic processing skills. The enhanced orthographic processing skill among Chinese students learning English has been documented by Wang et al (2003) and Leong et al. (2005). These previous studies, together with the current study offer off-line psycholinguistic evidence for the uniqueness of language processing influenced by first language orthographic background. Researchers from neuro-cognitive perspective have found that reading in Chinese and English results in different areas of brain activation (e.g., Liu & Perfetti, 2003; Tan et al., 2003). Liu and Perfetti (2003) used event-related potential (ERP) brain imaging technique and found that "Chinese more quickly initiates processing of graphic form" (p.174), which lends support to the finding that the contribution of OA was larger in the Chinese model than it was in the American model. PA was a known predictor to English word spelling and as expected, the contribution of PA was larger in the American model than it was in the Chinese model.

Analyses that compared the performance of the two groups on each individual measure also yielded some interesting results. The Chinese participants performed at a comparable level on the non-word morphological awareness task as the American participants despite a smaller pool of vocabulary. This finding indicates that EFL learners might have a better grasp of grammatical knowledge due to instruction emphasis. For native English speakers, the intra-word awareness such as morphological awareness is often tacit, which means “it is accessible in unconscious working memory but not necessarily available in conscious working memory” (Nagy et al., 2003, p. 730). Another possible explanation is the transfer of morphological knowledge from L1-Chinese to English. The results might fluctuate if the Chinese-English bilinguals were recruited from an ESL setting where the auditory and oral English input for the children is much larger than children from an EFL setting as included in this study. In an ESL setting, children will be exposed to more authentic language input and they will use English much more often to meet daily communication needs and educational requirements. The emphasis of the instruction they receive typically will not be on grammatical structures and word analysis. A future study might consider recruiting a comparison group of Chinese ESL learners to explore the effect of learning context.

Furthermore, future studies should benefit from including a comparison group of native English speakers learning to read and spell in Chinese so that the effect of L1 orthography can be studied from English to Chinese, two highly contrastive languages. It would fall into the research framework of basic processes of L1 alphabetic language learners learning to read and write in a non-alphabetic language.

Pedagogical Implications

Even though the American structural model and the Chinese structural model demonstrated high similarities, teaching spelling to second language learners needs some adaptations due to learning context and L1 orthographic experience. Chinese students, who depend less on phonological awareness in learning to spell, may need specific and systematic training on phonemic segmentation, blending and manipulation from early grades and continue into middle school as new vocabulary is introduced. Pinyin instruction may be used as a precursor for further phonological training in English but the effect of Pinyin instruction on English phonology development needs further exploration. In addition, classroom teachers might consider practicing reading out loud with the students while drawing their attention to specific word parts that contain reliable phonological information. Explicit instruction on pronunciation rules should be encouraged, for example, “in English words with a silent e, the vowel in the middle of the two consonants (the *v* in the *cvce* structure) is pronounced the same as the letter name”. Teacher education programs should incorporate hands-on exercises to help teachers to learn how to teach phonology explicitly. This kind of activity will facilitate the growth of Chinese-English bilinguals’ metalinguistic awareness and the sensitivity to words’ internal structure. In a recent systematic review and meta-analysis on the cognitive correlates of bilingualism (Adesope, Lavin, Thompson, & Ungerleider, 2010), bilinguals have increased metalinguistic skills. This should be used as an advantage by teachers of second language learners. Effective instruction on phonological awareness, which include comparing and contrasting the phonological systems of the two languages, deducing the rules for correct pronunciation and playing with sound units may help the learners better utilize their metalinguistic skill on phonology.

The results of the current study indicate that morphological awareness is emerging for 3rd graders in the United States and 8th graders in China to help the acquisition of basic English literacy skills. Therefore, spelling instruction lacking emphasis on morphological training should be improved by constantly analyzing and signaling minimal meaning units for the students when introducing new words. Koda (2005) pointed out that a large number of words children encounter in printed materials entail complex morphological information and meaning can be obtained by analyzing these morphological components. However, in reality "children, when confronted with a new word during reading, do not always exploit the available morphological information" (p. 77). Explicit instruction on morphology is needed because we cannot just assume that children will notice these morphological features and incorporate them in lexical learning.

Phonological training and morphological training will prepare learners to be better readers and spellers in terms of phoneme-grapheme and morpheme-grapheme mapping and therefore enhance their orthographic awareness. Students will benefit if teachers present explicit rules for orthographic mapping and constraints in English spelling patterns, for example, "ff" cannot begin an English word.

Moreover, associative word learning (Koda, 2005) will provide learners opportunities to compare words' internal structures and segmental elements so that they are more aware of these functional elements; in turn, this kind of awareness will facilitate their word learning and lexical processing.

Limitations of the Study

The research sites were not randomly selected. This reduces the generalizability of the research results to other parts of China and the US Research site characteristics (teachers' qualifications, hours of English instruction, instructional methods and materials) individually, and/or in combination, predict students' spelling skills and therefore are confounding variables. With group testing administration, it was not possible to closely monitor individual participants' attitude and effort in completing the tasks; therefore, there was a data loss with numbers dropping from 720 to 505. The loss was greater for Chinese sample (The number of participants dropped from 537 to 339).

The test battery was not counterbalanced. The test battery for the two groups had the same amount of items and was distributed in the same fashion and in the same order. Therefore, the results may be partially because of the order effect. Potential effect of fatigue was not controlled either.

All of the measures were paper-and-pencil tests and time of response was not recorded. Further studies may want to consider using computerized tests with similar psychometric properties and record in milliseconds the reaction time. This way, the result can be better utilized to understand the participants' processing efficiency.

The inclusion of predictors that exert possible influence on spelling acquisition was not exhaustive. Intelligence, working memory and analytical skills that might also be relevant were not measured and therefore not controlled in this study. That is especially true with the Chinese group, because the total explained variance in scores of Test Written Spelling by the current exogenous variables was only 40.2%.

These two groups of participants were not chronological age-matched. They were used as comparison groups, because, according to readability calculation, they are reading age-matched. The results that Chinese participants scored lower than the

American participants on most of the measures allude to some potential drawbacks of using readability test to determine reading level. The readability formula used in this study, Flesch-Kincaid readability test (FKRT), is a traditional way of obtaining reading grade level from text excerpts. FKRT does the calculation based on only surface structure of the passage submitted under testing, such as the length of words and the length of sentence. It assumes that longer words are more difficult to understand than shorter words; longer sentences are more difficult to understand than shorter sentences. It is not always the case especially when taking into consideration reader characteristics and lexical and syntactical complexity (Crossley, Greenfield, & McNamara, 2008). Therefore, for tests tapping into learners' understanding of words' internal structures such as the ones used in the current study to have matching scores, a cognitively based readability formula may be a better choice. A cognitively based readability formula according to Crossley, Greenfield, and McNamara (2008) includes word frequency information, syntactical complexity and overlapping of vocabulary in the passage that might be conducive to reading comprehension.

The correlational/non-experimental study design using tests that were standardized with North American monolingual English children increases the level of uncertainty about the validity of the findings for the Chinese participants. Therefore, caution must be taken in attributing any observed effect (e.g., percentage in explained variance of spelling) solely to the characteristics of current participants in this study, as other factors or confounders may be present that could also be responsible for any observed change. The conclusions could be modified based on age, measures selected or instructions participants received.

Because the analyses carried out in the current study are correlational, the results must be interpreted with caution. Based on the available data, it is not possible to make any claim about causality or direction of prediction. The predictor factors and the outcome variable are related and the relationship between them might be reciprocal. Children's increasing exposure to complex writing system through education or accrued literacy experience will foster their phonological, morphological and orthography awareness, or their linguistic repertoire as a whole.

In addition, because this study is confined to a certain grade level, it will not be possible to see a change over time. As the children progress with their learning to read and writing, the predictive value of each of the three metalinguistic skills might change. As mentioned in the literature review, for monolingual English speaking children in Grade 1, phonological awareness was the strongest predictor for English word reading (Carlisle & Nomanbhoy, 1993). For older English-speaking children (Grade 4-8), Roman et al. (2009) found orthographic awareness was the strongest predictor for real word reading and phonological awareness remained to be the strongest predictor for pseudoword reading.

For Chinese participants, as they continue to learn English and have an enlarged vocabulary size, their phonological awareness might increase and make more contribution to their overall linguistic competence. Dixon, Chuang and Quiroz (2010), in a correlational study investigating Singaporean kindergartens learning English with different ethnic language backgrounds, found that larger vocabulary knowledge in

English bolsters phonological awareness. This is a conjecture since intervention studies that investigated this direction of causal relationship are scarce.

Conclusions

Despite the limitations, theoretically this study provides more evidence for the processes of second language acquisition (SLA) from a psycholinguistic perspective. This study explored the possible foundations of L2 spelling and the effects of Chinese-English bilingual status on English spelling. It is worth noting that the predictors included in this study were all interrelated but none of them individually makes a unique contribution to word spelling. MA and PA are likely to be mutually facilitative and MA and OA may share some of the same underlying processing skills. It is helpful to understand the unique and joint contributions of PA, MA and OA to English spelling among Chinese learners with a background of an extremely opaque orthography. The comparison between the Chinese-English bilinguals and English monolinguals of matched reading level offers more evidence on the effect of L1 orthography. Pedagogically, this study provides empirical evidence for a “multi-linguistic spelling approach” (Masterson & Apel, 2010) which incorporates activities and exercises that enhance all three metalinguistic skills (PA, OA and MA) in spelling instruction.

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APPENDIX A

ADDITIONAL DESCRIPTION OF INSTRUMENTS

1. A Complete List of Orthographic Choice A (OCA) Items and Testing Prompt
In each of the following rows, circle the one that is NOT an English word.
Example: *see sea cee*
Now you try these: to tou too buy bye bie

_____1.	hear	here	heer
_____2.	knew	new	knwe
_____3.	no	know	knoe
_____4.	there	thier	their
_____5.	hole	hoale	whole
_____6.	blew	blue	bloo
_____7.	throu	threw	through
_____8	summ	sum	some
_____9	waigh	weigh	way
_____10	scente	cent	sent
_____11	sell	cell	scell
_____12	brake	braek	break
_____13	waek	weak	week
_____14	woode	wood	would
_____15	rose	rows	rwos
_____16	meet	meat	meate
_____17	bred	braed	bread
_____18	wone	one	won
_____19	plain	plane	plaine
_____20	reede	reed	read
_____21	pleas	please	plees
_____22	soe	sow	so
_____23	bete	beet	beat
_____24	rode	roade	road

_____25	peek	peak	peeck
_____26	roal	roll	role
_____27	nihgt	knight	night
_____28	wrote	rote	roat
_____29	steel	stael	steal
_____30	seen	scene	sceen
_____31	faire	fare	fair
_____32	rain	rayn	rein
_____33	peace	piece	peice
_____34	creack	creek	creak
_____35	root	route	ruote
_____36	haerd	herd	heard
_____37	wait	waite	weight
_____38	sole	soul	soal
_____39	syte	sight	site
_____40	idle	idel	idol

2. Scoring Rubric and Examples for Word Form Exercise Items (WFE)

N0.	Original word	0-wrong base (random error)	1-wrong base but good attempt	2-correct base but incorrect spelling	3-correct base
1	publicity	city	publict; publi	plublic; publik	public
2	sensitive	sensitov	sensit; sen	sens; sence	sense
3	breathe			brath	breath
4	musician			nusic	music
5	runner				run
6	fearful				fear
7	width	wild		wid	wide
8	continuous	contion		continu; contine; continou; continuo	continue
9	bathe				bath
10	procedure	podos; porduce		proced; procede	proceed
11	dangerous		dang		danger
12	cleanliness				clean
13	emptiness	emptex	empt; emptin	empti; empte; emptie	empty
14	assumption	ass; ask	assump	assum	assume
15	warmth				warm
16	recognition	recong; recinize	recognit; recogn; recogni	recognise; recognis; reconize	recognize
17	reduction	red; redu; redo; look at;	reduct	reduse	reduce
18	extension		extens	exten; exted; exdend	extend
19	remarkable				remark
20	discussion	discu		discus; disscuss	discuss
21	assistant		assis		assist
22	height	heavy; tall; hight; long; eight; heig; big		heigh	high
23	foggy			fogg	fog
24	combination		comb; combinat	combin; combind; comdine	combine
25	division		divi		divide
26	employment	ment		eploy	employ
27	density	den	densit	dens	dense
28	election		elec	elet	elect

3. Scoring Rubric and Examples for Word Form Exercise (Nonword) (WFENW)

N0.	Original word	0-wrong form random error	1-correct word form but incorrect spelling	2-correct word form
1	snig, snigging	snigger, singing,sing, song, did sing, spang, snag, sniger,did the same thing	sniged, was snigging, singed	snigged
2	mab, mabbed	street, mabbed,mabb, won, mabed	is mabbing, mabbes,mads	mabs
3	tigging, tigs	tags, tagged, tog, head, tiger	tiggied	tigged
4	clomming, clom	clomd, were clomming,farmers	clomed	clommed
5	seeping, sept	septed, septing, sleep, step		seep
6	zug	zuged		zugs
7	nuz	nuzing, nuzed	nuzzes	nuzes
8	bazing, bazed	bazed, bazy, bazer	bazs, bazes	baze, bazement, baz
9	Luggily, lugginess	lugged, luging, shining, luggilied, luggied, luggined, luger,	luggi	luggy
10	chowy, chowily	chowied, chowies, chowilied, chowed, chowil, chower	chowyness, chowes	chow

4. Speech Sound/Syllable Counting (SSSC) Items and Answer Keys

Part A
How many speech sounds are in the following words? For example, the word “cat” has 3 speech sounds ‘k’-‘a’-‘t’.

Number		Word	# of speech sounds	Item		Word	# of speech sounds
______	1	add	2	______	11	making	5
______	2	ship	3	______	12	sale	3
______	3	grass	4	______	13	basket	6
______	4	box	4	______	14	market	5
______	5	moon	3	______	15	cooked	4
______	6	brush	4				
______	7	knee	2				
______	8	through	3				
______	9	whether	4				
______	10	Tuesday	5				

Part B
How many syllables are in the following words? For example, the word “perfect” has 2 syllables, “per”-“fect”.

Number		Word	# of syllables	Number		Word	# of syllables
______	1	together	3	______	11	question	2
______	2	drink	1	______	12	strangely	2
______	3	bookkeeper	3	______	13	watermelon	4
______	4	frogs	1	______	14	political	4
______	5	pocket	2	______	15	university	5
______	6	achieve	2				
______	7	composition	4				
______	8	beautiful	3				
______	9	unhappy	3				
______	10	treat	1				

5. A Complete List of Sound Oddity Task (SOT) Items

Section A First sound different

Practice: 1. rot, rod, rock, box 2. lick, lid, miss, lip

___ 1.	_ud	_un	_us	_ug
___ 2.	_ip	_in	_ill	_ig
___ 3.	_am	_ap	_ad	_at
___ 4.	_eg	_en	_ell	_et
___ 5.	_id	_ick	_iss	_ill
___ 6.	_ot	_op	_ock	_og
___ 7.	_eap	_ean	_eal	_eat
___ 8.	_ack	_ab	_ag	_ap
___ 9.	_im	_ip	_ick	_ip
___ 10.	_oof	_oom	_ood	_oot

Section B End sound different

Practice: 1. fan, cat, hat, mat 2. leg, peg, hen, beg

___ 1.	pi_	wi_	si_	fi_
___ 2.	do_	ho_	to_	po_
___ 3.	bu_	hu_	gu_	su_
___ 4.	ma_	ca_	ga_	pa_
___ 5.	me_	re_	be_	fe_
___ 6.	wi_	fi_	pi_	di_
___ 7.	wee_	pee_	nee_	dee_
___ 8.	pa_	la_	sa_	ba_
___ 9.	san_	han_	lan_	ban_
___ 10.	sin_	min_	pin_	win_

Section C Middle sound different

Practice: 1. mop, hop, tap, lop 2. pat, bat, fit, cat

___ 1.	l_t	c_t	p_t	h_t
___ 2.	f_n	p_n	b_n	g_n
___ 3.	h_g	d_g	p_g	w_g
___ 4.	r_d	f_d	l_d	b_d
___ 5.	w_g	r_g	b_g	l_g
___ 6.	f_ll	d_ll	w_ll	b_ll
___ 7.	m_n	b_n	p_n	t_n
___ 8.	f_g	d_g	m_g	l_g
___ 9.	f_d	n_d	w_d	s_d
___ 10.	f_sh	d_sh	w_sh	m_sh

APPENDIX B

ADDITIONAL RESULTS

1. Correct Response Rate for Test of Written Spelling (TWS) Items by Group

Number	Target Word	American (n = 166)	Chinese (n = 339)
1	Yes	100%	97.9%
2	Bed	97.6%	72.9%
3	Let	96.4%	81.7%
4	Us	97.0%	64.3%
5	Went	93.4%	91.7%
6	much	93.4%	95.9%
7	Next	95.2%	95.0%
8	Spend	91.0%	96.8%
9	Who	83.1%	78.8%
10	Shake	88.0%	49.9%
11	Eight	78.3%	81.1%
12	Strong	89.8%	41.9%
13	Pile	84.3%	3.8%
14	Knife	74.7%	22.7%
15	Knew	68.7%	7.7%
16	Tardy	45.8%	9.1%
17	Nineteen	75.3%	18.6%
18	Section	59.6%	21.2%
19	Signal	51.8%	0.3%
20	Expect	60.2%	8.0%
21	Canyon	56.6%	0.3%
22	District	50.6%	3.2%
23	Fountain	30.7%	0.9%
24	Legal	34.9%	0.3%
25	Terrible	29.5%	10.6%
26	Unify	27.7%	0.3%
27	Bicycle	24.1%	9.4%
28	Institution	8.4%	0.0%
29	Collar	33.1%	0.0%
30	Agriculture	5.4%	0.0%
31	Visualize	12.0%	0.0%
32	Baste	17.5%	0.0%
33	Nucleus	4.8%	0.0%
34	Tangible	3.0%	0.0%
35	Tranquil	9.6%	0.0%
36	Continuity	6.0%	0.0%
37	Luminous	2.4%	0.0%
38	Laborious	3.0%	0.0%

Number	Target Word	American (n = 166)	Chinese (n = 339)
39	Linguistic	3.6%	0.0%
40	Opaque	1.2%	0.0%
41	Gauntlet	0.6%	0.0%
42	Panorama	2.4%	0.0%
43	Finesse	0.8%	0.0%
44	Gregarious	1.8%	0.0%
45	Zealous	0.0%	0.0%
46	Requisite	0.0%	0.0%
47	Champagne	0.6%	0.0%
48	Cyst	0.6%	0.0%
49	Versatile	0.6%	0.0%
50	Liaison	0.0%	0.0%

Results presented in the table above indicated that Chinese students performed better on high-frequency words in their textbooks such as “let”, “much” “spend”, and “went”. They also scored higher on numbers such as “eight” and “eighteen”. In middle school English instruction in China, memorization of numbers (e.g., one, two, three, first, second, and third), months (e.g., January through December), and dates (e.g., Monday through Sunday) and being able to recognize these in reading and to spell them out correctly is required and much emphasized. Therefore, the high correct response rate on these items might be due to multiple copying exercises these participants received in their daily instruction.

The pattern for correct response rate for American participants generally follows a descending order. This is consistent with how the test is designed: items are presented in an increasing difficulty order. For the Chinese group, however, this pattern is less obvious. The correct response rate is closely associated with whether the word is on the word list of the textbook or receives enough attention in daily instruction or is tested very often in quizzes and exams.

2. Detailed Cronbach's alpha information for all seven measures

Measure	Number of Items		Total (n = 720)	American (n = 183)	Chinese (n = 537)
		Valid n	715	180	535
TWS	50	alpha	0.912	0.914	0.755
		Valid n	602	167	435
OCA	40	alpha	0.823	0.754	0.765
		Valid n	686	175	511
OCB	18	alpha	0.736	0.712	0.723
		Valid n	648	176	472
WFE	28	alpha	0.951	0.931	0.923
		Valid n	567	177	390
WFENW	10	alpha	0.795	0.816	0.793
		Valid n	585	179	406
SSSC	30	alpha	0.825	0.768	0.834
		Valid n	624	152	472
SOT	30	alpha	0.836	0.887	0.820

3. Item Analyses Statistics for Test of Written Spelling

	American		Chinese	
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
TWS1	0.116	0.914	0.085	0.755
TWS2	0.160	0.914	0.319	0.747
TWS3	0.246	0.914	0.294	0.748
TWS4	0.289	0.914	0.290	0.750
TWS5	0.389	0.913	0.237	0.750
TWS6	0.414	0.912	0.252	0.749
TWS7	0.420	0.912	0.362	0.744
TWS8	0.331	0.913	0.239	0.750
TWS9	0.462	0.912	0.276	0.749
TWS10	0.470	0.912	0.205	0.758
TWS11	0.406	0.913	0.331	0.745
TWS12	0.528	0.911	0.384	0.742
TWS13	0.551	0.911	0.158	0.753
TWS14	0.536	0.911	0.502	0.733
TWS15	0.500	0.911	0.358	0.745
TWS16	0.403	0.913	0.200	0.751
TWS17	0.512	0.911	0.466	0.736
TWS18	0.647	0.909	0.537	0.731
TWS19	0.548	0.911	0.012	0.755
TWS20	0.616	0.910	0.471	0.740
TWS21	0.562	0.911	0.081	0.755
TWS22	0.569	0.911	0.283	0.749
TWS23	0.596	0.910	0.133	0.754
TWS24	0.517	0.911	0.054	0.755
TWS25	0.574	0.910	0.545	0.735
TWS26	0.481	0.912	0.081	0.755
TWS27	0.545	0.911	0.531	0.737
TWS28	0.322	0.913	0.000	0.755
TWS29	0.606	0.910	0.000	0.755
TWS30	0.392	0.913	0.000	0.755
TWS31	0.445	0.912	0.000	0.755
TWS32	0.498	0.911	0.000	0.755
TWS33	0.272	0.914	0.000	0.755
TWS34	0.337	0.913	0.000	0.755
TWS35	0.509	0.911	0.000	0.755
TWS36	0.378	0.913	-0.001	0.755
TWS37	0.311	0.913	0.000	0.755
TWS38	0.314	0.913	0.000	0.755

TWS39	0.351	0.913	0.000	0.755
TWS40	0.257	0.914	0.000	0.755
TWS41	0.140	0.914	0.000	0.755
TWS42	0.267	0.914	0.000	0.755
TWS43	0.193	0.914	0.000	0.755
TWS44	0.251	0.914	0.000	0.755
TWS45	0.000	0.914	0.000	0.755
TWS46	0.000	0.914	0.000	0.755
TWS47	0.193	0.914	0.000	0.755
TWS48	0.193	0.914	0.000	0.755
TWS49	0.193	0.914	0.000	0.755
TWS50	0.000	0.914	0.000	0.755

4. Item Analyses Statistics for Orthographic Choice Task A

	American		Chinese	
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
OCA1	0.354	0.749	0.480	0.758
OCA2	0.444	0.747	0.456	0.756
OCA3	0.196	0.751	0.427	0.759
OCA4	0.074	0.757	0.352	0.758
OCA5	0.249	0.751	0.466	0.755
OCA6	0.304	0.748	0.292	0.759
OCA7	0.085	0.754	0.250	0.760
OCA8	-0.020	0.755	0.407	0.753
OCA9	0.291	0.748	0.083	0.769
OCA10	0.257	0.749	0.098	0.768
OCA11	0.407	0.747	0.175	0.764
OCA12	0.278	0.747	0.409	0.754
OCA13	0.291	0.748	0.455	0.758
OCA14	-0.014	0.755	0.344	0.756
OCA15	0.295	0.748	0.427	0.754
OCA16	0.391	0.745	0.440	0.757
OCA17	0.336	0.743	0.366	0.754
OCA18	0.295	0.750	0.492	0.754
OCA19	0.349	0.743	0.349	0.756
OCA20	0.167	0.752	0.360	0.756
OCA21	0.076	0.761	0.082	0.768
OCA22	0.006	0.764	0.252	0.760
OCA23	0.254	0.749	0.321	0.758
OCA24	0.390	0.742	0.354	0.756
OCA25	0.270	0.750	0.203	0.762
OCA26	0.241	0.749	0.084	0.769
OCA27	0.275	0.749	0.275	0.759
OCA28	0.161	0.756	-0.095	0.777
OCA29	0.512	0.737	0.284	0.758
OCA30	0.353	0.742	0.002	0.771
OCA31	0.266	0.748	0.321	0.756
OCA32	0.137	0.756	0.203	0.762
OCA33	0.422	0.738	0.273	0.759
OCA34	0.150	0.753	0.179	0.764
OCA35	0.417	0.740	0.319	0.757
OCA36	0.321	0.745	0.344	0.756
OCA37	0.409	0.742	0.265	0.759

OCA38	0.174	0.756	-0.078	0.773
OCA39	0.259	0.748	0.305	0.757
OCA40	0.255	0.749	-0.132	0.774

5. Item Analyses Statistics for Orthographic Choice Task B

	American		Chinese	
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
OCB1	0.545	0.683	0.406	0.705
OCB2	0.493	0.687	0.540	0.695
OCB3	0.266	0.703	0.259	0.715
OCB4	0.299	0.699	0.480	0.694
OCB5	0.281	0.701	0.610	0.686
OCB6	0.486	0.685	0.241	0.718
OCB7	0.438	0.688	0.479	0.696
OCB8	0.358	0.695	0.537	0.691
OCB9	0.427	0.691	0.500	0.695
OCB10	0.452	0.688	0.587	0.691
OCB11	0.227	0.706	0.445	0.698
OCB12	0.379	0.692	0.169	0.727
OCB13	0.104	0.727	0.053	0.740
OCB14	0.070	0.733	-0.034	0.749
OCB15	0.627	0.685	0.437	0.700
OCB16	0.365	0.692	0.167	0.727
OCB17	-0.016	0.745	-0.180	0.762
OCB18	0.367	0.692	0.447	0.698

6. Item Analyses Statistics for Word Form Exercise

	American		Chinese	
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
WFE1	0.499	0.930	0.464	0.922
WFE2	0.676	0.926	0.377	0.922
WFE3	0.523	0.929	0.415	0.922
WFE4	0.548	0.928	0.540	0.920
WFE5	0.480	0.930	0.584	0.919
WFE6	0.456	0.930	0.649	0.918
WFE7	0.637	0.927	0.590	0.919
WFE8	0.585	0.928	0.581	0.920
WFE9	0.565	0.929	0.489	0.921
WFE10	0.626	0.927	0.601	0.919
WFE11	0.646	0.927	0.612	0.919
WFE12	0.480	0.929	0.549	0.920
WFE13	0.647	0.927	0.454	0.921
WFE14	0.578	0.928	0.570	0.921
WFE15	0.347	0.930	0.648	0.918
WFE16	0.602	0.928	0.471	0.922
WFE17	0.520	0.929	0.530	0.921
WFE18	0.643	0.927	0.637	0.920
WFE19	0.599	0.928	0.621	0.919
WFE20	0.505	0.929	0.577	0.920
WFE21	0.604	0.928	0.548	0.920
WFE22	0.370	0.932	0.296	0.923
WFE23	0.447	0.930	0.597	0.919
WFE24	0.618	0.927	0.633	0.920
WFE25	0.607	0.927	0.534	0.921
WFE26	0.595	0.928	0.658	0.918
WFE27	0.546	0.928	0.481	0.921
WFE28	0.670	0.927	0.545	0.920

7. Item Analyses Statistics for Word Form Exercise-Non Word

	American		Chinese	
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
WFENW1	0.566	0.794	0.455	0.776
WFENW2	0.366	0.814	0.431	0.779
WFENW3	0.655	0.783	0.574	0.761
WFENW4	0.633	0.787	0.570	0.763
WFENW5	0.416	0.810	0.477	0.774
WFENW6	0.481	0.802	0.562	0.764
WFENW7	0.459	0.804	0.549	0.765
WFENW8	0.598	0.788	0.356	0.788
WFENW9	0.393	0.811	0.373	0.785
WFENW10	0.459	0.806	0.323	0.793

8. Item Analyses Statistics for Speech Sound/Syllable Counting Task

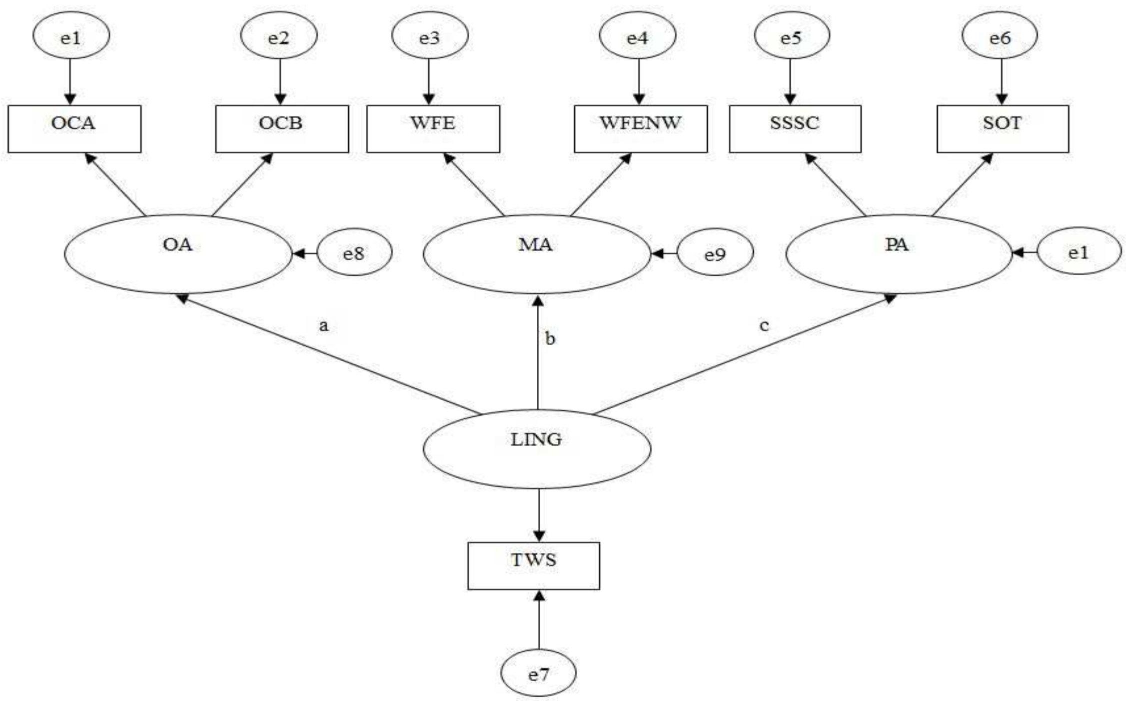
	American		Chinese	
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
SSSC1	0.213	0.765	0.170	0.834
SSSC2	0.321	0.759	0.512	0.823
SSSC3	0.245	0.763	0.572	0.821
SSSC4	0.052	0.769	0.304	0.831
SSSC5	0.318	0.759	0.520	0.823
SSSC6	0.376	0.756	0.555	0.822
SSSC7	0.206	0.765	0.252	0.833
SSSC8	0.189	0.767	0.265	0.832
SSSC9	0.297	0.761	0.542	0.822
SSSC10	0.286	0.762	0.538	0.823
SSSC11	0.061	0.769	0.292	0.832
SSSC12	0.360	0.757	0.524	0.823
SSSC13	0.312	0.760	0.484	0.825
SSSC14	0.143	0.767	0.532	0.823
SSSC15	0.273	0.762	0.446	0.826
SSSC16	0.342	0.759	0.232	0.833
SSSC17	0.294	0.761	0.311	0.830
SSSC18	0.207	0.765	0.239	0.833
SSSC19	0.299	0.760	0.369	0.829
SSSC20	0.387	0.757	0.238	0.833
SSSC21	0.333	0.758	0.006	0.840
SSSC22	0.239	0.764	0.348	0.829
SSSC23	0.220	0.764	0.235	0.833
SSSC24	0.235	0.764	0.244	0.833
SSSC25	0.326	0.759	0.431	0.827
SSSC26	0.394	0.755	0.224	0.834
SSSC27	0.215	0.766	-0.027	0.841
SSSC28	0.235	0.764	0.363	0.829
SSSC29	0.380	0.756	0.389	0.828
SSSC30	0.376	0.756	0.286	0.831

9. Item Analyses Statistics for Sound Oddity Task

	American		Chinese	
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
SOT1	0.362	0.885	0.346	0.815
SOT2	0.262	0.888	0.160	0.824
SOT3	0.445	0.883	0.373	0.813
SOT4	0.496	0.882	0.459	0.812
SOT5	0.642	0.879	0.535	0.809
SOT6	0.610	0.879	0.244	0.818
SOT7	0.554	0.880	0.434	0.812
SOT8	0.493	0.882	0.388	0.813
SOT9	0.313	0.887	0.337	0.815
SOT10	0.433	0.883	0.357	0.814
SOT11	0.401	0.884	0.475	0.812
SOT12	0.561	0.881	0.315	0.815
SOT13	0.491	0.882	0.385	0.813
SOT14	0.428	0.883	0.436	0.811
SOT15	0.336	0.885	0.461	0.810
SOT16	0.459	0.883	0.362	0.814
SOT17	0.394	0.884	0.538	0.810
SOT18	0.237	0.887	0.497	0.811
SOT19	0.500	0.883	0.584	0.808
SOT20	0.475	0.882	0.357	0.814
SOT21	0.467	0.883	0.413	0.811
SOT22	0.387	0.884	0.183	0.822
SOT23	0.417	0.884	0.315	0.815
SOT24	0.493	0.882	0.271	0.817
SOT25	0.483	0.883	0.231	0.821
SOT26	0.505	0.882	0.214	0.821
SOT27	0.312	0.886	0.319	0.816
SOT28	0.324	0.885	0.119	0.826
SOT29	0.281	0.886	0.321	0.815
SOT30	0.519	0.883	0.278	0.817

10. Model Evaluation for Constrained Structural Model

This constrained model estimation was conducted based on the model presented in Figure 9a and 9b, when the paths from the PA, OA and MA to LING were constrained to be equal across the two groups.



The overall model fit indices were: $\chi^2_{(26)} = 55.55$, $p = 0.01$, CFI = 0.958, RMSEA = 0.048 with the 90% confidence interval 0.030 - 0.065, and AIC = 115.553. The model fit suggested that the unconstrained model fitted the data better than the constrained model.

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