Learning to Read and Spell in Chinese:

The Role of Cognitive Skills

Lulin Zhou

UCL

Department of Developmental Science

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Author's Declaration

A study described in this thesis has been published elsewhere:

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I, Lulin Zhou, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Lulin Zhou

Abstract

This thesis explores the role of cognitive skills in learning to read and spell in Chinese using 4 studies. Chapter 1 reports a 2-year longitudinal study which examines a range of cognitive skills (i.e. phonological awareness, tone awareness, morphological awareness, visual skills, Rapid Automatized Naming (RAN), Pinyin knowledge, and vocabulary knowledge) as predictors of reading and spelling. Chapter 2 explores the learning mechanisms involved in learning to read and spell in Chinese. Chapters 3 and 4 report two training studies: Chapter 3 evaluates the causal influences of phonological and semantic skills on learning to read; Chapter 4 assesses the effect of Pinyin training on both reading and spelling.

Results show that Pinyin spelling and RAN are robust predictors of reading and spelling in Chinese. Vocabulary significantly predicts reading but plays a limited role in spelling. Phonological awareness and visual skills are important for children's early literacy development, whereas morphological awareness shows a greater effect on reading and spelling achievement in the later grades. Both visual-verbal and verbal-visual PAL are critical foundations of learning to read and spell in Chinese. Visual-verbal PAL is a significant predictor of reading beyond Pinyin spelling, morphological awareness, and vocabulary, and verbal-visual PAL is significant predictor of spelling after controlling for RAN, pinyin spelling, and age. The training studies confirm the causal influences of phonological and semantic skills on learning to read in Chinese, but fail to demonstrate a causal role of Pinyin knowledge in Chinese literacy skills.

These findings show strong consistency with previous studies in Chinese, but contrast with several English studies. These findings have practical implications for the identification of the children at risk of reading difficulties and how best to teach children to learn to read and spell in Chinese.

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Chapter One

The development of reading and spelling skills in Chinese

Reading is an important way for us to access information, and through spelling, we are able to convey information; both skills are critical to educational success. This thesis examines the development of children's literacy skills in Chinese. Chapter 1 introduces this work by reviewing studies of word reading and spelling in a) alphabetic languages in order to provide a context for studies of Chinese literacy development, and b) Chinese; this begins with a brief introduction to the Chinese language system and the educational context, before discussing concurrent and longitudinal studies of predictors of word reading and spelling in Chinese. Chapters 2 to 5 report four studies which examine the predictors of word reading and spelling in Chinese, and how these predictors influence Chinese literacy skills. Outcomes from these studies are summarised in Chapter 6 with reference to current literature.

1.1. Predictors of Word Reading and Spelling in Alphabetic Languages

A number of cognitive skills (including phonological awareness, letter knowledge, vocabulary, and Rapid Automatized Naming (RAN)) have been examined as possible predictors of word reading and spelling in alphabetic languages. It is useful to begin this chapter by clarifying these and describing the types of tasks that are typically used to measure them:

Phonological awareness refers to children's ability to manipulate the sounds in spoken words and nonwords. A commonly used measure of phonological awareness is a phoneme deletion test which requires children to delete an initial, middle, or final phoneme from a syllable (e.g. what is 'hat' without the 'h'). In line with task difficulty, syllable deletion is mainly used to measure phonological awareness in kindergarten children, with phoneme deletion tasks more commonly used to assess phonological awareness with primary school children.

Letter knowledge refers to children's ability to name both letters and produce letter sounds.

RAN refers to how fast children name a series of numbers, objects or colours. Children are presented with an array and are asked to name them as fast as they can; the time taken to complete the array is used as a measure of RAN. RAN measures the efficiency of phonological retrieval from visual information

It is widely accepted that phonological skills are foundations of literacy skills in alphabetic languages such as English (Anthony & Francis, 2005; Durand, Hulme, Larkin, & Snowling 2005; Hulme, Snowling, Caravolas, & Carroll, 2005; Rack, Hulme, Snowling, & Wightman, 1990). Durand et al. (2005) examined 162 British children (average age: 8;11 years) with tests of phoneme deletion and other oral language skills. A path analysis showed that phoneme deletion was a concurrent predictor of reading ability after controlling for verbal ability, nonverbal ability, phonological memory, search speed, and digit comparison.

This was in line with findings from a training study by Hatcher et al. (2004). This was a large-scale training study with 410 British children aged 4-5 years. Children were divided into 4 training groups: 1) Reading programme (incorporating training in concepts of print, letter identification, word reading, writing and spelling and text reading); 2) Reading with phoneme programme (providing additional training in phoneme awareness); 3) Reading with rhyme programme (supplementing reading training with additional work on rhyme awareness); and 4) Reading with phoneme and rhyme programme (including elements of all three programmes). The training lasted 17 months and was delivered in school by teachers. Although phoneme programme alone did not show any effect on reading ability, rhyme programme showed significant effect on reading ability for typically developing children, and phoneme and rhyme programme had additional benefit beyond rhyme programme. This supports a causal role for phoneme-level skills in the development of word reading ability.

Apart from phonological awareness, a growing number of studies have reported the importance of letter knowledge for English literacy skills (Caravolas, Hulme, & Snowling, 2001; Muter, Hulme, Snowling & Stevenson, 2004). Muter et al. (2004) examined 90 British children over 2 years, beginning at school entry (average age: 4;09 years). Children were given tests of phoneme sensitivity, letter knowledge, rhyme skills, vocabulary, and word recognition in this longitudinal study. Path analyses showed that phoneme sensitivity and letter knowledge at age 4 were unique predictors of word recognition at age 5 with all other constructs controlled; phoneme sensitivity, letter knowledge, and word recognition at age 5 were unique predictors of word recognition at age 6 with all other constructs controlled; phoneme sensitivity and letter knowledge had a reciprocal relationship between each other. In short, phoneme sensitivity and letter knowledge were found to be significant longitudinal predictors of reading, and they were reciprocally related to each other. Phoneme awareness had a greater effect on word reading than did rhyme skills, suggesting that it is phonological awareness at the phoneme level that is more critical for reading development.

Caravolas et al. (2001) conducted a 3-year longitudinal study with 153 British children (average age: 5;01 years), testing phoneme awareness and letter knowledge as predictors of English spelling. A path analysis showed that phoneme awareness (phoneme isolation) and letter knowledge were longitudinal predictors of spelling at age 5.5 and 6 years even with early reading and spelling ability controlled.

In addition to the empirical study above, a number of training studies have examined the effect of phoneme awareness and letter knowledge on literacy skills (Al Otaiba et al., 2008; Ball & Blachman, 1991; Byrne & Fielding-Barnsley, 1989; Hatcher, Hulme & Snowling, 2004). For example, Ball and Blachman (1991) conducted a 7-week intervention with 89 US kindergarten children (average age: 5;09 years). Children were divided into three training groups: phoneme-letter (phonological segmentation training and letter knowledge); language activities (vocabulary and letter knowledge), and a waiting control group. All training was delivered by the research group. Whilst there was no difference between the three groups at pre-test, the group who received phoneme-letter training performed significantly better than the other two groups in phoneme awareness, reading, and spelling at post-test. It was suggested that the combination of phonological segmentation training and letter knowledge produced significant improvements in literacy skills in English, while letter knowledge supplemented with vocabulary training was not sufficient to improve reading abilities.

Hulme, Bowyer-Crane, Carroll, Duff and Snowling (2012) also found that a training programme combining phonology and letter knowledge (P+R programme) had a significant benefit to reading and spelling in English. After a 20-week intervention delivered by a teaching assistant in the school, children in the P+R programme had a greater improvement in phonological awareness, letter knowledge, word-level reading and spelling, when compared with children who were taught vocabulary, narrative structure, and speaking and listening skills. Furthermore, these gains were maintained 5 months after the intervention ended.

Duff and Hulme (2012) questioned the causal effect of vocabulary in addition to that of phonological information on learning to read. They conducted a non-word learning study in which 18 children (average age: 6 years, 1 month) were exposed to non-words with or without an oral pre-exposure. Each child was taught to read 12 non-words: four non-words without a pre-exposure; four with pre-exposure to phonological information; and four with pre-exposure to phonological and semantic information. Both conditions which included oral pre-exposures showed improvements in non-word learning but pre-exposure to semantic information did not provide any additional benefit to phonological information. It was suggested that phonological information benefits learning new words whereas semantic information adds nothing beyond phonological information.

Although semantic information had no additional benefit in the study by Duff and Hulme (2012), Ricketts, Nation and Bishop (2007) found that semantic information benefit exception word reading. Eighty one English children aged 8 to 10 years participated in the concurrent study. Hierarchical regressions showed that vocabulary was a unique predictor of exception word reading (words with irregular spelling-sound patterns which cannot be decoded), but not for regular or non-word reading after controlling for age and IQ. In line with this, Ouellette (2006) also found vocabulary to be a concurrent predictor of exception word reading, but not for reading regular and nonwords after age and IQ were controlled. Taken together this work suggests that semantic information aids the reading of irregular or exception words but adds little to the reading of decodable words once phonological awareness is accounted for.

Similar to vocabulary, morphological awareness also has a limited effect on the development of English literacy skills. Deacon and Kirby (2004) conducted a 3-year longitudinal study with 103 Canadian children (average age: 7;04 years). Results showed that morphological awareness at age 7 was a longitudinal predictor of (real) word reading at age 9 with IQ and early nonword reading ability controlled. After controlling for phonological awareness, however, morphological awareness was no longer a significant predictor of learning to read.

Nunes, Bryant, and Olsson (2003) examined the causal influence of morphological awareness on reading and spelling in English using a 12-week intervention study. Four hundred and fifty-five children (average age: 8;03 years) participated in this study: 237 were in the control group and the rest of children were divided into 4 training groups (morphological training alone, morphological training with writing, phonological training alone, phonological training with writing). Morphological training taught children to classify words into grammatical categories, and phonological training taught children to classify words with similar phonemes. It was found that the four training groups showed significant gains in reading compared with the controls, but there were no differences between training and control groups in spelling ability.

It is clear that vocabulary and morphological awareness play relatively weak roles in the development of English literacy skills, whereas phoneme awareness and letter knowledge are robust predictors. According to Hulme and Snowling (2013), phoneme awareness, letter knowledge, and RAN were considered to be 3 “cognitive foundations” of English literacy skills. A growing number studies have examined RAN as a predictor of learning to read and spell in English (Furnes & Samuelsson, 2011; Parrila, Kirby, & McQuarrie, 2004). Furnes and Samuelsson (2011) tested 750 primary school-aged children from the U.S. and Australia from kindergarten (average age: 6:02) to Grade 2. Phonological skills (syllable and phoneme blending), RAN, and vocabulary were tested at the end of kindergarten (T1) and Grade 1 (T2); word reading was assessed at kindergarten (T1), Grade 1 (T2), and Grade 2 (T3). A hierarchical regression model showed that phonological awareness and RAN at T1 and T2 were unique longitudinal predictors of both word reading and spelling at T2, and spelling at T3 after controlling for all other constructs. Whilst RAN at T2 was also a unique predictor of reading at T3, phonological awareness at T2 did not predict reading at T3 after controlling for all other constructs. In this study phonological skills were measured using a syllable and phoneme blending test, which may explain this pattern of results. In other words, the syllable blending test was not a significant predictor of reading in English in this stage of reading development.

Furthermore, Parrila et al. (2004) examined phonological awareness, letter knowledge and RAN as predictors of learning to read in English. Ninety three kindergarten children (average age: 5:06) from Canada completed tests of phonological awareness (sound isolation and phoneme blending), letter recognition, RAN, articulation rate, and verbal short term memory at the end of kindergarten and Grade 1, and completed a word reading test at Grade 1, 2 and 3. Phonological awareness, letter knowledge and RAN were reliable concurrent and longitudinal predictors of word reading with all other constructs and the autoregressor (Autoregressor refers to the score of reading (or spelling) as a potential predictor of the subsequent reading (or spelling) ability in a longitudinal study. For example, the score of reading at Grade 1 is an autoregressor of reading at Grade 2) controlled. This suggests that a combined test of sound isolation and phoneme blending is a more reliable measure of phonological awareness for children in this age group.

Several studies have compared the patterns of prediction of reading and spelling skills between English and other alphabetic languages which differ in orthographic consistency. Caravolas, Lervåg, Defior, Malkova and Hulme (2012) tested 188 English children (average age: 5 years), 190 Spanish children (average age: 5;07 years), 153 Czech children (average age: 6 years), and 204 Slovak children (average age: 6 years). English is a phonologically inconsistent language; the other three languages are consistent. It was predicted that differences in orthographic consistency between languages would lead to different patterns of predictors in learning to read. All children were given tests of non-verbal IQ, phoneme awareness, letter knowledge, RAN, word memory span, word dictation and word recognition in this 10-month longitudinal study. Contrary to predictions, phoneme awareness, letter knowledge, and RAN were unique longitudinal predictors of word recognition in all languages with all other constructs controlled. The pattern of prediction of spelling was the same as that of reading. Thus, different alphabetic languages had equivalent predictors of reading and spelling.

Caravolas, Lervåg, Defior, Málková, and Hulme (2013) also explored the predictors of learning to read in alphabetic languages differing in orthographic consistency. This was a 3-year longitudinal study of reading conducted with 185 English children (average age: 5 years), 188 Spanish children (average age: 5;07 years), and 150 Czech children (average age: 6 years). The same cognitive skills emerged as unique predictors across languages of early reading skills (letter knowledge, phoneme awareness, and RAN), the growth of reading skills (letter knowledge and phoneme awareness), and the acceleration of growth of reading skills (RAN). Though the predictors were the same across languages, letter knowledge was a stronger predictor of early reading ability in Spanish and Czech than in English. The authors suggest that good letter knowledge helps children to decode phonological information more accurately in consistent orthographies in which a letter has a one-to-one correspondence of a sound.

In summary, phoneme awareness, letter knowledge, and RAN are significant predictors of literacy skills in English and in other alphabetic languages. Orthographic consistency affects the relative strength of relationships, with stronger relationships between letter knowledge and reading in consistent orthographies. With this evidence as a backdrop, we now turn to consider learning to read Chinese.

1.2. Learning to Read and Spell in Chinese

1.2.1. The Chinese Language System

While alphabetic orthographies are composed of strings of letters, Chinese characters are a collection of strokes evolved from pictures. Therefore, Chinese characters are called pictographs. Chinese characters can be categorized into simple-structure characters and complex-structure characters. Simple-structure characters have one radical (e.g.马/ma3/house); complex-structure characters have two or more radicals (A radical is part of a character. E.g.女/nü3/female and 马/ma3/house are radicals of 妈/ma1/mother).

According to Li and Kang (1993), 81% of frequent characters are pictophonetic characters that are composed of a phonetic radical and a semantic radical. A phonetic radical indicates the pronunciation of a character; a semantic radical indicates the meaning of a character. For example, in the character of 妈/ma1/mother, 马/ma3/house indicates the pronunciation of 妈/ma1/mother; 女/nü3/female indicates the meaning of 妈. As Taylor and Taylor (1983) reported, there are roughly 800 phonetic radicals in Chinese written system. Of the pictophonetic characters, 38% are regular pictophonetic characters whose phonetic radicals can indicate the correct pronunciation of characters (Zhou, 1978). Unlike alphabetic languages, semantic radicals provide semantic information for Chinese characters, semantic information might be more closely associated with learning to read and spell in Chinese than in alphabetic languages such as English.

While one character can be a Chinese word, most Chinese words are composed of 2 to 4 characters. Each character is a morpheme in a Chinese word, and provides semantic information. For example, 足球 football: 足 means foot; 球 means ball. A good understanding of each morpheme in a word supports memory for the meaning of the word.

1.2.2. Reading Instruction in China

In Mainland China (where the studies reported in this thesis were conducted), children start learning to read and spell after they enter primary school at the age of six. Each academic year is composed of 2 semesters. During the first semester, children learn Pinyin (explained further below), radical knowledge, several simple-structure characters and a small number of complex-structure characters. In the second semester children are exposed to numerous complex-structure characters.

In contrast to Mainland China, children in Hong Kong (where much of the existing literature is based) start formal literacy instruction at the end of kindergarten (when children are 5 years old). Children in Hong Kong do not learn Pinyin; otherwise, the process of learning to read and spell in Hong Kong is identical to that in Mainland China.

In order to understand the potential effects of learning Pinyin, it is necessary to briefly introduce what Pinyin is. Pinyin is an assistive tool for learning to read in Mandarin. It is a phonetic alphabetic system which represents the pronunciation of Chinese characters with Chinese syllables and lexical tones (e.g. the Pinyin word /ma1/ represents the pronunciation of the Chinese character 妈 (mother); /ma/ is the Chinese syllable, and /1/ is the lexical tone). Each Chinese syllable consists of an onset and a rime (e.g. ma) or a sole rime (e.g. a). An onset or rime has a unique phonological representation. There are 21 onsets and 37 rimes in total. As a characteristic feature in Chinese phonology, tone changes meanings of a syllable. One syllable with a different tone conveys a different meaning in Chinese. For example, /ma/ with Tone 1 (/ma1/) means mother; /ma/ with Tone 2 (/ma2/) means numb. As each Pinyin word clearly indicates the onset, rime, and tone of a Chinese character, knowledge of Pinyin can boost syllable awareness and tone awareness (McBride-Chang et al., 2010; Shu, Peng and McBride-Chang, 2008). Consequently, it will potentially be much easier for children who have learned Pinyin to perform well on an onset deletion test and a tone discrimination test. In addition, Pinyin builds a bridge between phonemes and the Chinese writing system. Potentially, instruction in Pinyin may change the way that children process phonemes for reading in Chinese, and for children who learn Pinyin, the ability to manipulate phoneme units may be important for reading.

1.3. Predictors of Reading and Spelling in Chinese

Several cognitive skills (including phonological awareness, tone awareness, morphological awareness, visual skills, RAN, Pinyin knowledge, and vocabulary) are considered as potential predictors of learning to read and spell in Chinese. This section introduces concurrent and longitudinal studies which have examined these cognitive skills as predictors of reading and spelling in Chinese.

1.3.1. Phonological Awareness

Phonological awareness refers to the perception and manipulation of sounds in words (at the level of syllables, rhymes or phonemes). It is typically assessed using syllable deletion or/and onset deletion tasks. A syllable deletion test requires children to delete a syllable from a multiple-syllable word (e.g. what is ‘cowboy’ without ‘cow’). An onset deletion test requires children to delete the first phoneme from a syllable (e.g. what is ‘ma’ without ‘m’).

1.3.1.1. Syllable Deletion

As each Chinese character has a one-to-one correspondence with a Chinese syllable, a syllable deletion test is a potential predictor of reading in Chinese. The concurrent and longitudinal correlations between syllable deletion and word reading are moderate to strong, ranging from .37 to .56 (Lin et al., 2010; Shu et al., 2008). Furthermore, performance on measures of syllable deletion predicts word reading measured concurrently after controlling for other variables. Li, McBride-Chang, Wong and Shu (2010) assessed 184 Beijing kindergarten children from Grade 2 (K2) and Grade 3 (K3) (K2: 4.84 years old; K3: 5.76 years old) in a concurrent study. Regression analyses showed that syllable deletion was a significant predictor of word reading with grade, rime awareness, orthographic knowledge, visual skills, morphological awareness, and RAN controlled. Similarly, Shu et al. (2008) who studied 202 Beijing kindergarten children in a similar age group (3;04 to 6;06 years old), found that syllable deletion was a concurrent predictor of word reading after controlling for age, vocabulary, RAN, and tone awareness.

Findings are consistent across different regions. McBride-Chang, Chow, Zhong, Burgess and Hayward (2005) reported a concurrent study with children from Hong Kong and Mainland China, Xiangtan. One hundred and eighteen Hong Kong children (average age: 5;04 years) and 96 Xiangtan children (average age: 4;11 years) participated in the study. Hierarchical regression analyses showed that syllable deletion was a significant predictor of concurrent word reading in both groups with age and vocabulary controlled.

Concurrent studies of reading in kindergarten therefore demonstrate significant relationships between reading and syllable deletion. In line with this, several longitudinal studies have found syllable deletion to be a significant predictor of reading in Chinese. Lin et al. (2010) examined reading skills in 296 Beijing kindergarten children (average age: 5 years 11 months) in a one-year longitudinal study. Path analysis showed that syllable deletion was a unique predictor of reading ability measured 12 months later after controlling for age, IQ, phoneme deletion, Pinyin letter reading, Pinyin spelling, and the autoregressor.

Similarly, Chow, Mcbride-Chang and Burgess (2005) tested 203 kindergarten children from Hong Kong in a 9-month longitudinal study. Syllable deletion was found to be a concurrent and longitudinal predictor of word reading after controlling for age, IQ, RAN, visual skills and verbal memory. Moreover, it was a significant longitudinal predictor of word reading with the autoregressor controlled.

Syllable deletion is therefore concurrently and longitudinally related to reading in kindergarten children. It also appears to predict children's reading in the early grades of primary school. Chen, Hao, Geva, Zhu and Shu (2009) examined the reading skills of 29 Grade 1 (average age: 6;10 years) and 30 Grade 2 (average age: 7;10 years) children. A regression model showed that syllable deletion was a significant concurrent predictor of reading after controlling for age, vocabulary, rime detection, RAN, morphological construction, and morpheme detection.

Syllable deletion is also a significant predictor of spelling in Chinese (Pan et al., 2011; Tong et al., 2011). Pan et al. (2011) tested 262 Beijing children (average age: 5;05 years) in a longitudinal study. Children were given a syllable deletion test at age 5, and a spelling ability test at age 9 and 10 years. Syllable deletion measured at age 5 was a significant predictor of spelling at age 9 and 10 years after controlling for age, IQ, vocabulary, Pinyin spelling, RAN and early word reading at age 5. Consistent with these findings syllable deletion was a significant longitudinal predictor of spelling measured 2 years later in a study of 187 Hong Kong kindergarten children (average age: 4;04 years; Tong et al., 2011).

In summary, syllable deletion is a reliable concurrent and longitudinal predictor of reading in kindergarten children and in children who are in the early grades of primary school. Few studies have examined syllable deletion as a predictor of learning to spell, but evidence from these longitudinal studies suggests that this relationship is also significant.

1.3.1.2. Onset Deletion

Phoneme awareness is a significant predictor of reading in alphabetic orthographies (Lervåg & Hulme, 2009; Muter et al., 2004). Although reading in Chinese does not require phoneme-level processing, an onset deletion test has been widely used to test children's phonological awareness. Compared with syllable deletion tasks, on which children score highly after starting formal reading instruction, onset deletion tasks are more difficult. In several studies reviewed below, a syllable deletion test was combined with an onset deletion test to provide a broader measure of children's phonological awareness.

McBride-Chang et al. (2008) tested 211 Hong Kong kindergarten children (average age: 4;05 years) in a concurrent study. Though onset deletion was significantly correlated with word reading ($r=.19$), it was not a significant concurrent predictor of reading after controlling for age, IQ, vocabulary, RAN, syllable awareness, and tone awareness.

Tong and McBride-Chang (2010) used a combined test of 29 syllable deletion items and 22 onset deletion items to assess children's phonological awareness in a concurrent study. One hundred and sixty-three Grade 2 children (average age: 8;01 years) and 163 children in Grade 5 (average age: 11;01 years) participated in this study in Hong Kong. The correlation between phonological awareness and reading was .15 ($p<.01$) after partialling out children's age. However, hierarchical regressions showed that phonological awareness as measured by the combined syllable- and onset-deletion measure was not a concurrent predictor of word reading in either grade after controlling for age, IQ, visual skills, and morphological awareness.

In addition to the concurrent studies reported above, Tong, McBride-Chang, Shu and Wong. (2009) tested 171 kindergarten children (average age: 6;02 years) from Hong Kong in a longitudinal study over one year using a combined syllable and onset deletion test. The concurrent correlation between onset deletion and reading was .79 ($p < .001$); the longitudinal correlation between onset deletion and reading one year later was .28 ($p < .001$). However, onset deletion was not a significant concurrent or longitudinal predictor of reading in Chinese after controlling for age, vocabulary, RAN, orthographic knowledge, and morphological awareness.

In summary, onset deletion (or combined syllable and onset deletion) does not appear to be a concurrent or longitudinal predictor of reading in Chinese. This finding is perhaps to be expected given that phonemes are not represented explicitly in Chinese orthography; thus, in contrast to alphabetic languages, phoneme awareness does not appear to make a significant contribution to reading in Chinese (where syllable deletion does). However, most of the existing studies which examine onset deletion (or combined syllable and onset deletion) have been conducted in Hong Kong; this pattern of results may not therefore accurately reflect the relationship between onset deletion and reading in Chinese for children who learn Pinyin (which marks onsets). Further studies are needed to examine syllable and onset deletion as a predictor of reading development in Mainland China.

Few studies have examined onset deletion as a predictor of spelling in Chinese. Tong et al. (2009) tested 171 kindergarten children in a 1-year longitudinal study in Hong Kong. A syllable and onset deletion test was used to assess children’s phonological awareness at the beginning of the study. A spelling test was also completed twice over the year. Phonological awareness was a longitudinal predictor of spelling in Chinese ($r = .56$; $p < .001$), but not a concurrent predictor of spelling in Chinese after controlling for age, vocabulary, RAN, orthographic knowledge, and morphological awareness ($r = .56$; $p < .001$). However, interestingly, orthographic knowledge and morphological awareness were found to be concurrent, but not longitudinal predictors of spelling in Chinese. Overall, phonological awareness, morphological awareness, and orthographic knowledge together contributed significant variances to spelling in the concurrent regression model. This suggests that, although phoneme awareness is not as important as orthographic knowledge and morphological awareness, it plays a role in learning to spell in Chinese. Again, further research is needed to confirm these findings and to explore the relationship between phoneme awareness and spelling in Pinyin learners.

1.3.1.3. Summary

Syllable deletion is a significant predictor of reading in kindergarten children and in children who are in the early grades of primary school. However, according to existing studies conducted in Hong Kong, tests which include phoneme-level manipulations (onset deletion; syllable and onset deletion combined) do not significantly predict reading. Furthermore, phonological awareness does not appear to be a reliable predictor of spelling when other factors (e.g. orthographic knowledge and morphological awareness) are controlled. This thesis examines phonological awareness (syllable and onset deletion) as a predictor of reading and spelling in Chinese (see Chapter 2), and conducts a word learning study to explore the causal relationship between phonological skills and learning to read (see Chapter 3).

1.3.2. Tone Awareness

Tone awareness refers to perception of a pitch of a syllable. It is typically measured using a tone discrimination test. This test requires children to identify which syllable has the same or a different tone from target words.

A large number of studies have examined tone awareness as a predictor of reading in Chinese (McBride-Chang et al., 2008; Shu et al., 2008). Shu et al. (2008) assessed reading and tone awareness in 202 kindergarten children aged between 3;04 to 6;06 years old. The tone awareness task required children to select one of two syllables which shared the same tone as a target word. Correlations between tone awareness and word reading were moderate (.25-.31). Tone awareness was a concurrent predictor of word reading with age, vocabulary, RAN, and phonological awareness statistically controlled. Similarly, McBride-Chang et al. (2008) reported that tone awareness was a concurrent predictor of word reading after controlling for age, vocabulary, RAN, and phonological awareness in kindergarten children (average age: 4;05 years).

Tone awareness therefore appears to be a significant predictor of concurrent reading skills in kindergarten children. In contrast, findings concerning tone awareness as a predictor of word reading in primary school children have not shown significant relationships (Siok & Fletcher, 2001; Xue, Shu, Li, Li & Tian, 2012).

Siok and Fletcher (2001) recruited 37 primary-school aged children in Grade 1 (average age: 6;05 years), 36 children in Grade 2 (average age: 7;10 years), 42 children in Grade 3 (average age: 9;01 years), and 39 children in Grade 5 (average age: 11 years) in Beijing. Children completed a variety of measures including a tone awareness test and a word reading test. The correlation between tone awareness and single-character word reading was significant in Grade 5 (r=.352). The correlations between tone awareness and multiple-character word reading were significant in Grade 2 (r=.353) and Grade 5 (r=.369). However, hierarchical regressions showed that tone awareness was not a significant concurrent predictor of word reading across all grades after controlling for age, IQ, phonological awareness, visual skills, orthographic skills, and morphological awareness.

Similarly, Xue et al. (2012) tested a large sample of 408 Grade 2 (average age: 8;04 years) primary school children, and found that tone awareness was not a significant concurrent predictor of word reading with IQ, orthographic knowledge, short term memory, morphological awareness, phoneme awareness, rime detection, and RAN controlled.

Tone awareness is not therefore a concurrent predictor of reading in primary school children. It does not appear to be a significant predictor of spelling either. McBride-Chang, Lin et al. (2010) examined tone awareness as a concurrent predictor of reading and spelling in Chinese with 43 primary school children (average age: 6;02 years) from Beijing. Tone awareness was significantly correlated with spelling ($r = .32$, $p < .05$), but not significantly correlated with reading ($r = .17$, $p > .05$). Hierarchical regressions showed that tone awareness was not a significant predictor of concurrent reading or spelling in Chinese after controlling for age, IQ, and phonological awareness.

In summary, tone awareness is a significant predictor of reading in kindergarten children but does not appear to predict reading or spelling in primary school children. In this thesis, tone awareness is examined as a predictor of reading in Grade 1 primary school children (see Chapter 2).

1.3.3. Morphological Awareness

Morphological awareness refers to the semantic knowledge of each character in a word. It is typically measured with a morphological construction test which requires children to construct a compound word according to a sentence with a familiar compound word and a sentence which describes the compound word. This compound word may not be a real word. For example, 'If a ball played with a foot is called '足球' (football), what should we call a ball which is played with the mouth?' The answer should be '嘴球' (mouthball).

Many studies have found that morphological awareness is a significant concurrent predictor of reading in kindergarten children (Li et al., 2010; Wang, McBride-Chang & Chan, 2014). Li et al. (2012) tested 184 Beijing kindergarten children (K2: 4.84 years old, K3: 5.76 years old) using a morphological construction test in a concurrent study of reading ability. Multiple regression showed that morphological awareness was a concurrent predictor of reading in Chinese after controlling for school Grade, visual skills, orthographic skills, phonological awareness, and RAN. In line with this, Wang et al. (2014) also reported morphological awareness to be a concurrent predictor of reading after controlling for age and IQ. In this study, 94 kindergarten children (average age: 5;05 years) were tested with a morphological construction test.

This predictive relationship is not however apparent in longitudinal studies with kindergarten children. Tong et al. (2011) tested 187 Hong Kong kindergarten children (average age: 4;04 years) with a morphological construction test in a 2-year study. Children completed a test of morphological construction at the beginning of the study, and tests of reading ability at T1, T2 and T3 at yearly intervals. Hierarchical regression showed that morphological awareness was a concurrent predictor of word reading after controlling for age, IQ, vocabulary, phonological awareness, and visual skills. However, morphological awareness was not a significant longitudinal predictor of reading measured at T2 ($r = .34$, $p < .001$) and T3 ($r = .30$, $p < .001$) with those constructs controlled.

In contrast, morphological awareness is a significant concurrent and longitudinal predictor of reading in primary school children. Yeung et al. (2013) reported a 3-year concurrent and longitudinal study of reading in 251 Hong Kong children from Grade 1 (average age: 6;10 years). Children completed a test of morphological construction in Grade 1, and were tested on a measure of word reading in Grade 1, Grade 2 and Grade 4. It was found that morphological construction in Grade 1 was a concurrent and longitudinal predictor of word reading in Grade 1, Grade 2 and Grade 4 after controlling for age, IQ, vocabulary, RAN, homophone judgment, phonological skills, and orthographic skills.

The relationship between morphological awareness and reading appears to differ depending on the population studied. Hu (2012) tested 94 Taiwanese children (average age: 8;09 years) on morphological construction in a concurrent and longitudinal study. The correlation coefficient between morphological awareness and concurrent measures of reading was .33 ($p < .001$). Hierarchical regression showed that morphological awareness was a concurrent predictor of reading after controlling for age, digit span, Taiwanese accent, and vocabulary. However, when phonological awareness (measured by syllable discrimination and onset deletion) was controlled, morphological awareness no longer predicted reading. Phonological awareness therefore contributed significant variance (10%) such that morphological awareness explained little additional variance in this model. However, morphological awareness was a longitudinal predictor of word reading (measured in Grade 5) after controlling for all factors including phonological awareness. This suggests that morphological awareness is a robust predictor of reading in the later grades, while phonological awareness is a stronger predictor of reading in the early grades. Unlike Hong Kong children, Taiwanese children learn Zhuyinfuhao (a phoneme manipulation tool like Pinyin). This significantly improves children's phoneme awareness, and builds a strong link between characters and phonemes in learning to read in Chinese (Huang & Hanley, 1997). When children are skilled in Zhuyinfuhao, their phonological awareness skills reach ceiling. Therefore, variations in phonological awareness explain significantly more variance in reading in the early grades, but little in the later grades when phonological awareness is close to ceiling levels, and other factors (such as morphological awareness skills) play a role in reading ability.

Findings concerning spelling in Chinese suggest a different pattern to studies of reading. Yeung et al. (2013) assessed 251 primary school children with a morphological construction test in Grade 1, and a Chinese word spelling test in Grade 1, Grade 2, and Grade 4. The hierarchical regression model showed that morphological awareness was a concurrent, but not a longitudinal predictor, of spelling in Chinese.

This finding is consistent with that of another longitudinal study by Tong et al. (2011). In this study of 187 Hong Kong kindergarten children (average age: 4;04 years) morphological awareness was not a longitudinal predictor of spelling measured 2 years later with age, IQ, vocabulary, phonological awareness, and visual skills controlled.

In summary, morphological awareness appears to be a concurrent, but not a longitudinal, predictor of reading in kindergarten children and of spelling in kindergarten and primary-aged children. However, morphological awareness is a consistent concurrent and longitudinal predictor of reading in proficient readers, and has been shown to significantly predict reading beyond phonological awareness in the later grades. In this thesis, morphological awareness is examined as a predictor of learning to read and spell in a 2-year longitudinal study (see Chapter 2).

1.3.4. Visual Skills

Visual skills refer to the ability to process visual information. As Chinese characters were evolved from pictures, visual skills are considered as a potentially important predictor of reading and spelling in Chinese. Visual skills are assessed using visual discrimination tests, visual memory tests, or visual spatial tests. In a typical visual discrimination test, a target shape and five choices are presented on a computer screen simultaneously. Children are required to select one of a set of shapes that is the same as the target shape. In a visual spatial test, children are required to select one of a set of shapes that is different from the others. To some extent, a visual discrimination test is similar to a visual spatial test. In a visual memory test, a target shape is presented briefly on the screen and is then replaced with a set of shapes. Children are required to select the shape that was presented previously. All the shapes consist of abstract complex line drawings without any verbal cues.

Li et al. (2012) assessed 184 kindergarten children (K2: 4;10 years, K3: 5;09 years) and 273 primary school children (P1: 6;11 years, P2: 7;11 years, P3: 8;11 years) from Beijing in a concurrent study. Each child was tested using a visual spatial test and a visual memory test (Gardner, 1996). Both visual tests correlated significantly with reading in kindergarten children (visual spatial test: $r = .29$, $p < .001$; visual memory test: $r = .22$, $p < .01$); however, visual skills were not significantly correlated with reading in primary school children. Moreover, visual skills did not significantly predict reading in kindergarten or primary school children after controlling for age, orthographic knowledge, phonological awareness, and RAN.

Findings differ if fewer variables are included in the hierarchical regression model. Tong et al. (2011) tested 187 Hong Kong kindergarten children (average age: 4;04 years) using a visual spatial test in a 2-year study. Visual skills were assessed at the beginning of the study, and reading ability was tested at yearly intervals. The visual spatial test was a concurrent and longitudinal predictor of word reading at all the time points after controlling for age, IQ, vocabulary, morphological awareness, and phonological awareness. Compared with the study of McBride-Chang et al. (2005), RAN was not included in the regression model. This may explain why the visual spatial test was found to be a significant predictor of reading in this study.

There are also different relationships between visual skills and reading across children from different regions. McBride-Chang et al. (2005) tested 118 Hong Kong kindergarten children (average age: 5;04 years) and 96 Xiangtan kindergarten children (average age: 4;11 years) in a 9-month study. Children from Hong Kong learn traditional scripts, while children from Xiangtan learn simplified scripts. Simplified scripts look simpler than traditional ones, but it is more difficult for young children to discriminate different characters as each character has little difference from others. Therefore, children who learn simplified scripts may have higher visual skills that those who learn traditional scripts. Hierarchical regressions showed that a visual spatial test was a significant concurrent predictor of reading with age and vocabulary controlled in both groups. When syllable deletion and RAN were included in the regression model, the visual spatial test was still a concurrent predictor of reading in children from Hong Kong but not in children from Xiangtan. Interestingly, the visual spatial test was a longitudinal predictor of reading with syllable deletion controlled in children from Xiangtan, but not from Hong Kong. In other words, visual skills appeared to be more important for children who learnt simplified scripts than those who learn traditional scripts.

Siok and Fletcher (2001) suggested that children's educational level affects the relationship between visual skills and reading in Chinese. They examined 154 primary school children from Grade 1 (average age: 6;05 years), Grade 2 (average age: 7;10 years), Grade 3 (average age: 9;01 years), and Grade 5 (average age: 11 years) using a visual memory test and a visual spatial test in a concurrent study. Hierarchical regression models showed that the visual spatial test concurrently predicted more than 11% of variance in character reading in Grade1 and Grade2, but predicted little variance in the later grades. The authors explained this in terms of reading strategies associated with instruction: younger children are inclined to holistic processing and rote memory making visual skills important for reading acquisition, while more proficient readers with more exposure to literacy instruction tend to rely less on visual skills (and more on other skills such as orthographic skills).

Interestingly, in addition to the studies that have examined visual skills as predictors of reading, McBride-Chang et al. (2011) examined the bidirectional relationship between word reading and visual skills. They explored the relationship between visual spatial skills and word recognition in 4 languages: Chinese, Korean, Spanish, and Hebrew. An analysis of variance (ANOVA) showed that children in Hong Kong and Korea had superior visual skills to those in Spain and Israel. Neither Hong Kong and Korean children nor Spanish and Israeli children showed a significant difference between each other. The findings suggested that orthographies with higher visual complexity (e.g. Chinese & Korean) might shape higher levels of visual spatial processing correspondingly. Their longitudinal data from 215 Hong Kong kindergarten children showed a bidirectional relationship between visual spatial skills and word reading. Visual spatial skills significantly predicted subsequent word reading, and word reading was a significant predictor of subsequent visual spatial skills. Notably, the correlation between word reading at age 5 and visual skills at age 6 was much stronger than that between visual skills at age 5 and word reading at age 6.

A small number of studies have examined visual skills as predictors of spelling in Chinese. For example, Tong et al. (2011) tested 187 kindergarten children (average age: 4;04 years) using a visual spatial test in a 2-year longitudinal study. Children’s visual skills were tested at the beginning of the study, and spelling ability was tested 2 years later. The visual spatial test was a significant longitudinal predictor of spelling in Chinese after controlling for age, IQ, vocabulary, morphological awareness, and phonological awareness.

In addition, visual memory, which does not appear to be a concurrent predictor of reading in Chinese in Grade 3 (Siok & Fletcher, 2001), was found to be a concurrent predictor of spelling in the same age group (Smythe et al., 2008). In this study, 84 children were tested with a visual memory test which required children to recall the sequence and orientation of pictures. Visual memory was a concurrent predictor of spelling in Chinese after controlling for phonological awareness, working memory, and RAN.

In summary, visual skills appear to be a significant concurrent and longitudinal predictor of reading in the early grades. For proficient readers who have received more literacy instruction, other factors such as morphological awareness, play a more crucial role in reading. However, the relationship between visual skills and word reading may vary according to region and the Chinese script used, as different scripts may shape different levels of visual skills.

Visual skills have been found to be significant concurrent and longitudinal predictor of spelling. As studies regarding the relationship between visual skills and spelling are few, more studies are needed to support this finding.

In this thesis, visual skills (visual discrimination & visual memory) are examined as predictors of learning to read and spell in a 2-year longitudinal study with a wide range of variables controlled (see Chapter 2). Furthermore, a paired association learning (PAL) study was conducted to explore basic associative learning mechanisms. This study examines four PAL tasks (visual-verbal, visual-visual, verbal-visual, and verbal-verbal) as predictors of learning to read and spell in Chinese (see Chapter 4).

1.3.5. RAN

Correlations between RAN and reading in Chinese range from -.32 to -.49 (Li, et al., 2010; Tong et al., 2009); correlations between RAN and Chinese spelling range from -.25 to -.30 (Yeung et al., 2011, 2012).

Findings concerning the relationship between RAN and reading in Chinese are extremely consistent. It is a reliable concurrent predictor of reading in kindergarten children (McBride-Chang et al., 2008; Shu et al., 2008) and primary school children (Chen et al., 2009; Xue et al., 2012) after controlling for all other constructs. In these studies, the average age of children ranges between 3 and 12 years old. Li et al. (2012) tested a large sample of 457 children from Beijing: 2 year groups of kindergarten children (K2: 4;10 years, K3: 5;09 years) and 3 year groups of primary school children (P1: 6;10 years, P2: 6; 11 years, P3: 7;11 years). In line with previous studies, RAN was a concurrent predictor of word reading in both kindergarten and primary school children after controlling for grade, visual skills, orthographic skills, phonological awareness, and morphological awareness.

RAN is also a significant concurrent predictor of reading in Chinese with spelling skills controlled (Wang, Yin, & McBride, 2015). 73 kindergarten children (average age: 5;02 years) from Beijing participated in this concurrent study. A multiple stepwise regression showed that RAN significantly predicted reading after controlling for age, IQ, spelling skills, radical skills, and vocabulary.

In addition to concurrent studies, a number of longitudinal studies have examined RAN as a predictor of later word reading. A longitudinal study (Tong et al., 2009) tested 171 kindergarten children (average age: 6;02 years) in Hong Kong. Children were given tests of RAN and word recognition twice over one year. It was found that RAN was a concurrent and longitudinal predictor of word reading with age and vocabulary statistically controlled.

Similarly, Yeung et al. (2011) examined a sample of 251 Hong Kong first grade primary children (average age: 6;09 years) in a 3-year longitudinal study.

RAN was tested in Grade 1; word reading was tested in Grade 1, Grade 2, and Grade 4. RAN was a concurrent and longitudinal predictor of word reading across all grades after controlling for age, IQ, vocabulary, orthographic knowledge, and phonological awareness.

RAN has been interpreted as a measure of the efficiency of phonological retrieval from visual information. As such, RAN has been speculated to be a significant predictor of reading fluency. Pan et al. (2011) conducted a 5-year longitudinal study with a sample of 262 Beijing children (average age: 5;05 years). Children were given tests of RAN at the beginning of the study, and completed tests of reading accuracy and fluency once a year from age 7 to age 10. Hierarchical regressions showed that RAN measured at 5 years was a consistent predictor of both reading accuracy and fluency from age 7 to 10 after controlling for age, IQ, vocabulary, syllable deletion, and early word recognition (measured at age 5).

Concurrent and longitudinal studies also support a significant relationship between RAN and spelling in Chinese. Yeung et al. (2011) tested 290 Grade 1 primary school children (average age: 6;07 years) and found that RAN was a significant concurrent predictor of reading and spelling with age, IQ, vocabulary, phonological awareness, orthographic skills, and morphological awareness statistically controlled.

Li et al. (2012) reported a longitudinal study showing that RAN was a significant longitudinal predictor of spelling in Chinese. 141 Hong Kong children were assessed on RAN at age 8 (average age: 8;01 years), and completed spelling tests at age 10. Multiple regression analyses showed that RAN at age 8 was a longitudinal predictor of spelling at age 10 after controlling for gender, family background, phonological skills, vocabulary, and reading accuracy.

However, findings differ if the autoregressor is included in the model. Lo, Yeung, Ho, Chan and Chung (2015) examined 289 Grade 1 primary school children from Hong Kong in a concurrent and longitudinal study. A simple regression showed that RAN was a concurrent and longitudinal predictor of reading and spelling in Grade 1, Grade 2 and Grade 4 in Chinese after controlling for age, IQ, phonological awareness, morphological awareness, semantic radical knowledge, and stroke knowledge. However, when the autoregressor was included as a control variable, RAN was not a longitudinal predictor of reading or spelling in any grades.

In summary, RAN is a consistent concurrent and longitudinal predictor of word reading across kindergarten and primary school children and this relationship is upheld when the autoregressor is controlled. Whilst RAN is also a significant and longitudinal predictor of spelling, it is no longer a significant longitudinal predictor of spelling when the autoregressor is controlled. In this thesis, RAN is examined as a predictor of learning to read and spell in a 2-year longitudinal study after controlling for all other constructs with and without the autoregressor (see Chapter 2).

1.3.6. Pinyin Knowledge

Pinyin is an assistive tool for learning to read in Mandarin. It is a phonetic alphabetic system which represents the pronunciation of Chinese characters with Chinese syllables and lexical tones (e.g. the Pinyin word /ma1/ represents the pronunciation of the Chinese character 妈 (mother); /ma/ is the Chinese syllable, and /1/ is the lexical tone).

Pinyin knowledge refers to the understanding of Pinyin. It is typically assessed using a Pinyin letter reading test, a Pinyin reading test, and a Pinyin spelling test. A Pinyin letter reading test requires children to read a list of Pinyin letters. A Pinyin reading test requires children to read a list of Pinyin words (Chinese syllables with tones). A Pinyin spelling test requires children to spell Pinyin words.

Ding et al. (2014) found a positive relationship between Pinyin spelling and reading. 54 Grade 4 primary school children (average age: 10;05 years) were divided into 3 groups according to their reading levels: good, average, and poor. Good readers scored significantly higher on the Pinyin spelling test than the average group, and average readers scored significantly higher than the poor reader group. In other words, Pinyin spelling was closely associated with reading ability.

Pinyin reading has also been examined as a predictor of reading and spelling. For example, Wang, McBride-Chang and Chan (2014) tested 94 Mainland Chinese children (average age: 5;05 years) using a Pinyin letter reading test and a Pinyin spelling test. Pinyin letter reading was a significant concurrent predictor of reading after controlling for age, IQ, and morphological awareness. Although Pinyin spelling was significantly correlated with word reading ($r= .24$, $p< .05$), it was not a significant concurrent predictor of reading in Chinese. In this study, neither Pinyin letter reading nor Pinyin spelling was significantly correlated with spelling in Chinese.

These findings may reflect the small sample size as findings differed in a study with a larger sample of subjects: Lin et al. (2010) tested 296 kindergarten children with a Pinyin letter reading test and a Pinyin spelling test. A path analysis showed that Pinyin spelling was a longitudinal predictor of reading in Chinese after controlling for age, IQ, phonological awareness, Pinyin letter reading, and the autoregressor. Although Pinyin letter reading was significantly correlated with word reading at T2 ($r=. 20$, $p<. 01$), it was not a longitudinal predictor of word reading with word reading at T1 controlled. Thus, the autoregressor predicted so much variance that Pinyin letter reading added little variance in this model.

In line with this finding, Pan et al. (2011) reported a 5-year longitudinal study which tested 262 children (average age: 5;05 years) from Beijing.

Children were tested on Pinyin spelling at age 6, and completed a reading test once a year from age 7 to age 10. Hierarchical regressions showed that Pinyin spelling was a longitudinal predictor of word reading from age 7 to 10 after controlling for age, IQ, vocabulary, syllable deletion, and early word recognition at age 5.

In summary, Pinyin spelling is a longitudinal predictor of reading in Chinese. However, Pinyin reading and Pinyin letter reading are not reliable predictors of reading. Very few studies have addressed the relationship between Pinyin knowledge and spelling in Chinese. In this thesis, Pinyin spelling, Pinyin reading, and Pinyin letter reading are examined as predictors of learning to read and spell in a 2-year longitudinal study (see Chapter 2). To further explore the causal role of Pinyin knowledge in Chinese literacy skills, a Pinyin training study is conducted in Grade 1 primary school children (see Chapter 5).

1.3.7. Vocabulary

Vocabulary refers to children's semantic knowledge of a word. It is typically assessed by asking children to name picture or explain the meaning of a word they hear. Some studies have examined vocabulary only as a controlled variable (e.g. Tong et al., 2009); others have examined vocabulary as a predictor of learning to read and spell in Chinese (e.g. Wang et al., 2015).

Tong et al. (2009) examined vocabulary as a control variable in a concurrent and longitudinal study. One hundred and seventy-one Hong Kong children (average age: 6;02 years) participated in this study over 1 year. Although vocabulary was significantly associated with reading ability (T1: $r = .40$, $p < .001$; T2: $r = .39$, $p < .001$), no further regression analysis was conducted to explore the unique effect of vocabulary on reading in Chinese.

Vocabulary has been found to be a significant predictor of reading in several studies. Wang et al. (2015) tested 73 kindergarten children (average age: 5;02 years) from Beijing in a concurrent study. A multiple stepwise regression showed that vocabulary significantly predicted reading after controlling for age, IQ, spelling skills, and radical skills.

Findings differ in different age groups: McBride-Chang, Shu, Zhou, Wat and Wagner (2003) tested 100 kindergarten children (average age: 5;03 years) and 100 Grade 2 primary school children (average age: 7;03 years) in a concurrent study. Although vocabulary was a significant predictor of reading in kindergarten children ($r = .48$, $p < .001$), it was not a significant concurrent predictor of reading in primary school aged children after controlling for age, visual skills, speed ability (visual matching and cross out: Woodcock & Johnson, 1989), syllable deletion, onset deletion, RAN, morpheme identification, and morphological construction ($r = .36$, $p < .001$).

Unlike McBride-Chang et al. (2003), Shu et al. (2008) did not find vocabulary to be a significant predictor of reading in their study of 202 kindergarten children aged from 3;04 to 6;06 years old after controlling for age, rime detection, syllable deletion, tone detection, and RAN (K1: $r = .30$, $p < .05$; K2: $r = .38$, $p < .01$; K3: $r = .36$, $p < .01$). Unlike the studies mentioned above, the vocabulary test in this study tapped receptive vocabulary as it asked children to select one of four pictures that showed the meaning of a target word. It can be explained that understanding the meaning of a word is not a unique predictor of reading; instead, the ability to explain the meaning is the unique predictor of reading.

This significant predictive relationship between vocabulary (word definition) and reading has also been found in longitudinal studies. Hu (2012) assessed 94 Taiwanese children (average age: 8;09 years) in a 2-year concurrent and longitudinal study. Vocabulary measured in Grade 3 was a concurrent and longitudinal predictor of reading in Grade 3 and Grade 5 after controlling for age, digit span, and Taiwanese accent.

Consistent with these findings, Pan et al. (2011) found a significant effect of vocabulary on reading in a 5-year longitudinal study. Two hundred and sixty-two Beijing children (average age: 5;05 years) completed tests of vocabulary at age 5 and tests of word reading once a year from age 7 to 10. The correlations were .32, .32, .32, and .26 ($p < .01$) at age 7 to 10 respectively. Vocabulary measured at age 5 was a significant longitudinal predictor of word reading measured at age 8 to 10 after controlling for age, IQ, phonological awareness, RAN, Pinyin spelling, and early word reading at age 5. However, this significant relationship was only found at age 7 when controlling for limited variables (age, IQ, and early word reading at age 5); it was no longer significant when controlling for syllable deletion, RAN, and Pinyin spelling. Thus, these variables contributed so much variance to this model that vocabulary added little to it.

Pan et al. (2011) also gave children a spelling test at the age of 9 and 10. The results showed that with age, IQ, early word reading at age 5, phonological awareness, RAN, and Pinyin spelling controlled, vocabulary was a significant predictor of word spelling at the age of nine ($r=.29$, $p < .01$), but not at ten ($r=.19$, $p < .01$). In other words, vocabulary was not a reliable predictor of spelling in Chinese.

In line with this, Tong et al. (2009) also reported that vocabulary was not a concurrent or longitudinal predictor of spelling in Chinese. One hundred and seventy-one kindergarten children (average age: 6;02 years) from Hong Kong participated in this 1-year longitudinal study. Although vocabulary at age 6 was significantly associated with spelling at age 6 ($r= .26$, $p < .01$) and age 7 ($r= .15$, $.05 < p < .10$), it was not a unique predictor of spelling when age was controlled.

In summary, vocabulary is found to be closely associated with reading, but contributes little variance to spelling in Chinese. However, few studies have examined vocabulary as a predictor of Chinese literacy skills with other variables controlled.

In this thesis, vocabulary is examined as a predictor of reading and spelling in a 2-year longitudinal study (see Chapter 2). Furthermore, a word learning study is conducted to explore the causal effect of semantic information on learning to read in Chinese (see Chapter 3).

1.4. Chapter Summary and Research Aims

A large number of studies have examined the predictors of reading and spelling in Chinese. Tone awareness, phonological awareness and visual skills appear to be significant predictors of reading in kindergarten children. In contrast, morphological awareness predicts more variance in reading in the later grades. RAN, Pinyin spelling, and vocabulary appear to be consistent predictors of reading across all grade levels. As the quantity of studies regarding Pinyin knowledge and vocabulary is limited, more studies are needed to examine Pinyin knowledge and vocabulary as predictors of reading in Chinese.

Fewer studies have examined the predictors of spelling in Chinese. RAN and visual skills appear to be consistent predictors of spelling. In contrast, phonological awareness, morphological awareness, and vocabulary do not appear to be reliable predictors of spelling. Few studies have examined the effect of tone awareness and Pinyin knowledge on spelling.

Most of the existing studies were conducted in Hong Kong. There have been insufficient longitudinal studies that examine a large range of cognitive skills in Mainland China where Mandarin and simplified scripts are widely used.

Moreover, few studies have tapped the mechanism of reading and spelling, or explored predictors of learning to read and spell in Chinese.

In this thesis, four studies are reported which address these gaps in current understanding of learning to read and spell in Chinese:

1. To examine a large range of cognitive skills as predictors of learning to read and spell in Chinese in Mainland China. A 2-year longitudinal study examines phonological awareness, tone awareness, morphological awareness, visual skills, RAN, Pinyin knowledge, and vocabulary as predictors of learning to read and spell in Beijing, China
2. To tap the mechanism of reading and spelling, a paired association learning (PAL) study examines four PAL tasks (visual-verbal, visual-visual, verbal-visual, and verbal-verbal) as predictors of learning to read and spell in Chinese.
3. To explore the causal relationships between phonological and semantic knowledge and learning to read, a word learning study was conducted. Children's performance in different training groups indicate the effect of phonological and semantic knowledge on learning to read in Chinese.
4. To explore the causal relationships between Pinyin knowledge and learning to read and spell, a Pinyin training study was conducted. Children's performance in different training groups indicate the effect of Pinyin knowledge on learning to reading and spell.

Chapter Two

Cognitive Skills as Predictors of Learning to Read and Spell Chinese Characters

2.1. Introduction

As reported in Chapter 1, a number of studies have examined a range of cognitive skills (i.e. phonological awareness, tone awareness, morphological awareness, visual skills, RAN, Pinyin knowledge, and vocabulary knowledge) as possible predictors of individual differences in learning to read and spell in Chinese. However, relatively few studies have used a longitudinal design, and studies that have included a wide range of theoretically critical measures are rare. This Chapter presents a large-scale longitudinal study of early literacy development in Beijing, China. Three hundred and two primary school children from Grade 1 (mean age 6 years, 10 months) were assessed 4 times on measures of cognitive and literacy skills at 6-month intervals. Of these children, 155 were followed up again (T5) 6 months after T4. The results of this study have important educational implications for how to identify children who may be at risk of developing reading and spelling problems and for how best to teach reading and spelling in Chinese

This Chapter begins with a brief review of previous studies that have examined the cognitive predictors of reading and spelling in Chinese before describing the current study.

2.1.1. Phonological Awareness

It is generally accepted that phoneme awareness is a concurrent and longitudinal predictor of learning to read and spell in alphabetic languages (e.g. English: Muter et al., 2004; Norwegian: Lervag et al., 2009). Although phoneme awareness does not predict Chinese literacy skills in Hong Kong children (Tong et al., 2009; Tong & McBride-Chang, 2010), few studies that include tests of phoneme manipulation have been conducted in Mainland China. Differences in the way these two groups of children are taught to read may lead to different patterns of predictors. Specifically, children in Mainland China learn Pinyin as an auxiliary phonetic tool at the start of formal literacy instruction, whereas children in Hong Kong do not. Due to its nature, learning Pinyin may boost phonological skills (McBride-Chang et al., 2010; Shu et al., 2008); thus, it is possible that phoneme awareness may play a more important role in children's literacy acquisition in Mainland China than in Hong Kong.

Whilst phoneme awareness is critical for literacy development in alphabetic languages (Caravolas et al., 2012, 2013; Lervag et al., 2009; Muter et al., 2004), the nature of the Chinese written language system (in which each Chinese character corresponds to one syllable) suggests a significant role for syllable awareness in the development of Chinese literacy skills. A number of studies have demonstrated that syllable deletion is a significant concurrent and longitudinal predictor of learning to read (Chen et al., 2009; Li et al., 2010; Lin et al., 2010) and spell (Pan et al., 2011; Tong et al., 2011) in Chinese. This measure has typically only been used with children in kindergarten and the early grades of primary school. Few studies have included syllable deletion as a measure of phonological awareness in children who are in Grade 2 of primary school or above (probably because performance on this task appears to reach a ceiling in older children).

The present study includes measures of phonological awareness at the syllable- (T1) and phoneme-level (onset-deletion; T2 to T5) as potential predictors of Chinese literacy skills in 6-8-year-old children in Mainland China.

2.1.2. Tone Awareness

Tone in linguistics refers to the pitch of a syllable. Differences in tone are an important feature in the Chinese phonological system. The same syllable can be inflected with a different tone to convey a different meaning in Chinese. As a result, awareness of tone is likely to play a significant role in Chinese literacy development. Consistent with this, tone awareness has been found to predict reading in kindergarten children (McBride-Chang et al., 2008; Shu et al., 2008). It does not, however, appear to predict reading in older (primary school-aged) children (McBride-Chang et al., 2010; Xue et al., 2012). It is possible that older children reach ceiling in tests of tone awareness. The present study examines tone awareness as a predictor of learning to read and spell in children from Grade 1 to 3.

2.1.3. Pinyin Knowledge

In Mainland China, Pinyin is taught at the start of formal literacy instruction to help children learn to read and spell. Pinyin is a written system for representing the pronunciation of a character, and is composed of an onset, a rime, and a tone. Therefore, a good understanding of Pinyin may improve both phonological awareness and tone awareness.

Although Pinyin is assumed to be crucial for literacy development in Chinese, few studies have examined Pinyin knowledge as a predictor of reading and spelling achievement after children have begun formal literacy instruction. Participants in most existing studies regarding Pinyin reading and spelling are kindergarten children who have not learnt Pinyin systematically (Lin et al., 2010; Pan et al., 2011; Wang et al., 2014). In these studies, Pinyin letter reading is a concurrent predictor of word reading, but not word spelling (Wang et al., 2014); Pinyin spelling is both a concurrent (Lin et al., 2010) and longitudinal (Pan et al., 2011) predictor of word reading. However, few studies have examined the relationship between Pinyin knowledge and Chinese literacy acquisition using a large-scale longitudinal study in children who have started formal literacy instruction. The present study addresses this gap in the current literature by examining Pinyin letter reading, Pinyin word reading, and

Pinyin spelling as predictors of learning to read and spell in Chinese primary school-aged children.

2.1.4. Morphological Awareness

It is well-established that morphological awareness shows a stronger relationship with reading in proficient readers than beginners across languages (Kuo & Anderson, 2006), and it plays a more important role in reading comprehension than word reading in alphabetic languages (English: Carlisle, 1995; French: Casalis & Louis-Alexandre, 2000). Chinese words are typically composed of one to four characters, with most containing two characters. Each character represents a morpheme in Chinese. The meaning of a word in Chinese therefore typically depends on the combination of at least two morphemes in that word. Morpheme awareness is therefore likely to influence how well an individual understands the meaning of a word. As such, morphological awareness is assumed to be critical for learning to read and spell in Chinese. This was examined in a 3-year longitudinal study (Yeung et al. 2013) which tracked children from Grade 1 to Grade 4 in Hong Kong. In this study, morphological awareness was a concurrent and longitudinal predictor of reading, and was a concurrent, but not a longitudinal, predictor of spelling in primary school children after controlling for age, vocabulary, RAN, homophone judgment, phonological skills, and orthographic skills. This finding was questioned by a study conducted Hu (2012) who found phonological awareness predicted reading in early grades (Grade 1 and Grade 2), but morphological awareness played a more important role in reading ability in later grades (Grade 5). Hu’s study (2012) was conducted in Taiwan where Zhuyinfuhao was taught as a phonetic tool at the start of formal literacy instruction, which might make phonological awareness more important for early reading development. The present study examines morphological awareness alongside phonological awareness as predictors of Chinese literacy skills in Mainland China where children are taught Pinyin as a phonetic tool. A similar pattern of results to that found in Hu (2012) may therefore be expected.

2.1.5. Visual Skills

Unlike alphabetic languages which are represented by letters, the Chinese language is represented by a series of characters. These are composed of complex strokes that have evolved from pictures. Some characters differ only to a small degree in visual form; the meanings, however, differ greatly (e.g. 尤 /you2/ means especially; 无 /wu2/ means none; 龙 /long2/ means dragon). As such, visual skills may play a more important role in learning to read in Chinese than in alphabetic languages. A study by Tong et al. (2011) supports this idea: visual spatial skills were a significant longitudinal predictor of Chinese reading and spelling over 2 years in kindergarten children. This predictive relationship appears to depend, however, on the age (and educational level) of the children studied: Siok and Fletcher (2001) reported that visual spatial skills predicted more than 11% of the variance in character reading in Grade 1 and Grade 2, but predicted little variance in later grades in primary school. One potential explanation for this is that children use different learning strategies in different stages of reading development: where younger children may be inclined to learn a character holistically as a picture (making visual skills important for reading acquisition), more proficient readers with greater exposure to literacy instruction may rely more on orthographic skills (dividing a character into separate radicals rather than seeing it as a picture. E.g. 鸣 tweet can be divided into 口 (a radical) mouth and 鸟 (a radical) bird). The present study uses a longitudinal design to track children from Grade 1 to Grade 3, looking at the influence of visual skills on Chinese reading and spelling at different developmental stages.

2.1.6. RAN

Rapid Automatic Naming (RAN) is considered to reflect the speed of retrieval of phonological information (Bowey, 2005) and visual processing (Wolf and Bowers, 1999). RAN is a unique predictor of reading accuracy in alphabetic languages (English, Spanish, Czech, and Slovak) with phonological awareness and visual skills controlled (Caravolas et al., 2012). It also appears to be a reliable unique predictor of reading and spelling in Chinese across ages from 3 to 12 years old in concurrent (Chen et al., 2009; Shu et al., 2008; McBride-Chang et al., 2008; Xue et al., 2012) and longitudinal studies (Tong et al., 2009; Yeung et al., 2011). However, when the autoregressive effects of early reading/spelling ability are included in the regression model, RAN no longer appears to predict later reading/spelling skills in Chinese (Lo et al., 2015). The role of RAN in Chinese reading and spelling is examined further in this study.

2.1.7. Vocabulary

Relative to phonological awareness, vocabulary has a weaker relationship with word reading in English. In a study by Ricketts, Nation, and Bishop (2007), vocabulary was a concurrent predictor of exception word reading (i.e. words with irregular phoneme-grapheme correspondence, such as ‘yacht’), but did not predict regular word reading, nonword reading, or text reading accuracy. It is likely that semantic information provides top-down support for learning to read words; this support is especially important for learning to read exception words which cannot be read using phonological decoding and is less important for reading words that follow consistent spelling-sound patterns (for which phonological awareness is important).

Unlike alphabetic languages, most Chinese characters cannot be decoded from their orthographies (unless a character is a standard phonogram which can be decoded by its radical). Semantic information may potentially provide top-down support for reading Chinese characters, and there is growing interest in the role of vocabulary in the development of Chinese literacy skills.

In line with this, vocabulary appears to be a concurrent and longitudinal predictor of reading with age, digit span, and Taiwanese accent controlled (Hu 2012), and with age, IQ, spelling skills, and radical skills controlled (Wang et al., 2015). However, this significant effect disappeared if early reading ability and phonological awareness were included (Pan et al., 2011). Furthermore, there is little evidence that vocabulary predicts spelling in kindergarten children (Tong et al., 2009). The relationship between vocabulary and Chinese literacy development has yet to be studied in children who are 6 to 8 years old and who are therefore at a critical stage of literacy development. The present study extends earlier work by examining vocabulary as a predictor of Chinese literacy skills in a large sample of children who were followed from age 6 to 8.

2.1.8. Aims and Predictions of the Present Study

Previous studies have examined numerous cognitive skills as predictors of Chinese literacy skills in different age groups; however, many of these studies are limited by failing to include potentially critical measures, failing to account for autoregressive effects in regression models, and by the limited age range in some samples. The present study aims to address these limitations by studying the development of reading and spelling skills in a sample of children (aged 6 years old at the first assessment) in a 2-year longitudinal study. A comprehensive range of potential predictors of reading and spelling are examined; namely, phonological awareness (syllable- and phoneme-level), tone awareness, morphological awareness, visual skills, RAN, Pinyin knowledge, and vocabulary knowledge. Based on previous studies, it is predicted that:

1) Pinyin spelling, vocabulary, and RAN will predict Chinese literacy skills.

2) Phonological awareness and visual skills will predict reading and spelling in the early stages of literacy development.

3) Morphological awareness will predict reading and spelling in the later grades.

2.2. Method

2.2.1. Participants

Three hundred and eleven children were included at T1, when the children were aged 6 years 10 months. Across the 2-year study, 9 children were lost from the sample due to moving to another school. The remaining 302 children (84 boys) were assessed with tests of cognitive skills, reading ability, and spelling ability. This study reports the data only from the 302 children who participated at each time point. The average age of the 302 children was 6;10 (years; months; SD=0;06), 7;05 (SD=0;05), 7;11 (SD=0;06), 8;05 (SD=0;05) at T1, T2, T3， and T4 respectively. Of the 302 children, 155 (84 boys) were followed up at T5 when their average age was 9 years 3 months (SD=0;05).

All participants were native Mandarin speakers from 2 public primary schools in Beijing, China. Based on teacher reports, all the children were developing typically and none had diagnosed learning difficulties.

All testing was conducted in school. Pinyin spelling and word spelling tests were administered to whole-class groups of roughly 30 children. The remaining tests were individually administered. At each time point, individual testing was conducted in 2 sessions of approximately one hour, completed one week apart. Tests were given in a fixed order to all children.

2.2.2. Measures

A battery of tests were used to assess phonological awareness (syllable deletion and onset deletion), tone awareness (tone discrimination), morphological awareness (morphological construction), visual skills (visual discrimination and visual memory), Pinyin knowledge (rapid Pinyin reading, rapid Pinyin letter reading, and Pinyin spelling), RAN, vocabulary, Chinese word reading, and Chinese word spelling.

2.2.2.1. Phonological Awareness

Syllable and phoneme (onset) deletion (T1). A combined syllable- and phoneme (onset) deletion test measured children's phonological awareness (McBride-Chang et al., 2003) at T1. The syllable deletion test consisted of 5 real words and 14 nonsense syllables (19 items in total). First, children were required to repeat the syllables to make sure that they heard them clearly, and then they were required to delete an initial, middle or final syllable from the word or nonsense word. For example, after repeating 红绿灯 /hong2lv4deng1/, children were asked to delete 红 /hong2/ when saying 红绿灯 /hong2lv4deng1/. The answer should be 绿灯 /lv4deng1/. The onset deletion test consisted of 7 trials. Children were required to repeat a syllable to make sure that they heard it clearly, and then they were required to delete an initial phoneme from this syllable. For example, after repeating 泼 /po1/, children were asked to delete an initial phoneme when saying 泼 /po1/. The answer should be 喔 /o1/. All syllables were two-phoneme syllables. For both tests, each correct answer was awarded 1 point. The maximum combined score was 26.

Onset deletion (T2-T5). Children completed a compound onset deletion test (McBride-Chang et al., 2003) at T2 to T5. At T2 and T3, this consisted of three parts: 1) a seven-trial single-syllable onset deletion test; 2) a seven-trial multiple-syllable onset deletion test; and 3) an eight-trial complex multiple-syllable onset deletion test. At T4, the complex multiple-syllable onset deletion test (3) was extended to include 5 additional trials (13 in total). This was further extended at T5, to include five more trials (18 in total). The single-syllable onset deletion test (1) at T2 to T5 was more difficult than at T1: with more multiple-phoneme syllables (specify the number at T1 and T2-T5). In the multiple-syllable onset deletion test (2), children were required to repeat a multiple-syllable word to make sure that they heard it clearly, and then they were required to delete an initial phoneme from this multiple-syllable word. For example, after repeating 申请 /shen1qing3/, children were asked to delete an initial phoneme when saying 申请 /shen1qing3/. The answer should be 恩请 /en1qing3/. In the complex multiple-syllable onset deletion test (3), children were required to repeat the multiple-syllable word to make sure that they heard it clearly, and then they were required to delete an initial phoneme from each syllable. For example, after repeating 申请 /shen1qing3/, children were asked to delete an initial phoneme of each syllable when saying 申请 /shen1qing3/. The answer should be 恩影 /en1ing3/. In each test, a correct answer was awarded 1 point. The maximum score was therefore 22 at T2 and T3, 27 at T4, and 32 at T5. The test was discontinued if a child provided 4 incorrect answers in any single part (e.g. if a child provided 4 incorrect answers in Part 1, he/she would not proceed to Part 2 or Part 3).

2.2.2.2. Tone Awareness

Tone awareness was measured at T1 only using a test of tone discrimination. This test was modelled after McBride-Chang et al. (2003). The original test was developed for Cantonese. As there are 9 pitches of tone in Cantonese, while only 5 pitches of tone in Mandarin, some trials were modified according to the phonological rules of Mandarin. The test comprised 3 practice trials followed by 24 test trials. Children heard four syllables (each of which were spoken twice), three of which were of the same tone and one which differed in tone. The child was required to select the syllable that had a different tone. For example, among 写 /xie3/, 耳 /er3/, 鸟 / niao3/, 象 /xiang4/, the syllable with a different tone should be 象 /xiang4/. Each correct answer was awarded 1 point. The maximum score of this test was 24.

2.2.2.3. Pinyin Knowledge

Pinyin knowledge was assessed using 3 measures: 1) rapid Pinyin reading, 2) rapid Pinyin letter reading, and 3) Pinyin spelling.

1) Rapid Pinyin reading (T1). Children were presented with 100 Pinyin words which were randomly selected from the book *Xinhua Chinese dictionary* (2011). Children were required to read as many words as possible within 30 seconds. Each correct Pinyin word was awarded 1 point (maximum score = 100).
2) Rapid Pinyin letter reading (T1). Children were presented with 100 Pinyin letters which were randomly selected from the book *Xinhua Chinese dictionary* (2011). Children were required to name as many letters as possible within 30 seconds. Each correct Pinyin letter was awarded 1 point (maximum score = 100).
3) Pinyin spelling (T1-T5). The Pinyin words were randomly selected from the book *Xinhua Chinese dictionary* (2011). Children heard the spoken form of Pinyin words and were asked to write them down. Each correct word spelled correctly was awarded 1 point. Any error on onset, rime, or tone was penalized. The number of test items at T1-T3 was 20; this was increased at T4 to 26, and at T5 to 31.

2.2.2.4. Morphological Awareness

Morphological awareness was assessed using a morphological construction task (McBride-Chang et al., 2003). In this task, children listened to 2 spoken sentences. The first sentence described a familiar word as a morphological cue. The second sentence described a novel object or concept for which children were required to construct a compound word based on a morphological cue. For example, 'If a ball played with a foot is called '足球' (football), what should we call a ball which is played with the mouth?' The answer should be '嘴球' (mouthball). The test was discontinued when the child failed to provide correct answers on 4 consecutive trials. Each correct answer was awarded 1 point. The task included 27 trials at T1-T3; this was extended to 32 trials at T4, and to 37 trials at T5.

2.2.2.5. Visual Skills

Visual skills were assessed using 1) a visual discrimination task, and 2) a visual memory task; both of these tasks were modified from Gardner's visual test (Gardner, 1996).

1) Visual discrimination (T1-T5). On each trial, a target shape was presented alongside five alternative choices on a computer screen. Children were required to select which one of the five shapes was the same as the target shape. Distractor shapes look very similar to the target. They were allowed 6 seconds to respond on each trial. Each correct answer was awarded 1 point. At T1-T3 there we 20 items; this was extended to 25 items at T4, and 30 items at T5.

2) Visual memory (T1). Stimuli in this task were the same as those in the visual discrimination test. On each trial, a target shape was presented on a computer screen for 2 seconds. After it disappeared, children were required to select which one of five shapes was the same as the target shape. They were allowed 6 seconds to respond on each trial, with 20 trials presented in total. Each correct answer was awarded 1 point.

2.2.2.6. RAN (T1-T5)

In this task, children were presented with a 5*5 matrix on paper of five digits: 1, 2, 5, 6, and 8 (Denckla & Rudel, 1976). Children were required to name the digits from left to right and from top to bottom as rapidly and accurately as possible. Response time was recorded in seconds.

2.2.2.7. Vocabulary (T1-T5)

Vocabulary was assessed using a test from McBride-Chang et al. (2003). Children were required to give the meaning of each word they heard. The score for each trial was 0, 1, or 2 according to the accuracy of the explanation. The scoring criterion followed McBride-Chang et al. (2003). Only the verbal responses were scored. The maximum score of this test was 106 (53 items) at T1 to T4, and 126 (63 items) at T5.

2.2.2.8. Chinese Word Reading (T1-T5)

At T1 and T2, 150 two-character words from a test of McBride-Chang et al. (2003) were given to the children to read. To avoid ceiling effects, the number of words used in the reading test was extended to 170 at T3, 190 at T4, and 210 at T5. These new words were randomly selected from the book *Chinese Textbook* (2004, 2005, an official Chinese teaching material for primary schools in Beijing) in Grade 4 to 5. The order of the words is from easy to difficult. Children were required to read the words from top to bottom and from left to right. Each correct answer was awarded 1 point. The 150-word reading test would stop if a child failed to read 15 consecutive trials. All children were asked to read the new words at T3, T4, and T5. The maximum score was 150 at T1 and T2, 170 at T3, 190 at T4, and 210 at T5.

2.2.2.9. Chinese Word Spelling (T2-T5)

There were 48 two-character words (McBride-Chang et al., 2003). Children were required to write down the words that they heard and were asked to attempt to write all words (48 at T2 to T4; 58 at T5). Each correct character was awarded 1 point. All errors in writing were penalised. The maximum score of this test was 96 at T2 to T4, and 116 at T5.

2.3. Results

2.3.1. Descriptive Statistics

Table 2.1 presents the means, standard deviations, and ranges of scores on all measures from T1 to T4 (N=302), and T5 (N=155). All measures were well distributed without floor or ceiling effects.

Table 2.1. Means, Standard Deviations, and Ranges for the Measures at T1 to T5

	T1			T2			T3			T4			T5		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age[a]	82.17	6.06	69.57-111.53	88.54	5.21	77.33-116.53	94.79	6.03	82.07-125.08	101.23	5.20	90.14-129.40	111.03	5.38	101.03-137.65
Chinese word reading	52.19	40.93	0-144	79.62	35.23	9-146	109.18	35.45	17-184	131.97	33.44	39-188	165.40	28.41	17-210
Chinese word spelling	N/A	N/A	N/A	24.35	11.50	0-63	40.51	15.09	7-76	53.17	15.37	11-87	72.74	15.68	8-105
RAN[b]	16.78	5.86	7.9-44.0	10.99	3.17	5.6-23.3	10.34	2.73	5.0-20.9	9.54	2.31	5.0-21.3	8.48	1.89	4.3-13.1
Rapid Pinyin letter reading	18.23	8.73	0-61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rapid Pinyin reading	6.84	6.19	0-31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pinyin spelling	10.74	7.25	0-20	14.16	4.79	0-20	14.89	4.21	1-20	20.17	5.06	2-26	24.05	4.78	3-31

Visual discrimination	15.12	2.80	5-20	16.72	1.98	6-20	17.98	1.82	10-20	21.06	2.09	15-25	23.80	2.57	16-29
Visual memory	10.83	3.00	0-18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Syllable deletion and onset deletion	20.07	6.33	0-26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Onset deletion	N/A	N/A	N/A	12.97	6.61	0-22	16.53	5.36	0-22	20.88	5.97	2-27	25.21	7.02	2-32
Tone discrimination	13.71	7.42	0-24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Morphological construction	18.27	6.59	0-27	22.98	3.79	1-27	23.34	3.18	10-27	26.38	4.73	9-32	32.46	4.24	15-37
Vocabulary	30.87	13.15	2-73	43.61	16.87	4-102	58.17	19.26	18-106	67.89	20.62	16-106	82.74	19.99	28-116

Note. T1, T2, T3, T4: N=302 (166 boys); T5: N=155 (84 boys)

Measures are recorded in raw scores. RAN is the time to complete the task. [a] In months. [b] In seconds.

2.3.2. Correlations

Table 2.2.1 displays the correlations between age, reading-related cognitive skills, and Chinese word reading skills at T1. All cognitive skills were significantly correlated (correlations ranged from .143 to .415, $p < .05$) with Chinese word reading ability. The correlations between Chinese word reading and RAN, Pinyin spelling, syllable and onset deletion, and vocabulary were strongest (.3 or above). The correlations among the ten reading-related cognitive skills and age ranged from .003 to .621. Only Pinyin reading, syllable and onset deletion, and morphological awareness were significantly correlated with both visual discrimination and visual memory. Morphological awareness was significantly correlated with RAN, visual discrimination, visual memory, syllable and onset deletion, and vocabulary. Correlation coefficients among Pinyin spelling, Pinyin reading, Pinyin letter reading, syllable and onset deletion, tone discrimination, and vocabulary were all significant.

From T2 to T5, word spelling was included in the study, four cognitive skills (tone discrimination, Pinyin letter reading, Pinyin reading, and visual memory) were excluded, and a syllable and onset deletion test was changed to an onset deletion test. Table 2.2.2, Table 2.2.3, Table 2.2.4, and Table 2.2.5 respectively display the correlations between age, six reading/spelling-related cognitive skills, word reading and word spelling at T2, T3, T4, and T5. All cognitive skills were significantly correlated with word reading (correlations ranged from .165 to .629) and word spelling ability (correlations ranged from .140 to .637) except for visual discrimination at T3 (reading: $r = .111$; spelling: $r = .054$). Correlations among the cognitive skills ranged from .029 to .468. Correlations among onset deletion, morphological awareness, and vocabulary were all significant over four time points.

Table 2.2.6 displays the correlations between word reading and word spelling from T1 to T5. All measures of reading and spelling were strongly correlated, ranging from .437 to .910. Correlations between scores of reading from T1 to T5 were from 0.743 to .910, and scores of spelling were from .593 to .799.

Table 2.2.1. Correlations between Age, Chinese Word Reading, RAN, Pinyin Letter Reading, Pinyin Reading, Pinyin Spelling, Visual Discrimination, Visual Memory, Syllable and Onset Deletion, Tone Discrimination, Morphological Construction, and Vocabulary at T1

	1	2	3	4	5	6	7	8	9	10	11	12
1.Age[a]	--											
2.Chinese word reading	.240***	--										
3.RAN[b]	-.189***	-.373***	--									
4.Rapid Pinyin letter reading	.408***	.289***	-.332***	--								
5.Rapid Pinyin reading	.456***	.269***	-.317***	.605***	--							
6.Pinyin spelling	.528***	.406***	-.322***	.617***	.751***	--						
7.Visual discrimination	-.236**	.139*	-.032	-.125*	-.176**	-.114*	--					
8.Visual memory	.096	.163**	-.240***	.096	.145*	.198***	.237***	--				

9.Syllable deletion and onset deletion	.222***	.424***	-.350***	.400***	.405***	.529***	.144*	.279***	--			
10.Tone discrimination	.335***	.310***	-.181**	.388***	.479***	.620***	-.004	.166**	.438***	--		
11.Morphological construction	-.056	.237***	-.205***	.052	.080	.039	.245***	.181**	.273***	.045	--	
12.Vocabulary	.207***	.323***	-.216***	.184***	.182**	.214***	.080	.194***	.267***	.214***	.224***	--

Note. N=302 $^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$

Table 2.2.2. Correlations between Age, Chinese Word Reading, Chinese Word Spelling, RAN, Pinyin Spelling, Visual Discrimination, Onset Deletion, Morphological Construction, and Vocabulary at T2

	1	2	3	4	5	6	7	8	9
1.Age[a]	--								
2.Chinese word reading	.168**	--							
3.Chinese word spelling	.263***	.541***	--						
4.RAN[b]	.010	-.224***	-.146*	--					
5.Pinyin spelling	.181**	.319***	.482***	-.029	--				
6.Visual discrimination	.087	.205***	.203***	-.034	.202***	--			
7.Onset deletion	.176**	.345***	.327***	-.063	.315***	.172**	--		
8.Morphological construction	.144*	.329***	.230***	-.053	.157**	.190***	.243***	--	
9.Vocabulary	.141*	.396***	.228***	-.100	.054	.158**	.268***	.357***	--

Note. N=302 *p<.05; **p<.01; ***p<.001

Table 2.2.3. Correlations between Age, Chinese Word Reading, Chinese Word Spelling, RAN, Pinyin Spelling, Visual Discrimination, Onset Deletion, Morphological Construction, and Vocabulary at T3

	1	2	3	4	5	6	7	8	9
1.Age[a]	--								
2.Chinese word reading	.254***	--							
3.Chinese word spelling	.428***	.629***	--						
4.RAN[b]	-.187***	-.440***	-.465***	--					
5.Pinyin spelling	.229***	.455***	.494***	-.395***	--				
6.Visual discrimination	-.092	.111	.054	-.081	.244***	--			
7. Onset deletion	.204***	.384***	.384***	-.314***	.401***	.230***	--		
8.Morphological construction	.324***	.521***	.450***	-.337***	.305***	.035	.282***	--	
9.Vocabulary	.200***	.460***	.274***	-.188***	.098	.036	.287***	.255***	--

Note. N=302 *p<.05; **p<.01; ***p<.001

Table 2.2.4. Correlations between Age, Chinese Word Reading, Chinese Word Spelling, RAN, Pinyin Spelling, Visual Discrimination, Onset Deletion, Morphological Construction, and Vocabulary at T4

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1.Age[a]	--								
2.Chinese word reading	.207***	--							
3.Chinese word spelling	.197***	.615***	--						
4.RAN[b]	-.003	-.346***	-.391***	--					
5.Pinyin spelling	.128*	.493***	.545***	-.371***	--				
6.Visual discrimination	.047	.165**	.140*	-.107	.145*	--			
7. Onset deletion	.113*	.342***	.371***	-.280***	.388***	.222***	--		
8.Morphological construction	.291***	.502***	.547***	-.372***	.536***	.167**	.280***	--	
9.Vocabulary	.180**	.467***	.272***	-.031	.134*	.109	.262***	.312***	--

Note. N=302 *p<.05; **p<.01; ***p<.001

Table 2.2.5. Correlations between Age, Chinese Word Reading, Chinese Word Spelling, RAN, Pinyin Spelling, Visual Discrimination, Onset Deletion, Morphological Construction, and Vocabulary at T5

	1	2	3	4	5	6	7	8	9
1.Age[a]	--								
2.Chinese word reading	-.008	--							
3.Chinese word spelling	-.061	.507***	--						
4.RAN[b]	.065	-.331***	-.403***	--					
5.Pinyin spelling	.088	.387***	.637***	-.291***	--				
6.Visual discrimination	.067	.171*	.204*	-.112	.270***	--			
7. Onset deletion	.093	.305***	.392***	-.275***	.358***	.194*	--		
8.Morphological construction	.087	.356***	.579***	-.215**	.468***	.210**	.372***	--	
9.Vocabulary	-.019	.496***	.260***	-.154	.141	.123	.214**	.354***	--

Note. N=155 *p<.05; **p<.01; ***p<.001

Table 2.2.6. Correlations between the Reading and Spelling Tests at Each Time Point

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1.Chinese word reading(T1)	--								
2.Chinese word reading(T2)	.910***	--							
3.Chinese word reading(T3)	.823***	.903***	--						
4.Chinese word reading(T4)	.743***	.815***	.883***	--					
5.Chinese word reading(T5)	.693***	.754***	.762***	.794***	--				
6.Chinese word spelling (T2)	.538***	.541***	.549***	.571***	.487***				
7.Chinese word spelling (T3)	.547***	.565***	.629***	.623***	.445***	.799***	--		
8.Chinese word spelling (T4)	.522***	.555***	.568***	.615***	.503***	.751***	.822***	--	
9.Chinese word spelling (T5)	.437***	.510***	.574***	.601***	.507***	.593***	.734***	.798***	--

Note. T1, T2, T3, T4: N=302; T5: N=155 $^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$

2.3.3. Concurrent Predictors of Chinese Word Reading

To identify the most important concurrent cognitive predictors of Chinese word reading at each time point, we used a series of simultaneous regression models. First, all cognitive predictors of word reading were entered into five simultaneous regression models (one for each time point). In each model, the non-significant predictors with the smallest contribution were iteratively dropped to leave a model in which all predictors were statistically significant. These models for each time point are shown in Figure 2.1.1 to 2.1.5. Solid arrows represent statistically significant predictive relationships with the other predictors in the model controlled. Nonsignificant predictive relationships are not shown in the path diagrams. The arrow above the dependent variable represents the error variance, that is, the proportion of variance not predicted by the variables in the model.

At T1, five cognitive skills: RAN, pinyin spelling, visual discrimination, syllable and onset deletion, and vocabulary were significant predictors of word reading [$F(5,296) = 26.898$, $p < .001$] together these predictors accounted for 31%, of the variance in reading. At T2, five cognitive skills: RAN, pinyin spelling, onset deletion, morphological awareness, and vocabulary were significant predictors of word reading [$F(5,296) = 27.967$, $p < .001$] together these predictors accounted for 32%, of the variance in reading. At T3, four cognitive skills: RAN, pinyin spelling, morphological awareness, and vocabulary were significant predictors of word reading [$F(4,297) = 74.784$, $p < .001$] together these predictors accounted for 50%, of the variance in reading. At T4, four cognitive skills: RAN, pinyin spelling, morphological awareness, and vocabulary were significant predictors of word reading [$F(4,297) = 62.881$, $p < .001$] together these predictors accounted for 46%, of the variance in reading. At T5, three cognitive skills: RAN, pinyin spelling, and vocabulary were significant predictors of word reading [$F(3,151) = 30.818$, $p < .001$)] together these predictors accounted for 38%, of the variance in reading.

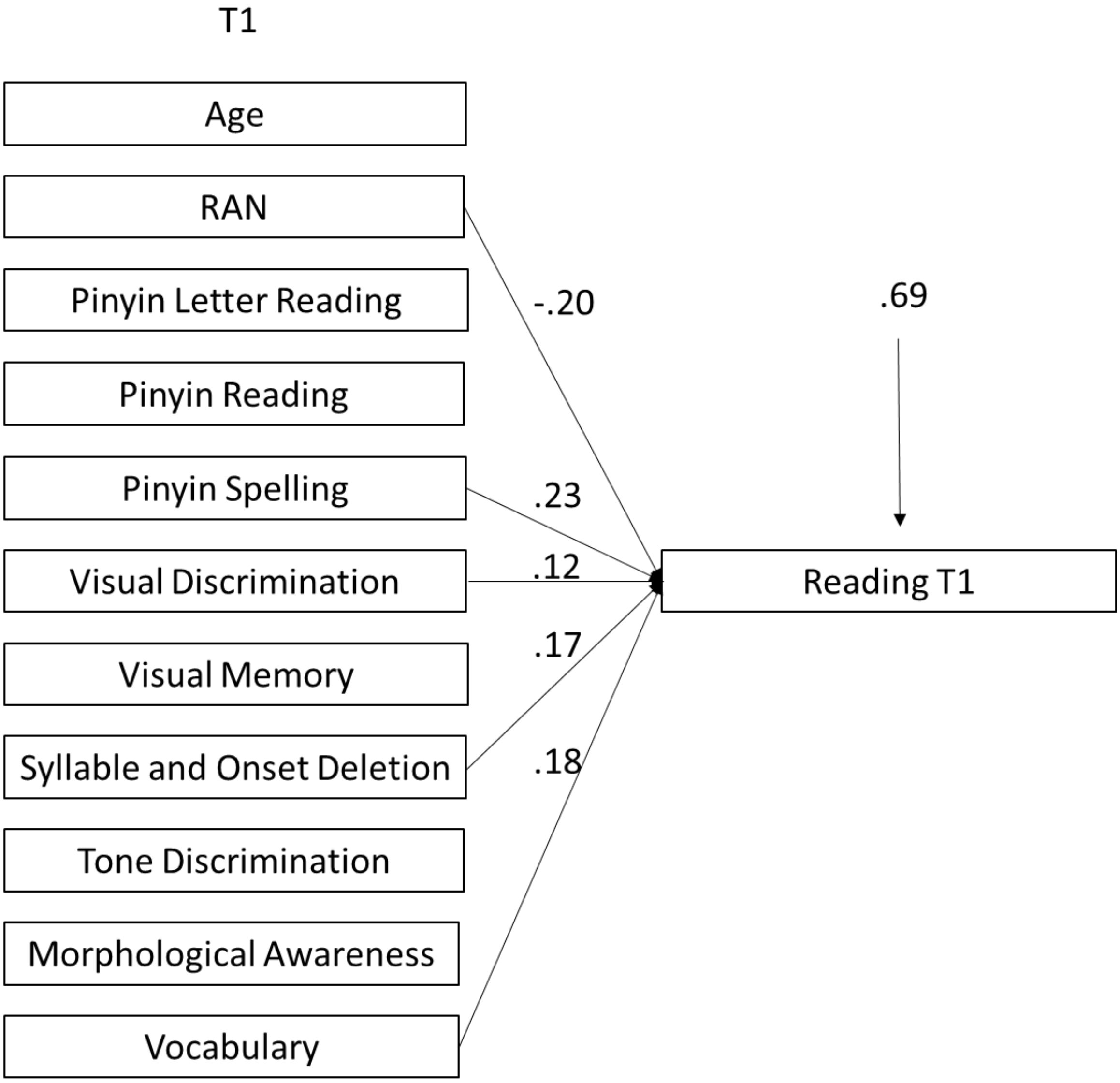


Figure 2.1.1. Path diagram showing concurrent predictors of reading accuracy at T1. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

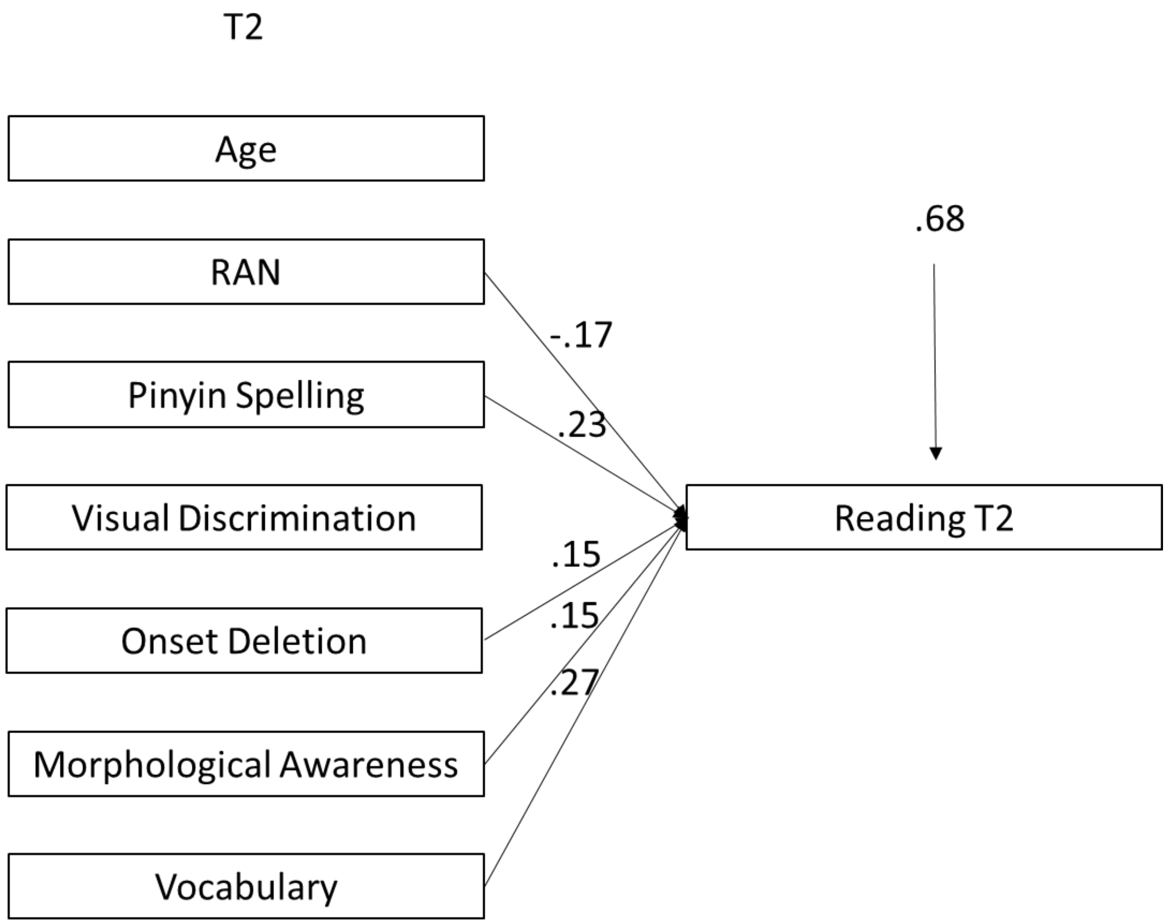


Figure 2.1.2. Path diagram showing concurrent predictors of reading accuracy at T2. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

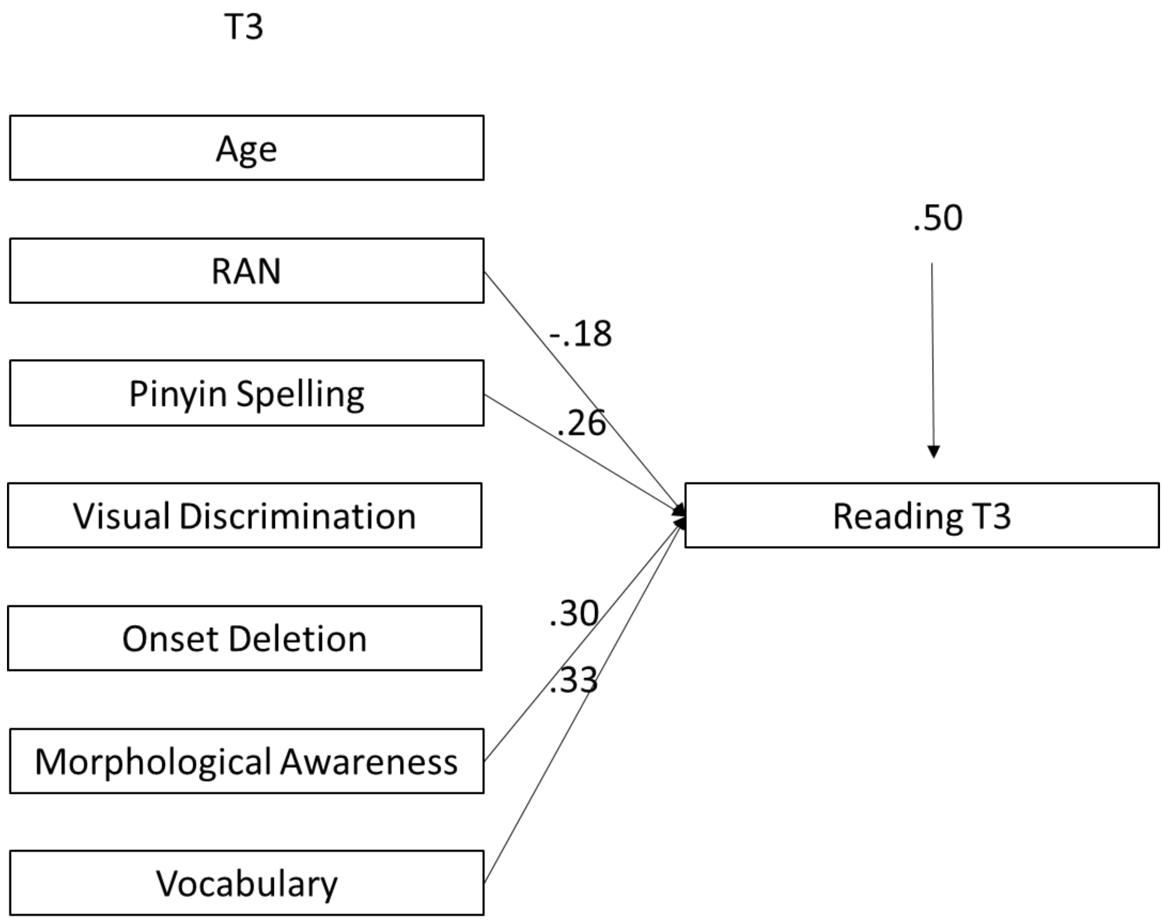


Figure 2.1.3. Path diagram showing concurrent predictors of reading accuracy at T3. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

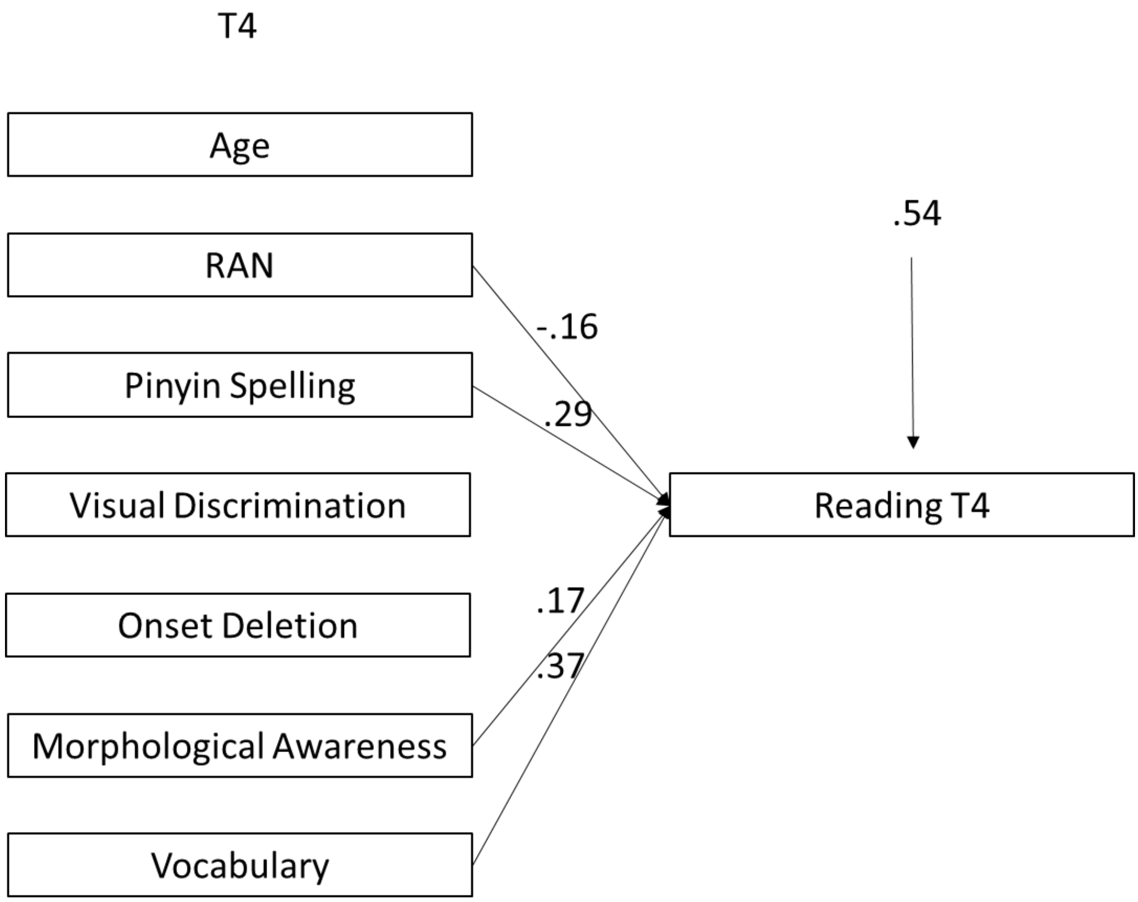


Figure 2.1.4. Path diagram showing concurrent predictors of reading accuracy at T4. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

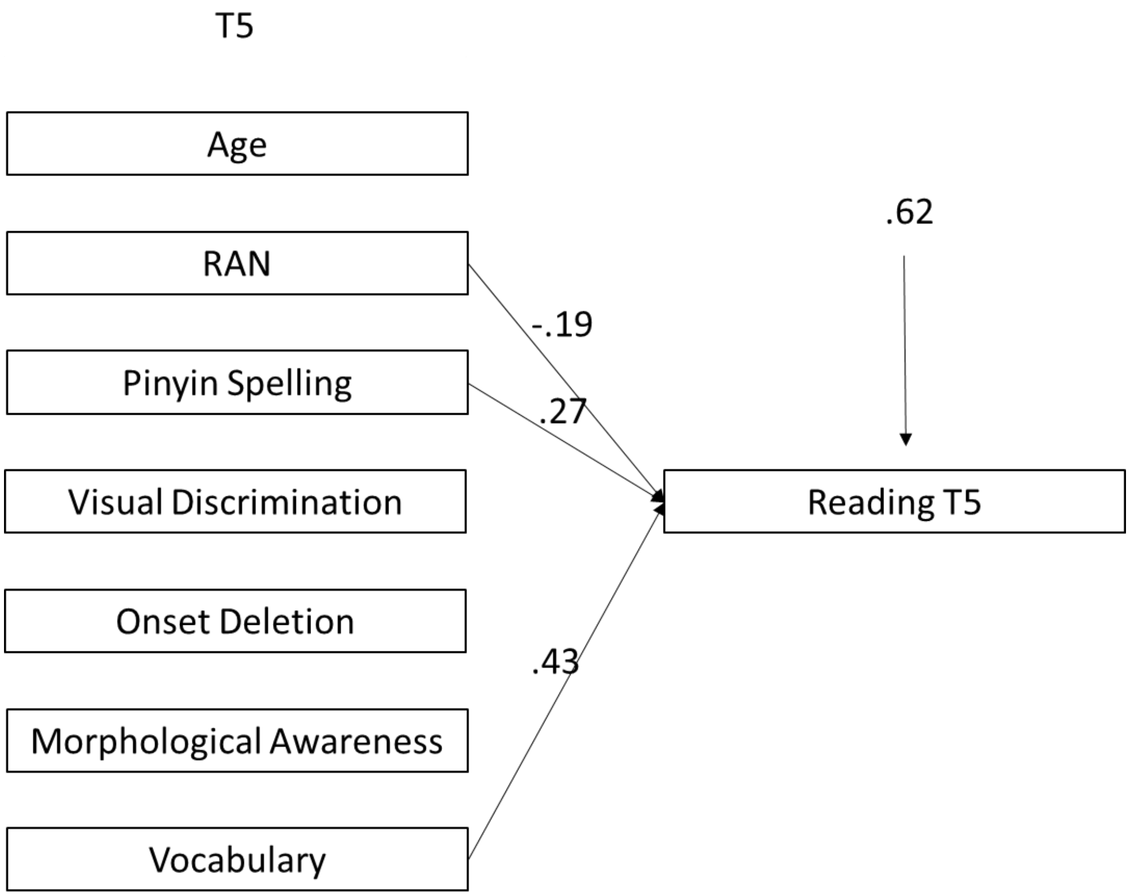


Figure 2.1.5. Path diagram showing concurrent predictors of reading accuracy at T5. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

2.3.4. Concurrent Predictors of Chinese Word Spelling

To identify the most important concurrent cognitive predictors of Chinese word spelling at each time point, we used a series of simultaneous regression models. The process of analysis was the same as that of word reading. First, all cognitive predictors of word spelling were entered into four simultaneous regression models (one for each time point). In each model, the non-significant predictors with the smallest contribution were iteratively dropped to leave a model in which all predictors were statistically significant. These models for each time point are shown in Figure 2.2.1 to 2.2.4 (spelling was only assessed from T2).

At T2, five cognitive skills: age, RAN, pinyin spelling, onset deletion, and vocabulary were significant predictors of word spelling [F (5,296) =28.401, $p < .001$] together these predictors accounted for 32%, of the variance in spelling. At T3, five cognitive skills: age, RAN, pinyin spelling, morphological awareness, and vocabulary were significant predictors of word spelling [F (5,296) =50.335, $p < .001$] together these predictors accounted for 46%, of the variance in spelling. At T4, five cognitive skills: RAN, pinyin spelling, onset deletion, morphological awareness, and vocabulary were significant predictors of word spelling [F (5,296) =45.603, $p < .001$] together these predictors accounted for 44%, of the variance in spelling. At T5, four cognitive skills: age, RAN, pinyin spelling, and morphological awareness were significant predictors of word spelling [F (4,150) =47.613, $p < .001$)] together these predictors accounted for 56%, of the variance in spelling.

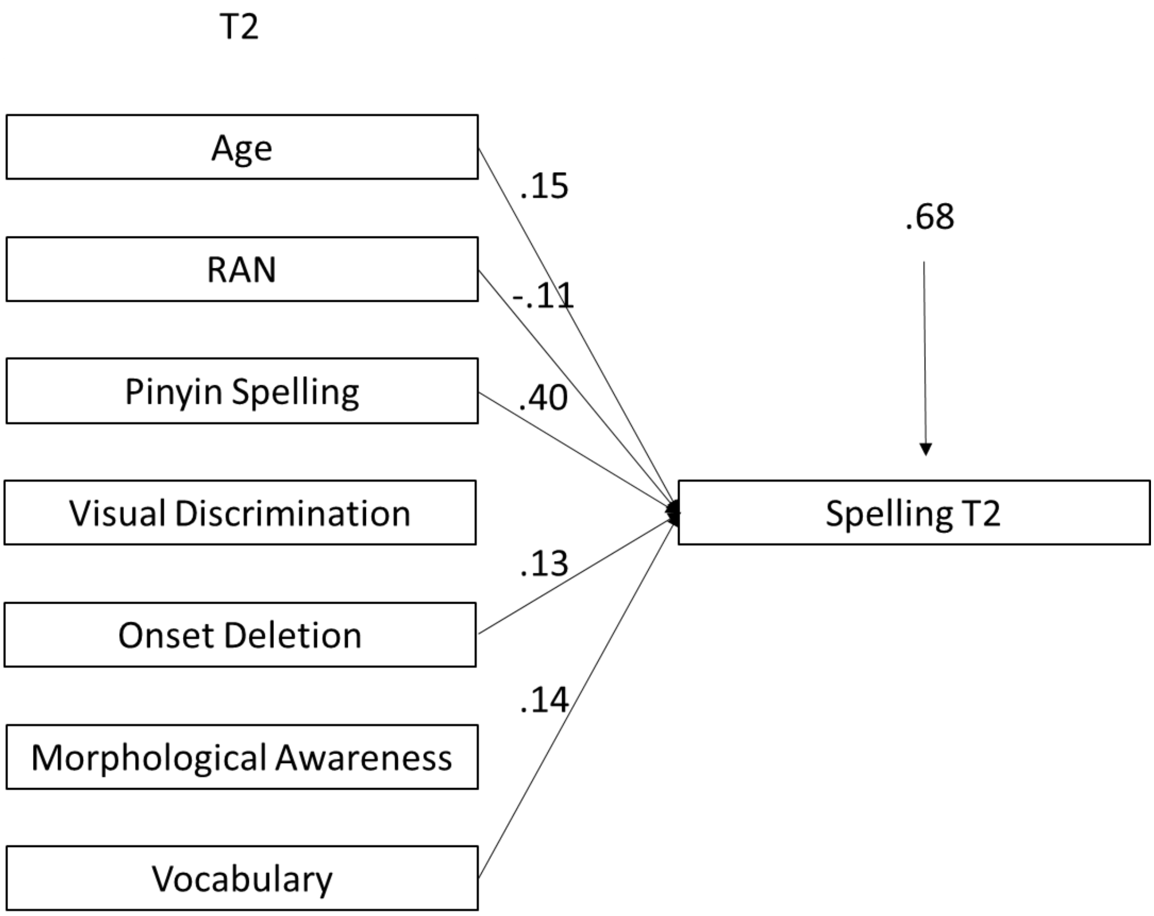


Figure 2.2.1. Path diagram showing concurrent predictors of spelling accuracy at T2. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

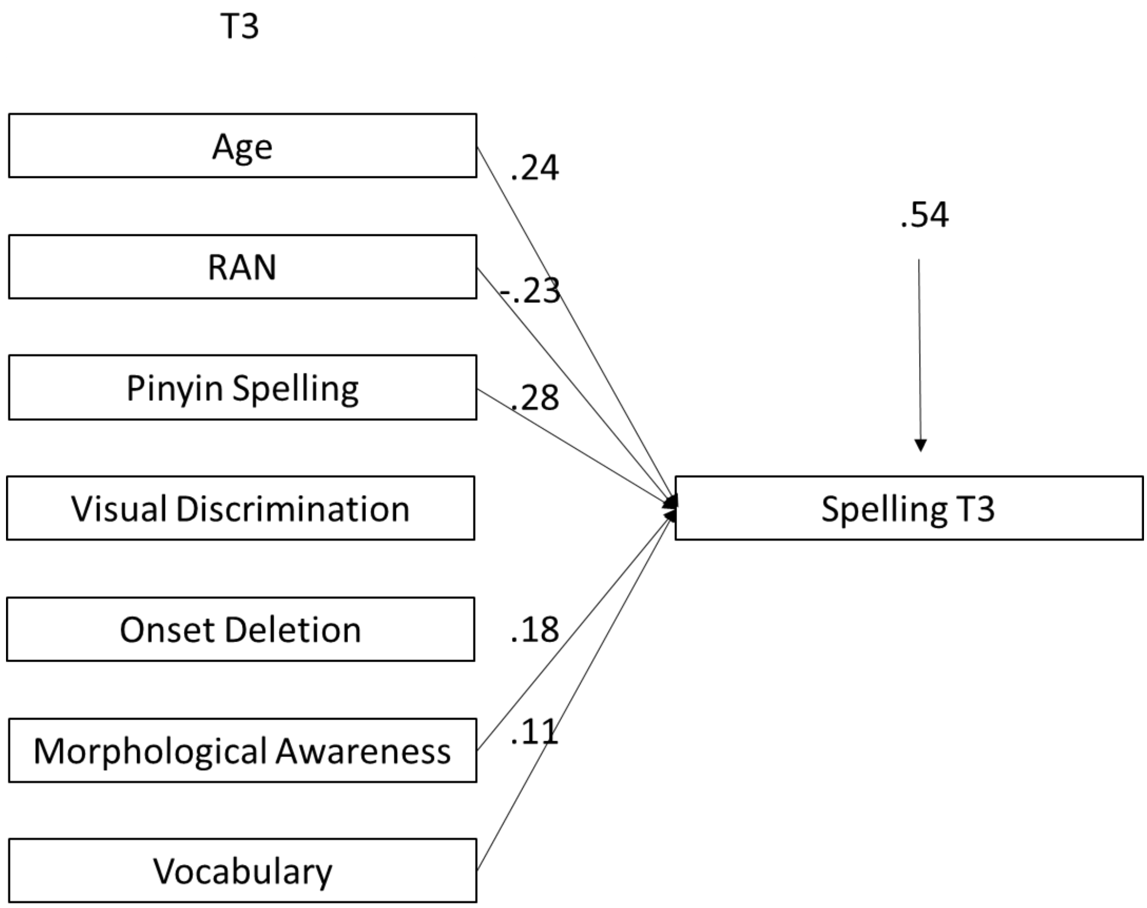


Figure 2.2.2. Path diagram showing concurrent predictors of spelling accuracy at T3. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

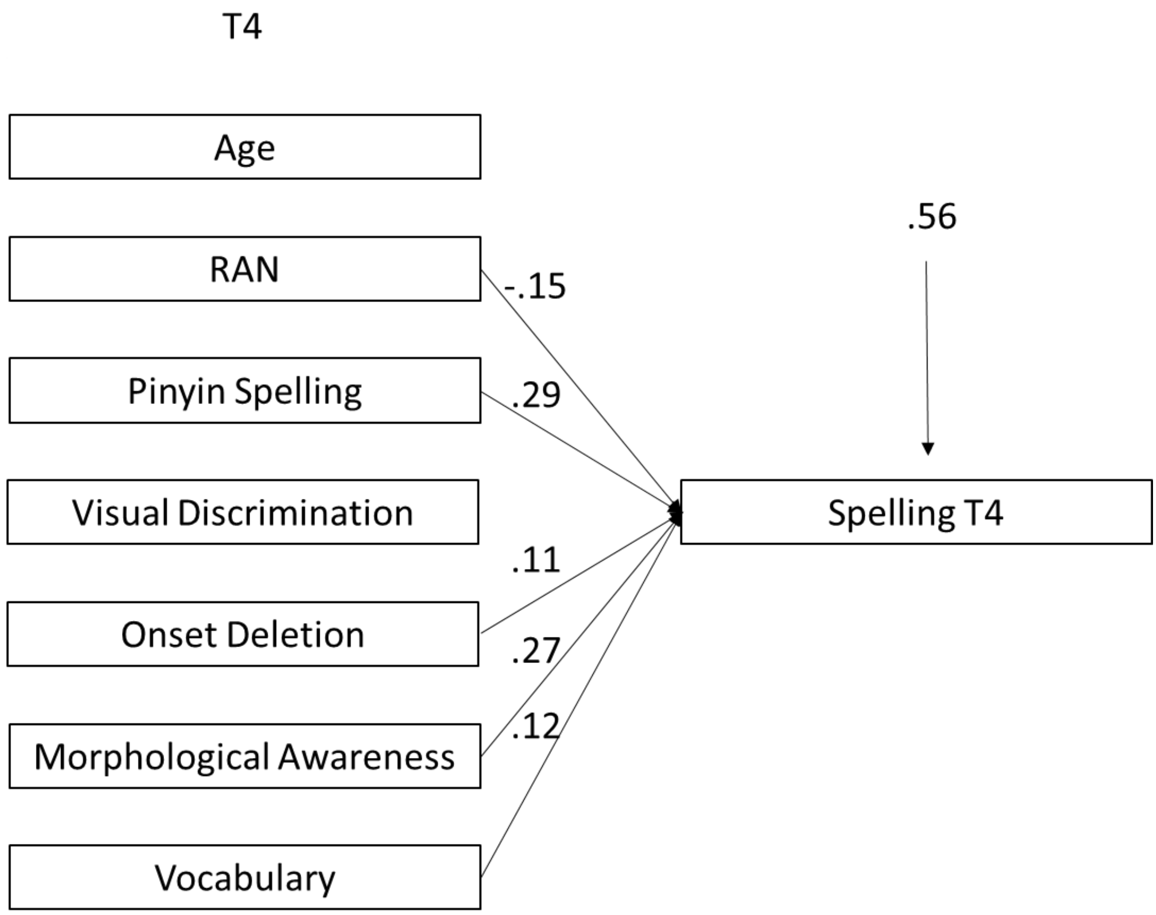


Figure 2.2.3. Path diagram showing concurrent predictors of spelling accuracy at T4. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

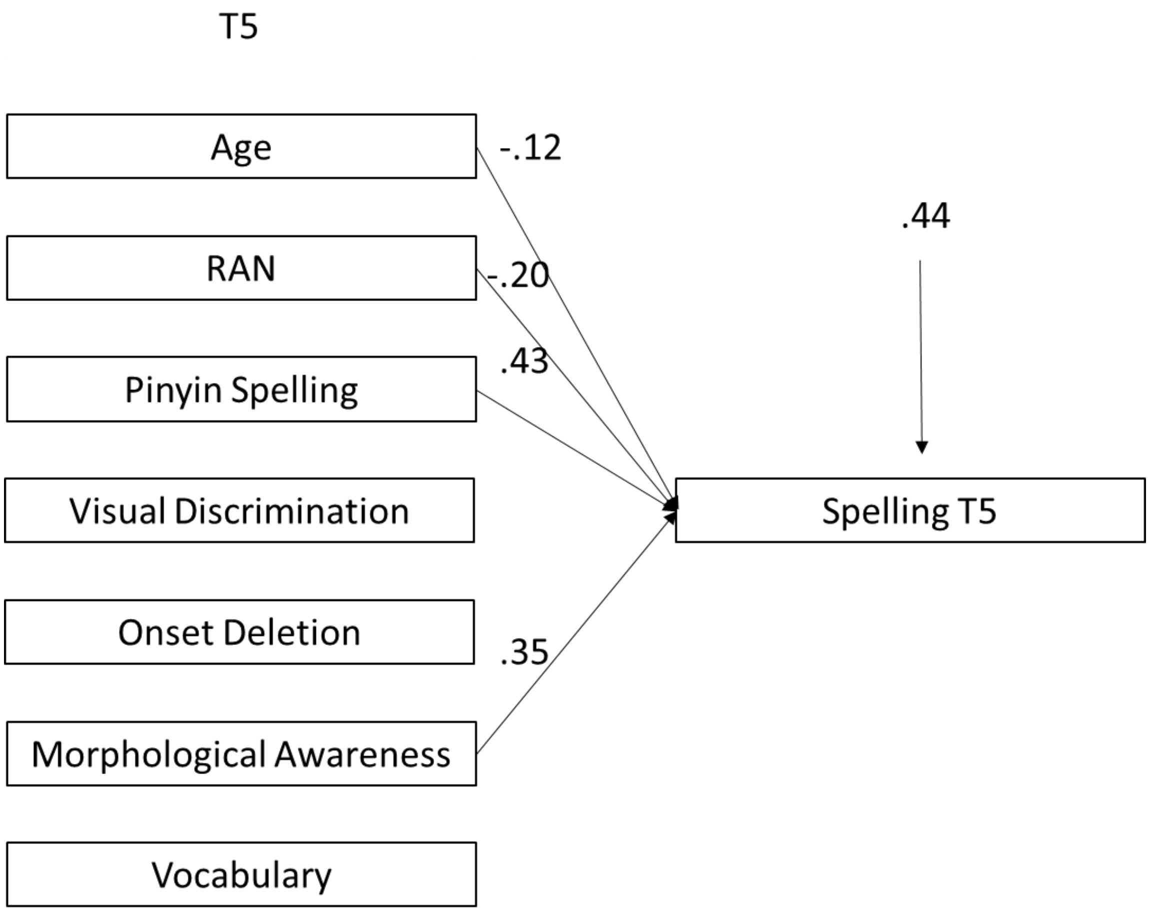


Figure 2.2.4. Path diagram showing concurrent predictors of spelling accuracy at T5. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

2.3.5. Longitudinal Predictors of Chinese Word Reading

To examine the degree of change in Chinese word reading between adjacent time points, and what explains that change, a set of simultaneous regression models were constructed with early Chinese word reading (the autoregressor) included. All cognitive predictors including the autoregressor were first entered in one step. In each model, the non-significant predictors with the smallest contribution were iteratively dropped to leave a model in which all predictors are statistically significant. These models for each time point are shown in Figure 2.3.1 to 2.3.4.

Two variables, RAN and word reading at T1 were significant predictors of word reading at T2 [F (2,299) =738.275, p< .001] together these predictors accounted for 83%, of the variance in reading. Two variables, Pinyin spelling and word reading at T2 were significant predictors of word reading at T3 [F (2,299) =677.448, p< .001] together these predictors accounted for 82%, of the variance in reading. Three variables, Pinyin spelling, vocabulary, and word reading at T3 were significant predictors of word reading at T4 [F (3,298) =395.611, p< .001] together these predictors accounted for 80%, of the variance in reading. Only the autoregressor was a unique predictor of Chinese word reading at T5 [F (1,153) =260.919, p< .001)]; word reading at T4 alone accounted for 63%, of the variance in reading at T5.

The autoregressive effects of earlier word reading on later word reading in models 2.3.1 to 2.3.4 are powerful, meaning that there is high stability in reading. Stability means that the rank order of children hardly changes over time. It seemed important therefore to explore the longitudinal cognitive predictors of Chinese word reading, in models which excluded the autoregressor. In these models, as before, all cognitive predictors were entered in one step and non-significant predictors with the smallest contribution were iteratively dropped to leave a model in which all predictors are statistically significant. These models for each time point are shown in Figure 2.4.1 to 2.4.4.

Five variables, RAN and Pinyin spelling, visual discrimination, syllable and onset deletion, and vocabulary at T1 were significant predictors of word reading at T2 [F (5,296) =28.591, p< .001] together these predictors accounted for 33%, of the variance in reading. Four variables, RAN, Pinyin spelling, onset deletion, and vocabulary at T2 were significant predictors of word reading at T3 [F (4,297) =30.736, p< .001] together these predictors accounted for 29%, of the variance in reading. Four variables, RAN, Pinyin spelling, morphological awareness, and vocabulary at T3 were significant predictors of word reading at T4 [F (4,297) =75.205, p< .001] together these predictors accounted for 50%, of the variance in reading. Three variables, RAN, Pinyin spelling, and vocabulary at T4 were significant predictors of word reading at T5 [F (3,151) =27.682, p< .001)] together these predictors accounted for 36%, of the variance in reading.

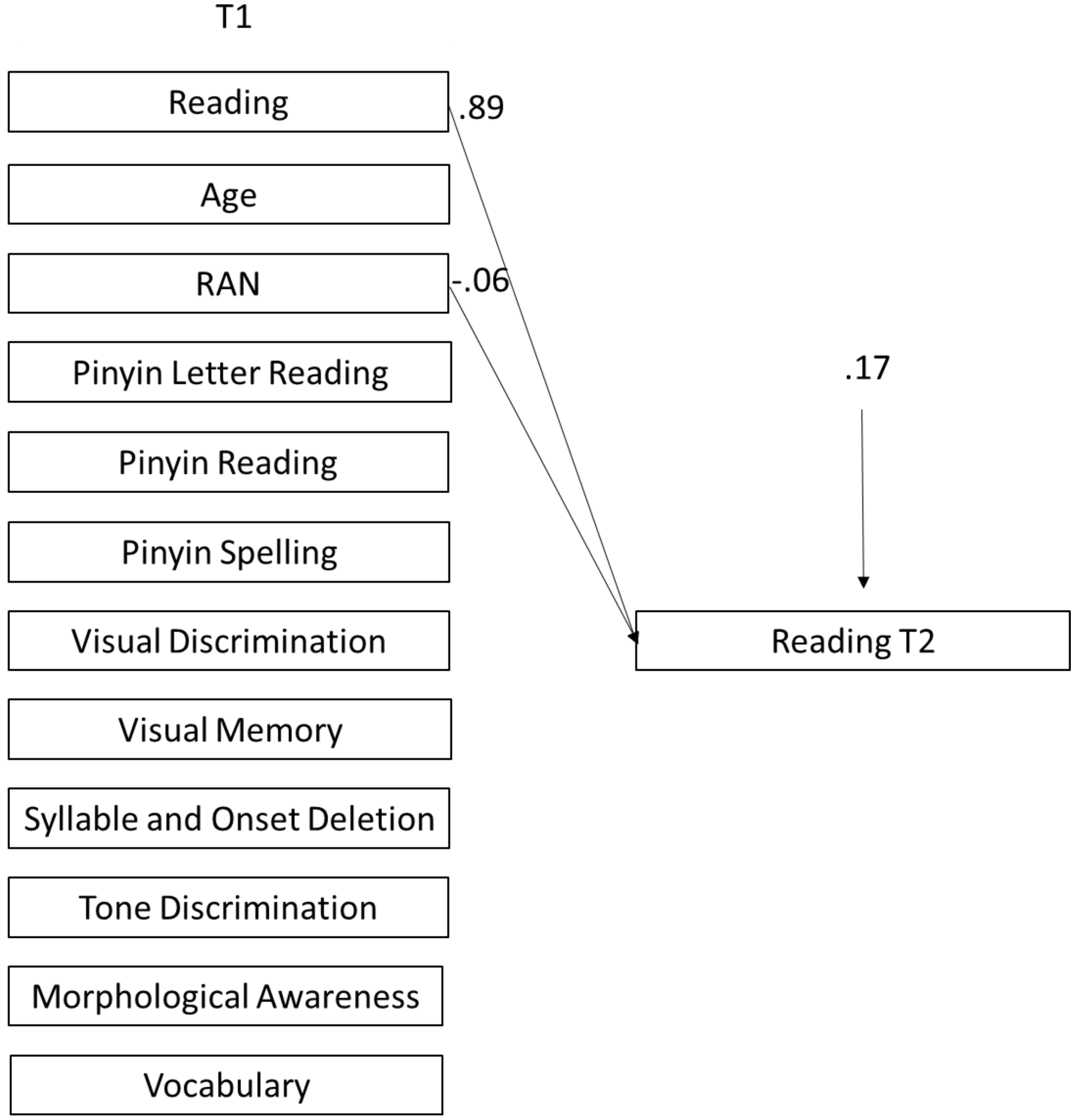


Figure 2.3.1. Path diagram showing longitudinal predictors including the autoregressor at T1 of reading accuracy at T2. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

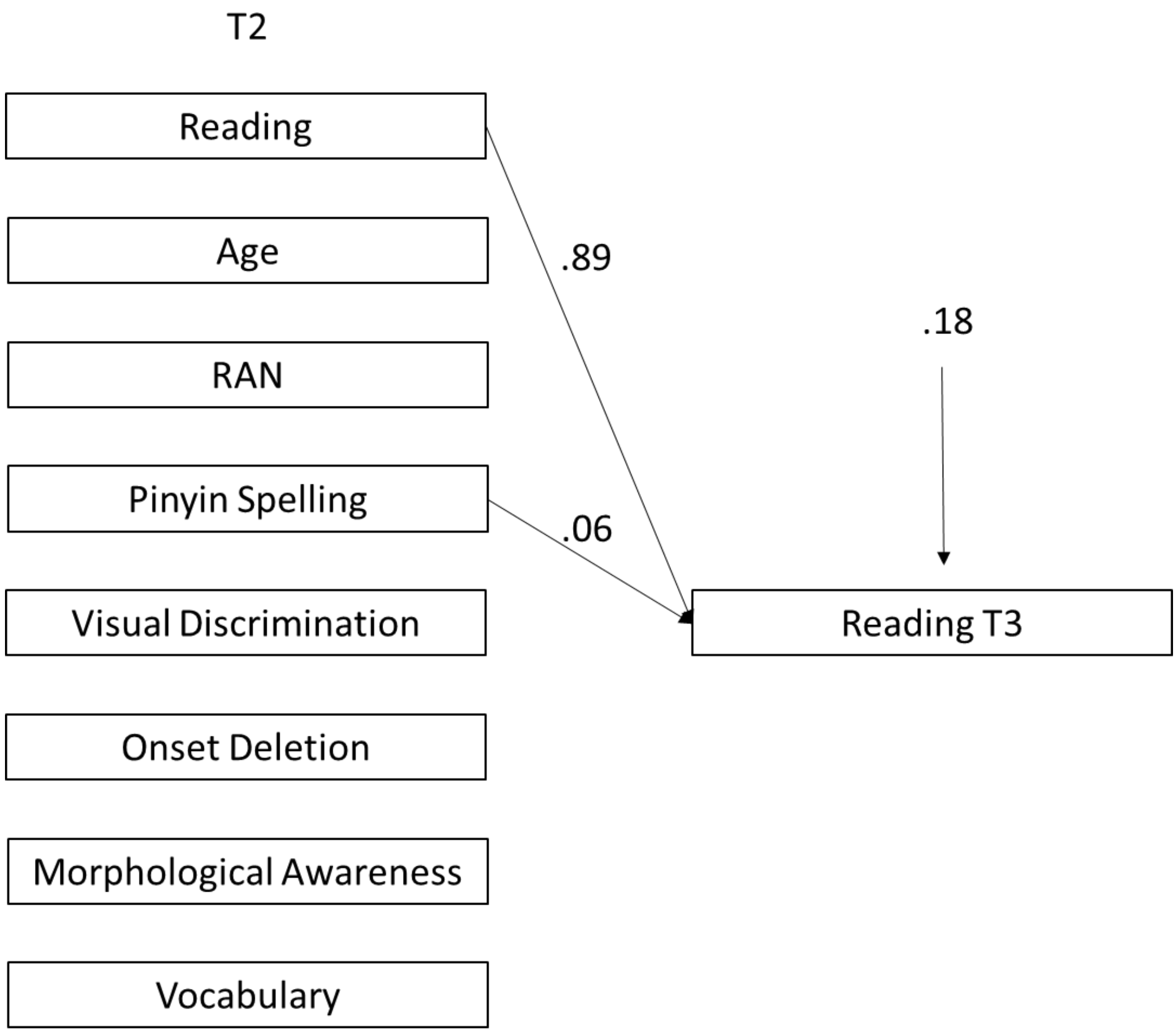


Figure 2.3.2. Path diagram showing longitudinal predictors including the autoregressor at T2 of reading accuracy at T3. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

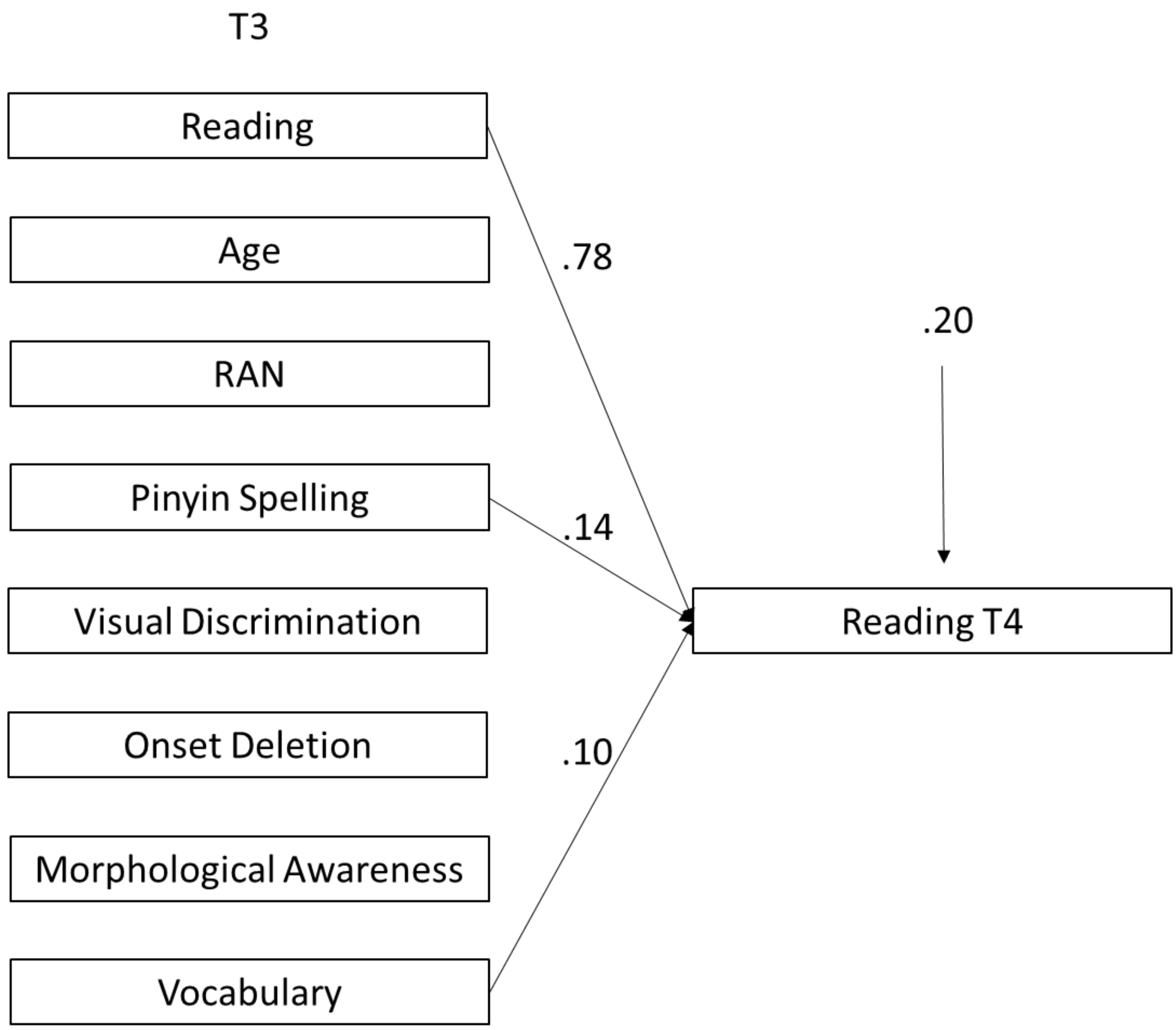


Figure 2.3.3. Path diagram showing longitudinal predictors including the autoregressor at T3 of reading accuracy at T4. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

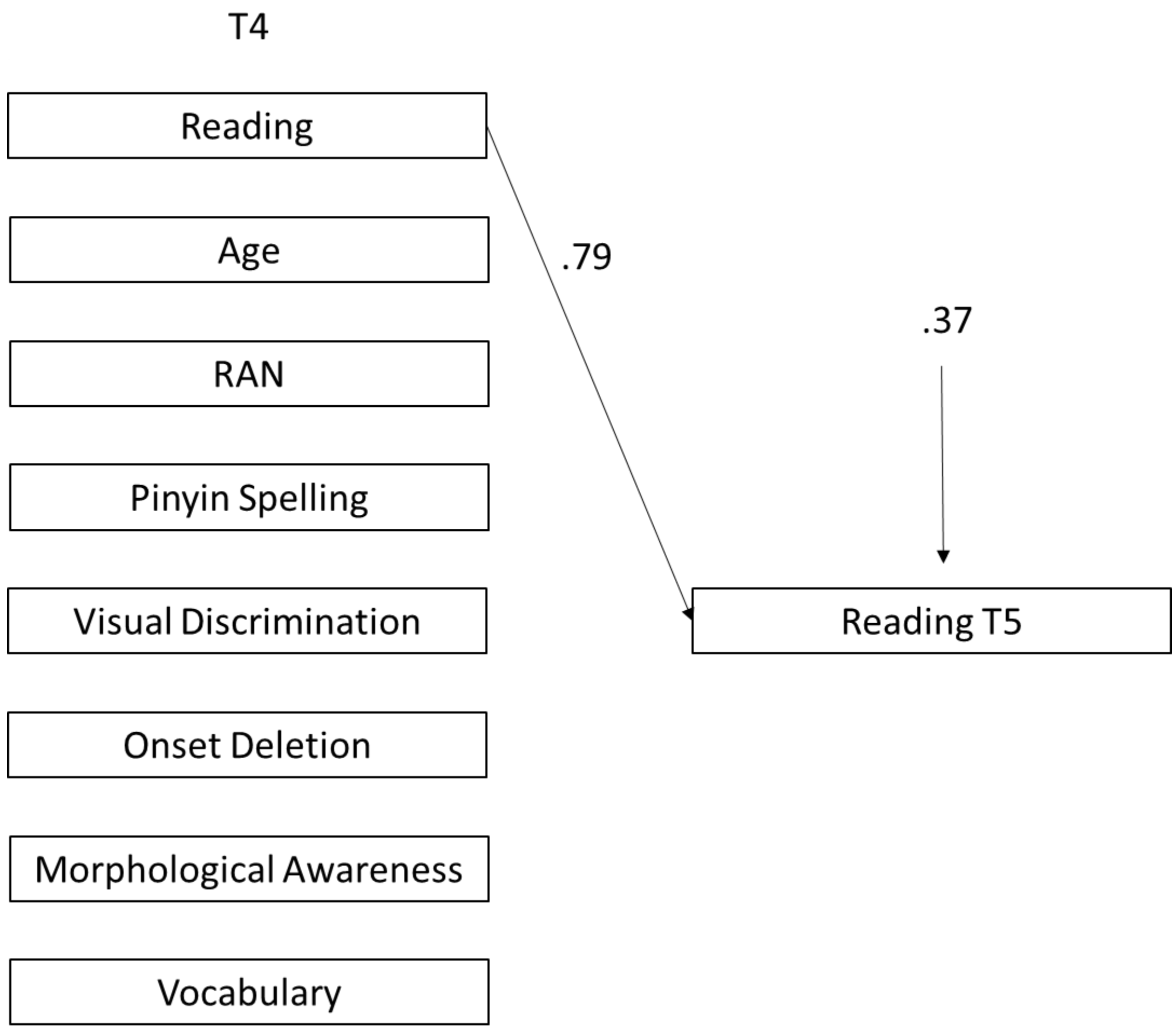


Figure 2.3.4. Path diagram showing longitudinal predictors including the autoregressor at T4 of reading accuracy at T5. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

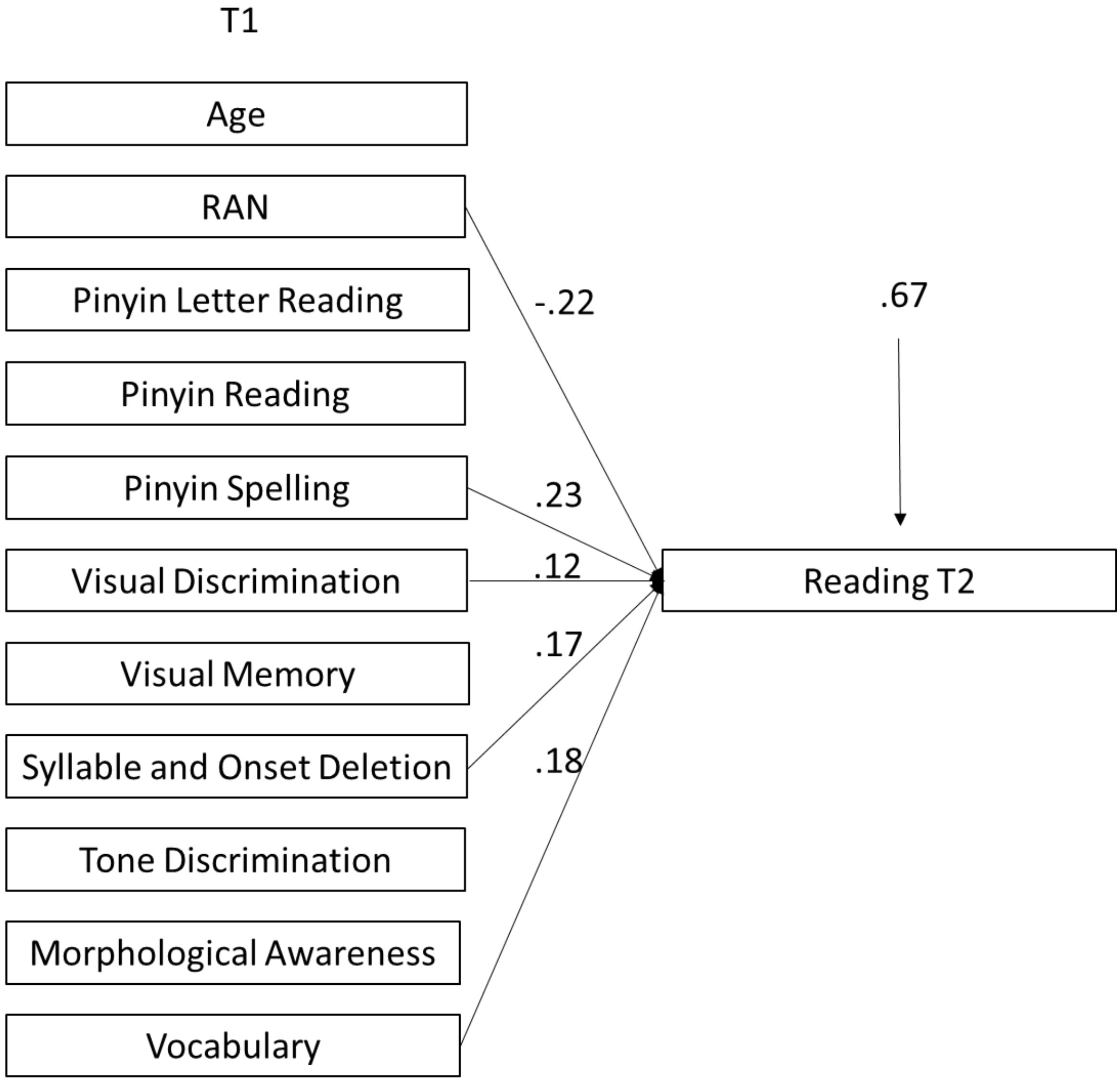


Figure 2.4.1. Path diagram showing longitudinal predictors at T1 of reading accuracy at T2. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

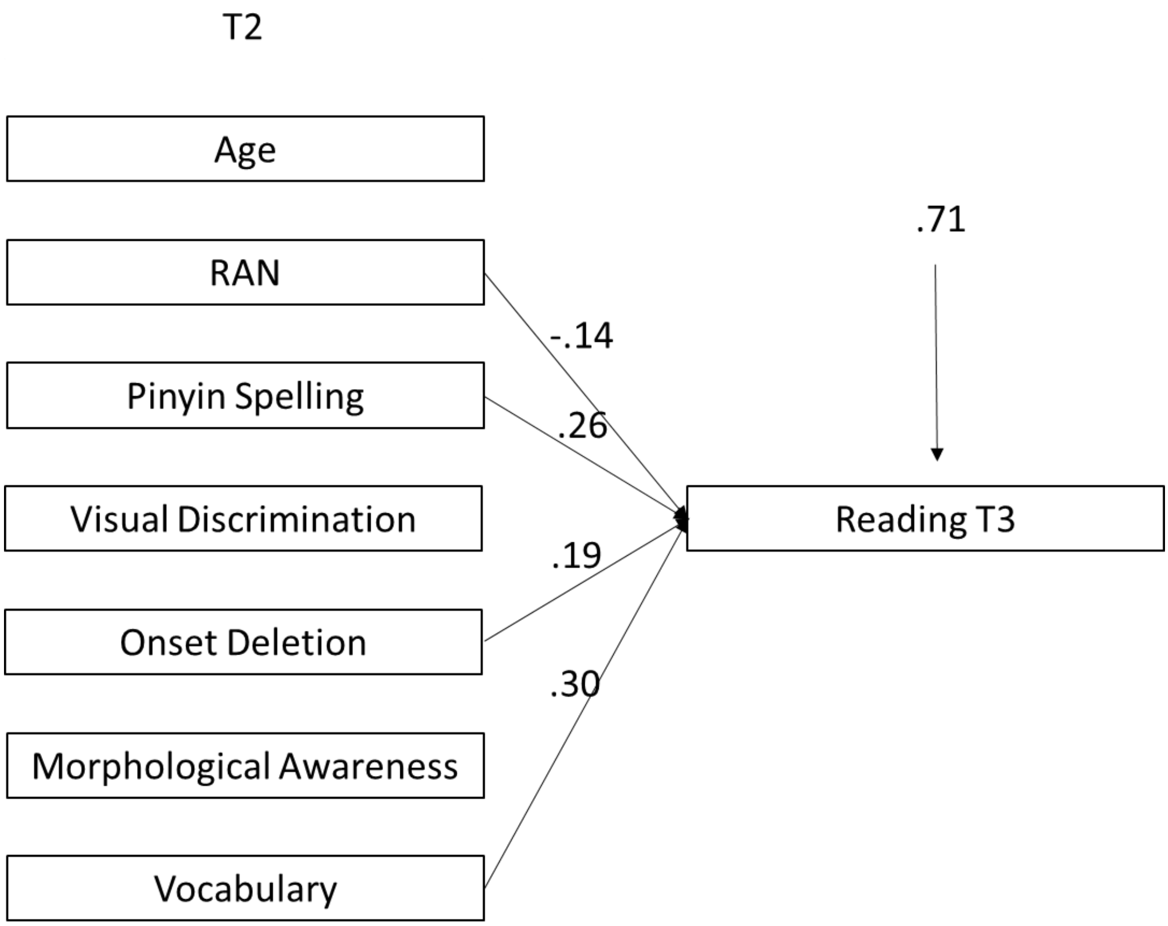


Figure 2.4.2. Path diagram showing longitudinal predictors at T2 of reading accuracy at T3. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

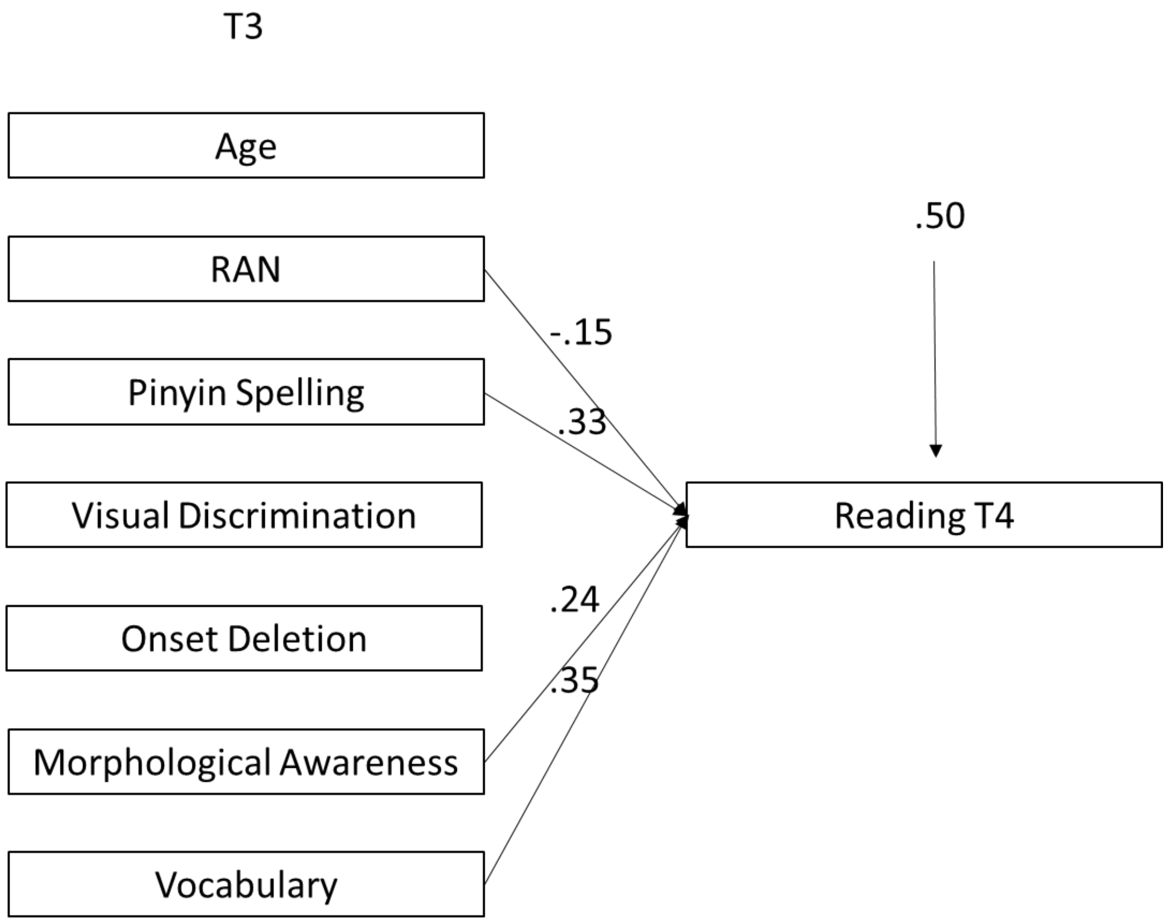


Figure 2.4.3. Path diagram showing longitudinal predictors at T3 of reading accuracy at T4. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

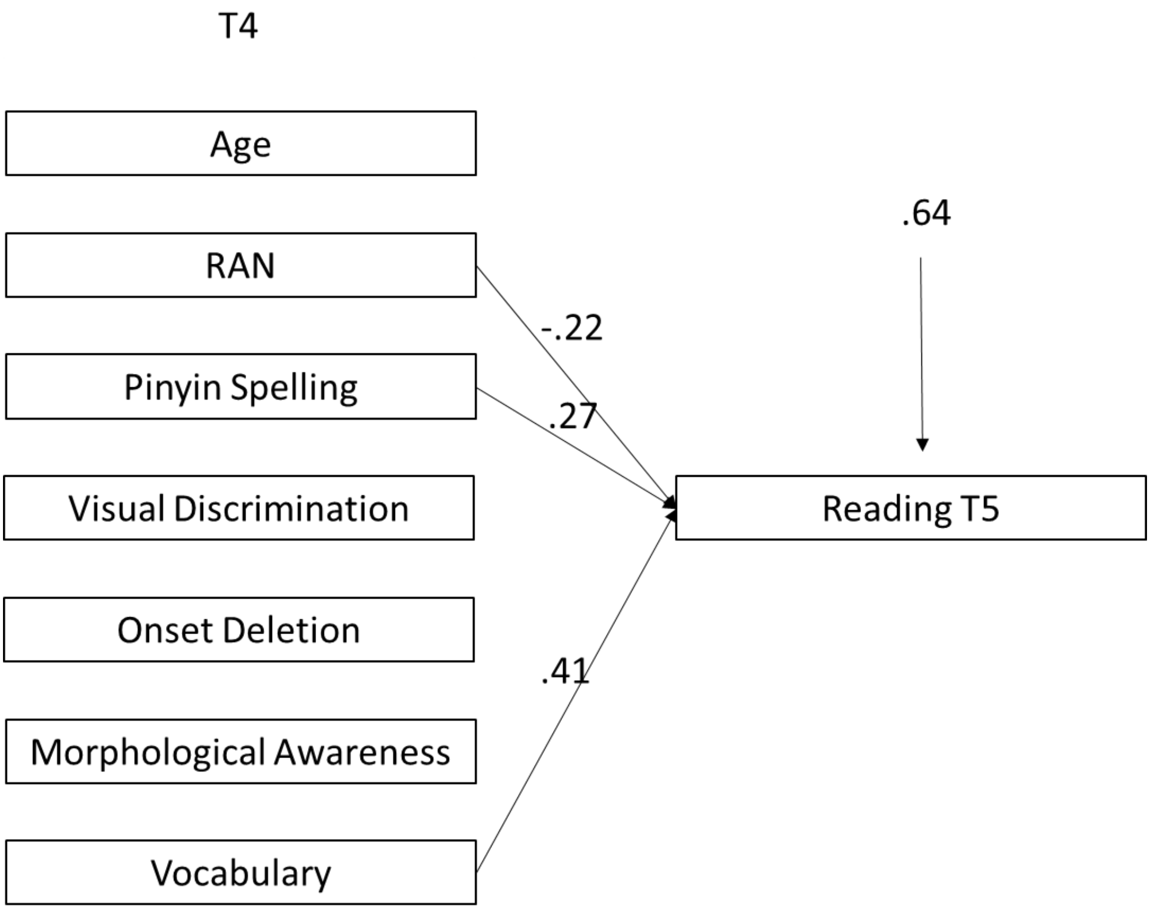


Figure 2.4.4. Path diagram showing longitudinal predictors at T4 of reading accuracy at T5. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

2.3.5. Longitudinal Predictors of Chinese Word Spelling

To examine the degree of change in Chinese word spelling between adjacent time points, and what explains that change, a set of simultaneous regression models were constructed with early Chinese word spelling (the autoregressor) included. All cognitive predictors including the autoregressor were first entered in one step. In each model, the non-significant predictors with the smallest contribution were iteratively dropped to leave a model in which all predictors are statistically significant. These models for each time point are shown in Figure 2.5.1 to 2.5.3 (spelling was only assessed from T2).

Four variables, age, Pinyin spelling, onset deletion, and word spelling at T2 were significant predictors of word spelling at T3 [F (4,297) =146.143, $p< .001$] together these predictors accounted for 66.3%, of the variance in spelling. Two variables, visual discrimination and word spelling at T3 were significant predictors of word spelling at T4 [F (2,299) =326.044, $p< .001$] together these predictors accounted for 68.6%, of the variance in spelling. Three variables, Pinyin spelling, onset deletion, and word spelling at T4 were significant predictors of Chinese word spelling at T5 [F (3,151) =107.026, $p< .001$)] together these predictors accounted for 68 %, of the variance in spelling.

The autoregressive effects of earlier word spelling on later word spelling in models 2.5.1 to 2.5.3 are powerful, meaning that the rank order of children is stable in spelling as well. It seemed important therefore to explore the longitudinal cognitive predictors of Chinese word spelling, in models which excluded the autoregressor. In these models, as before, all cognitive predictors were entered in one step and non-significant predictors with the smallest contribution were iteratively dropped to leave a model in which all predictors are statistically significant. These models for each time point are shown in Figure 2.6.1 to 2.6.3.

Four variables, age, Pinyin spelling, visual discrimination, and onset deletion were significant predictors of word spelling at T3 [F (4,297) =34.775, $p< .001$] together these predictors accounted for 31.9%, of the variance in spelling. Five variables, age, RAN, Pinyin spelling, onset deletion, and vocabulary at T3 were significant predictors of word spelling at T4 [F (5,296) =29.219, $p< .001$] together these predictors accounted for 33%, of the variance in spelling. Three variables, RAN, Pinyin spelling, and onset deletion at T4 were significant predictors of word spelling at T5 [F (3,151) =45.087, p< .001)] together these predictors accounted for 55.9%, of the variance in spelling.

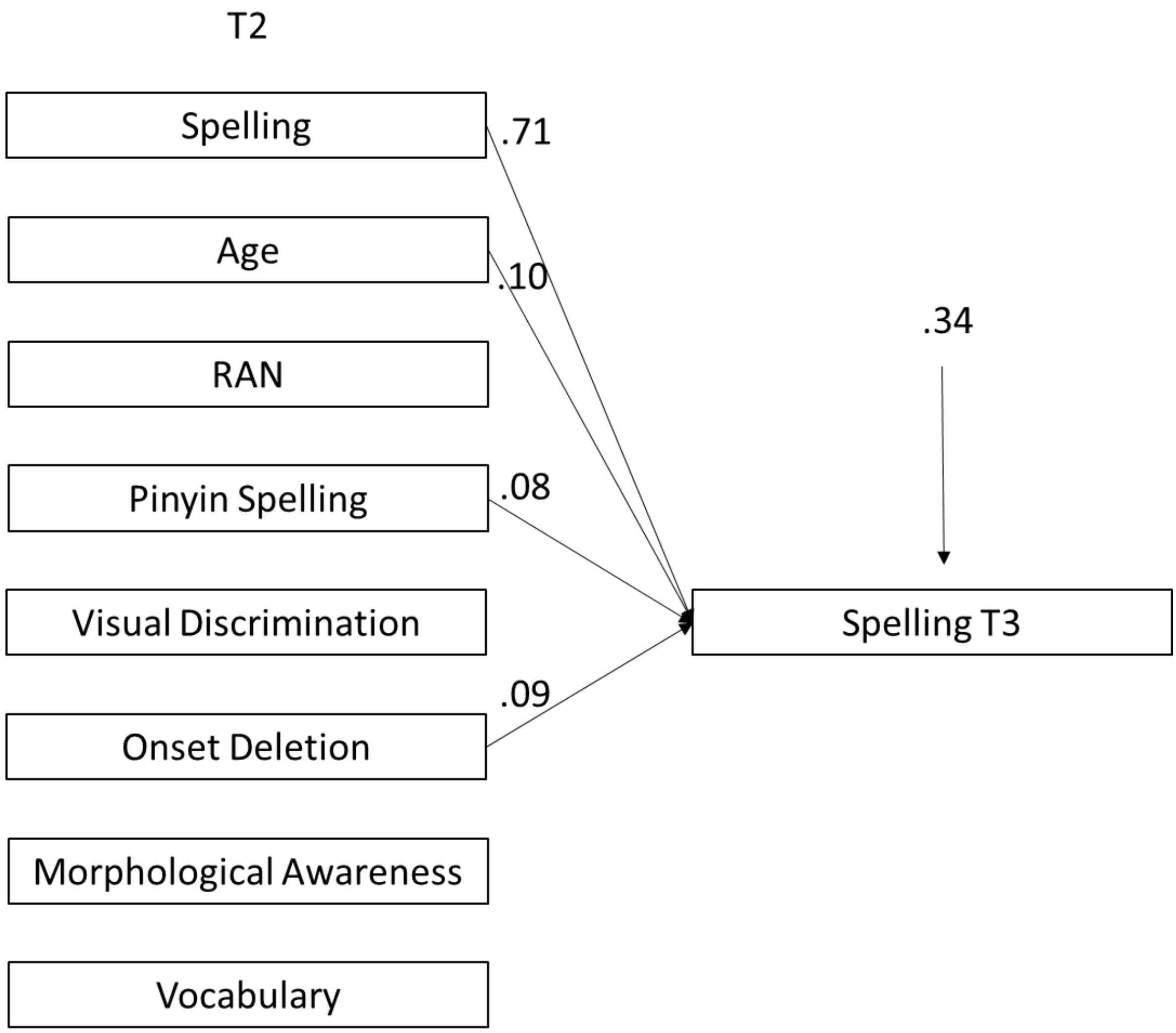


Figure 2.5.1. Path diagram showing longitudinal predictors including the autoregressor at T2 of reading accuracy at T3. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

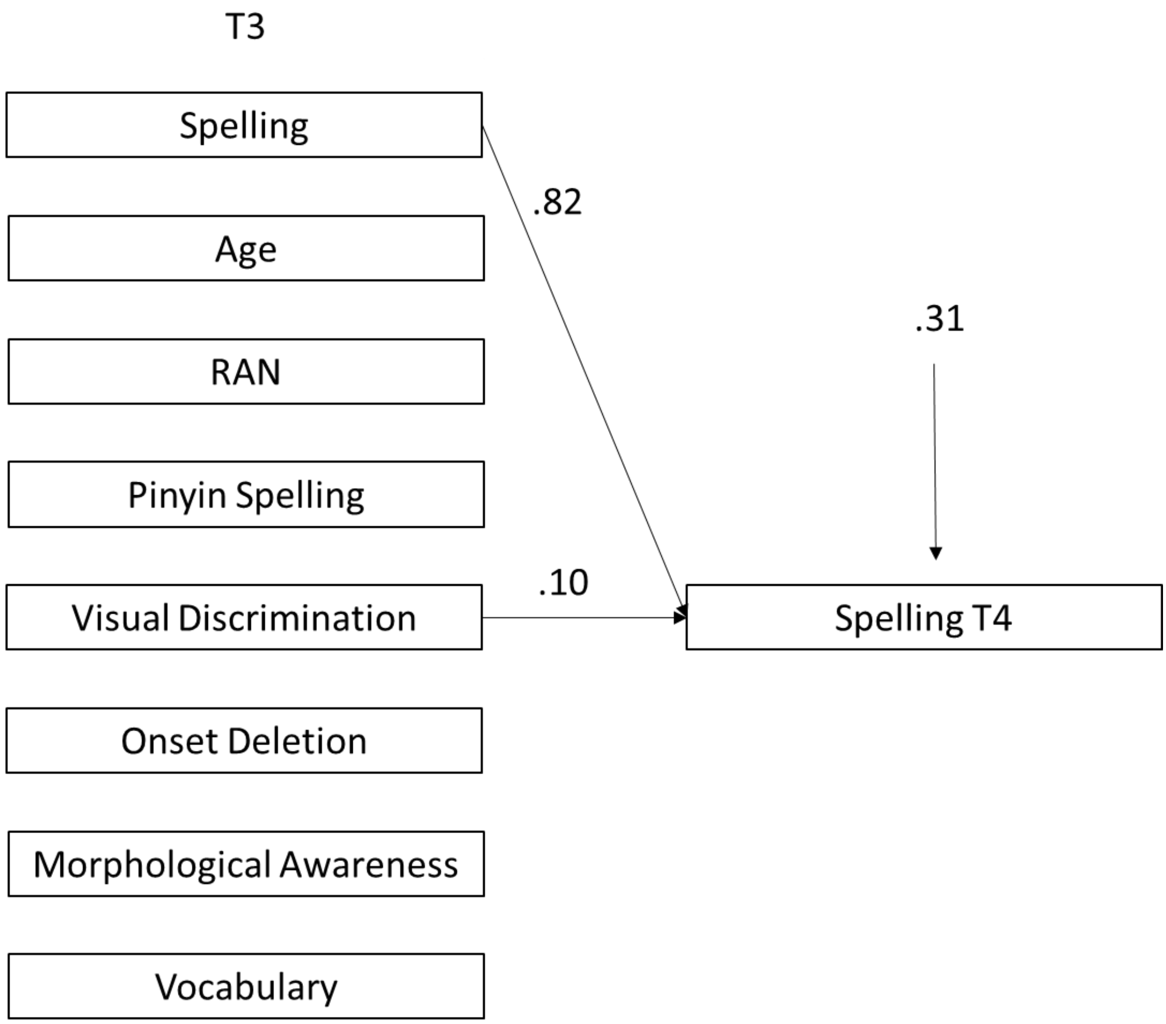


Figure 2.5.2. Path diagram showing longitudinal predictors including the autoregressor at T3 of reading accuracy at T4. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

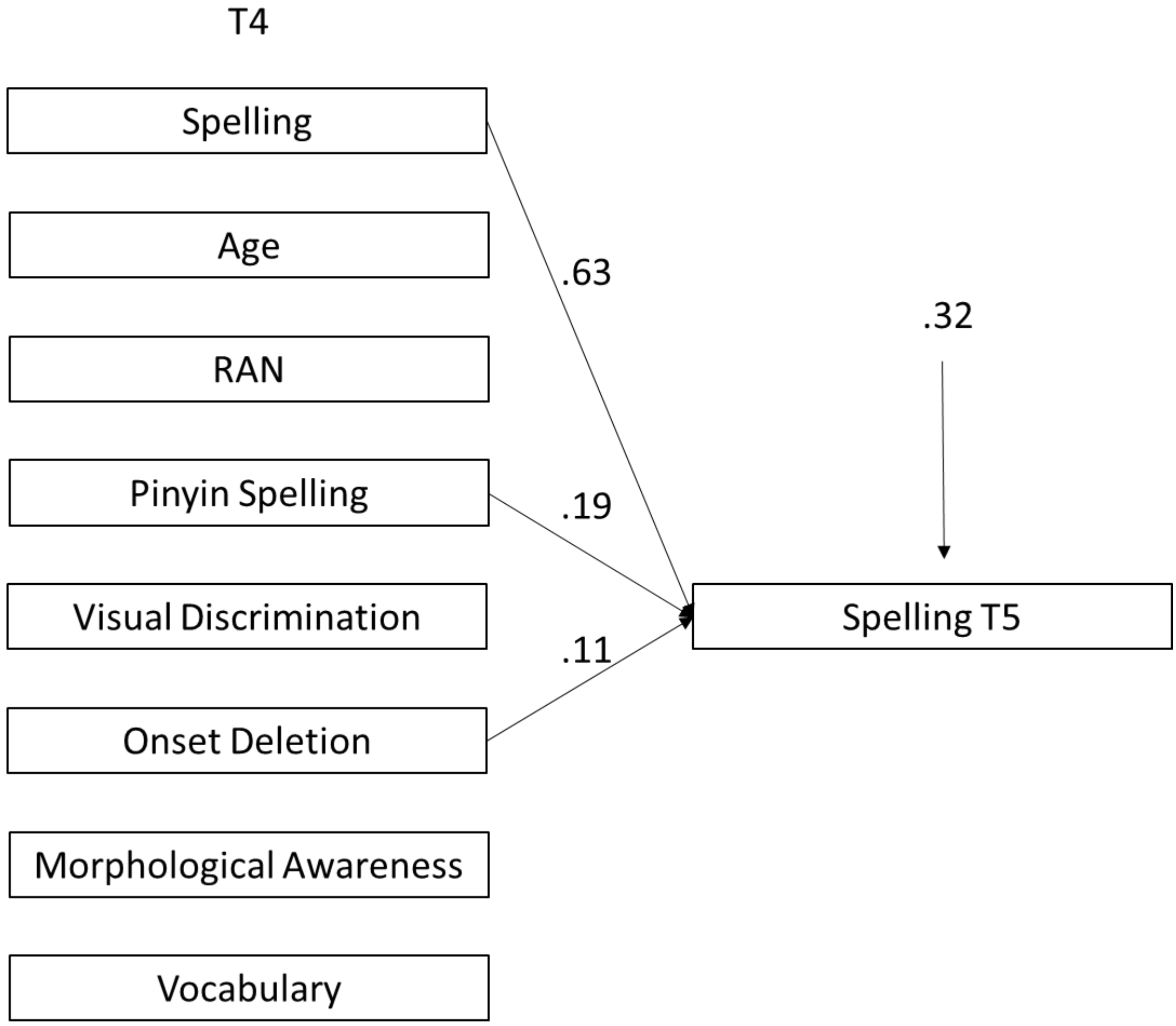


Figure 2.5.3. Path diagram showing longitudinal predictors including the autoregressor at T4 of reading accuracy at T5. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

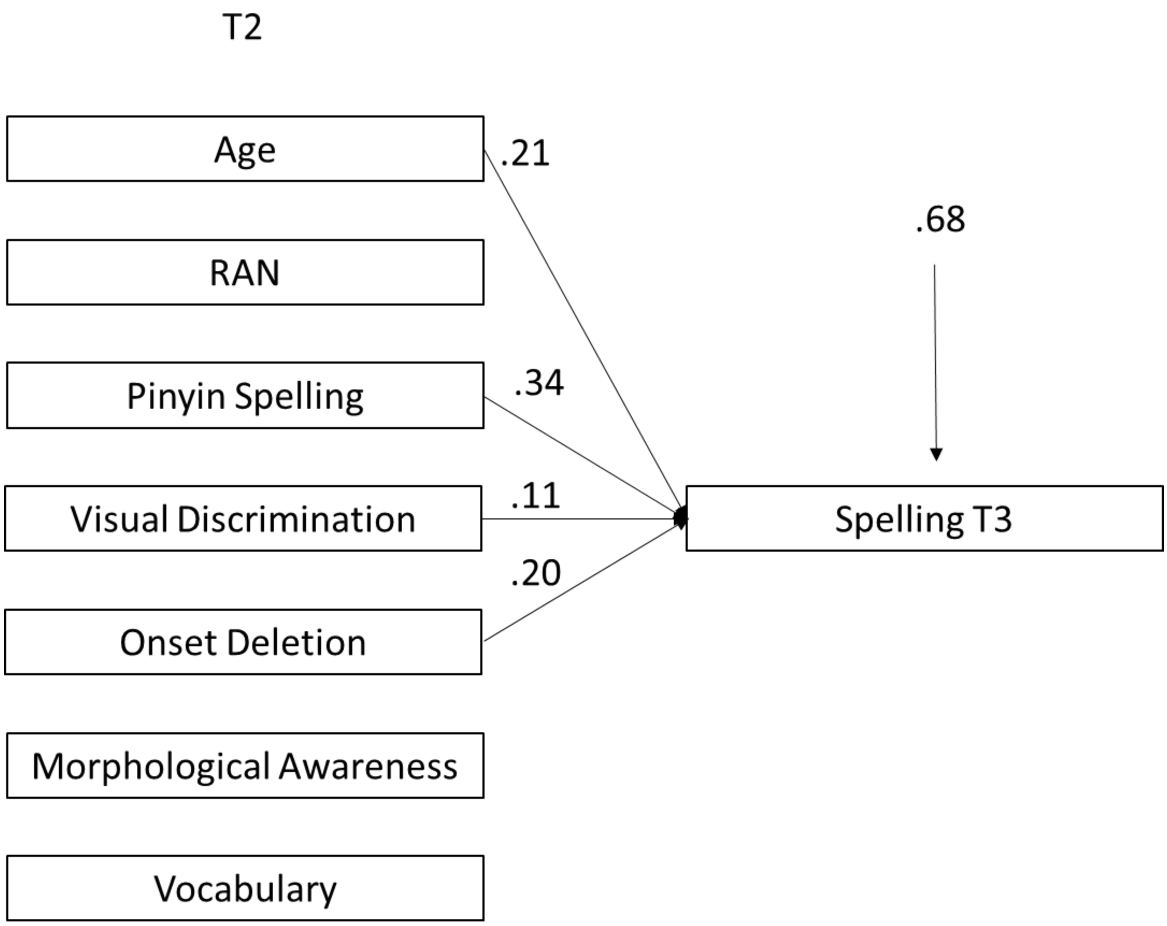


Figure 2.6.1. Path diagram showing longitudinal predictors at T2 of reading accuracy at T3. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

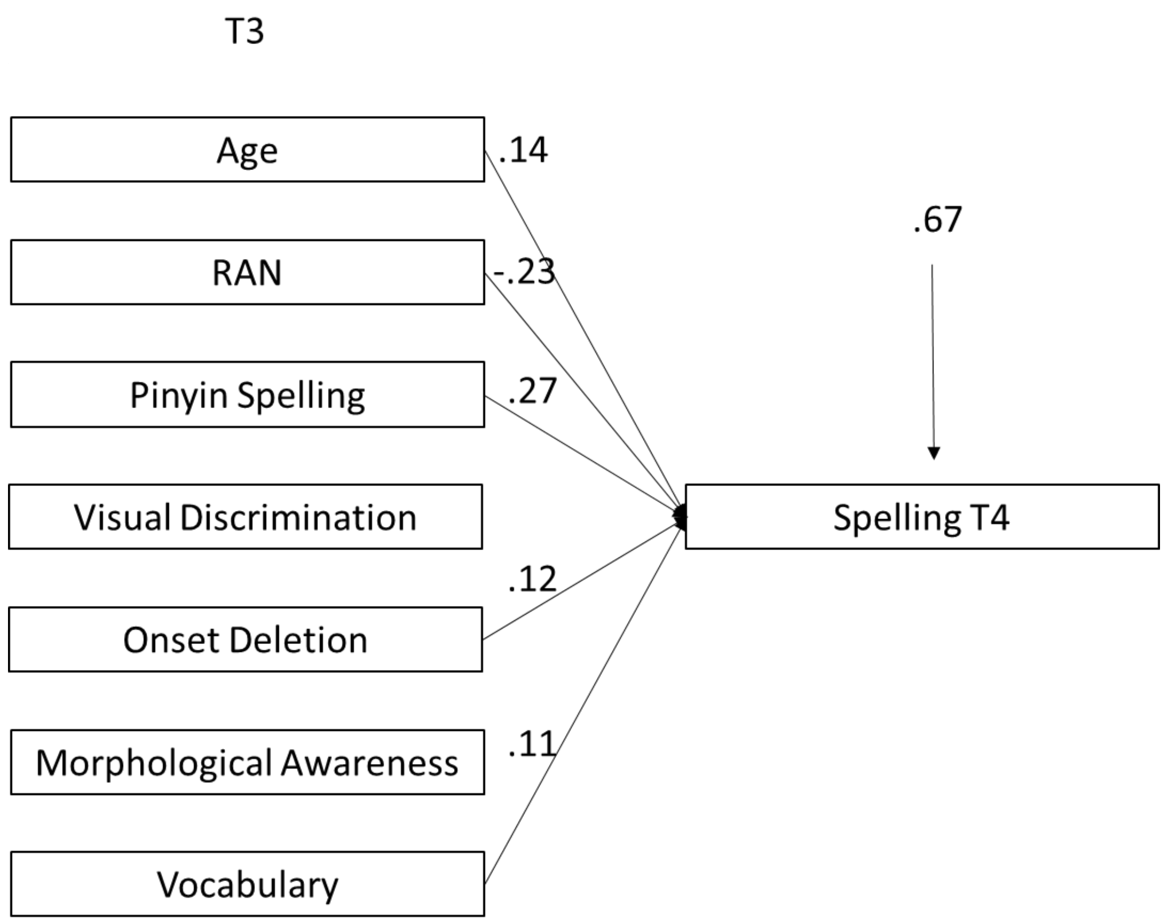


Figure 2.6.2. Path diagram showing longitudinal predictors at T3 of reading accuracy at T4. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

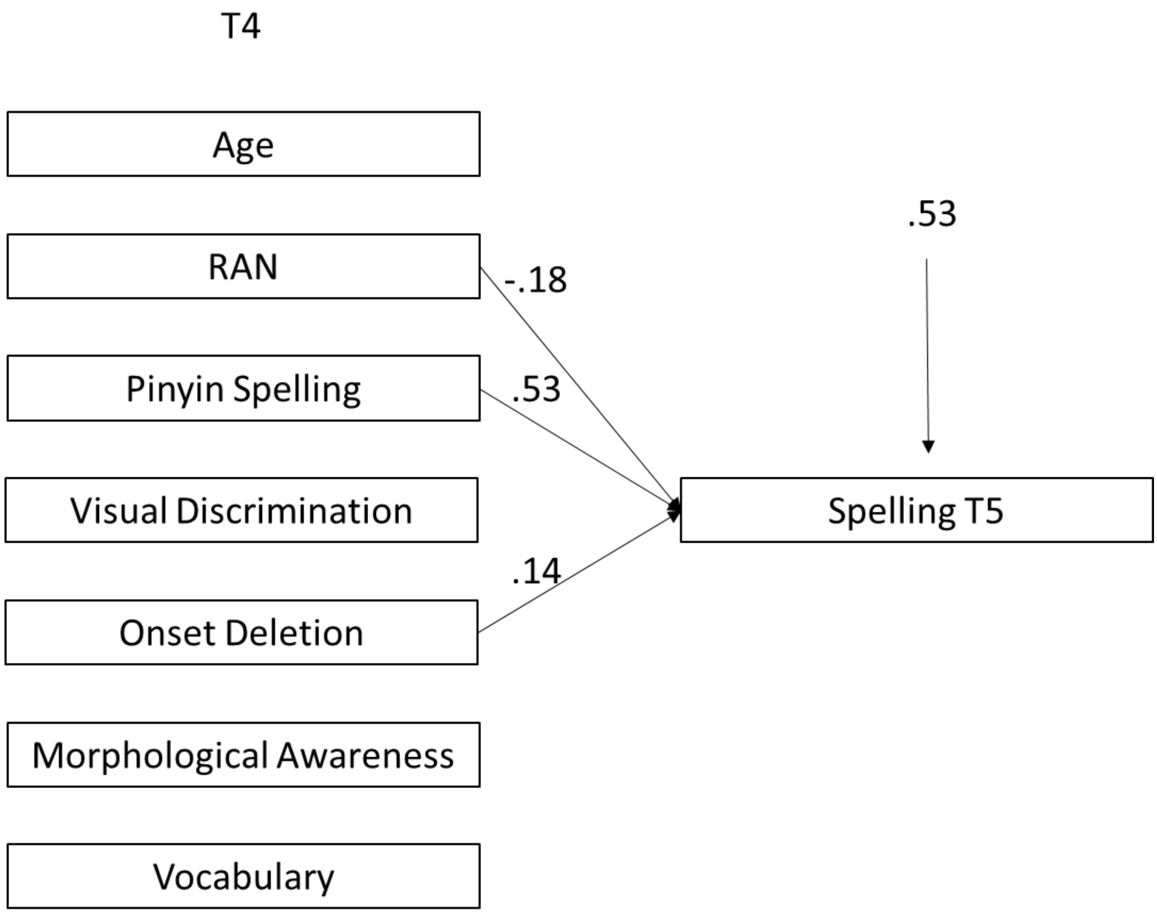


Figure 2.6.3. Path diagram showing longitudinal predictors at T3 of reading accuracy at T4. Path weights are standardized regression coefficients. Nonsignificant effects were omitted from the model and not shown in the diagram.

2.4 Discussion

This large-scale longitudinal study was designed to examine phonological awareness, tone awareness, morphological awareness, visual skills, RAN, Pinyin knowledge, and vocabulary as predictors of learning to read and spell in Chinese in primary school children aged 6-8 years. The results fit well with our hypotheses, showing strong similarities to the pattern found in previous studies of reading and spelling in Chinese, and highlight the importance of Pinyin spelling, RAN, and vocabulary for the development of literacy skills in Chinese.

2.4.1. Concurrent and Longitudinal Predictors of Reading in Chinese

In general, the results of the regression analyses reported are consistent with our hypotheses. There were significant contributions from six cognitive skills (i.e. vocabulary, Pinyin spelling, RAN, phonological awareness, visual discrimination, and morphological awareness) to Chinese word reading at different time points with all the other constructs controlled. Even beyond the autoregressor, Pinyin spelling, phonological awareness, and vocabulary were found to be concurrent and longitudinal predictors of reading at some certain time points (e.g. RAN at T1 significantly predicted reading at T2; Pinyin spelling at T2 and T3 significantly predicted reading at T3 and T4; vocabulary at T3 significantly predicted reading at T4).

2.4.1.1. Pinyin Spelling, RAN, and Vocabulary as Reliable Predictors of Reading

Pinyin spelling and RAN emerged as unique concurrent and longitudinal predictors of Chinese reading across all the time points. This is in line with previous studies (Pinyin spelling: Lin et al., 2010; Pan et al., 2011; RAN: Li et al., 2012; Yeung et al., 2011) which also reported Pinyin spelling and RAN as longitudinal predictors of reading and spelling.

Pinyin knowledge benefits reading in the following two ways. First, Pinyin knowledge influences individuals' self-teaching ability. Pinyin is taught as an aid to reading in Chinese at the start of formal literacy instruction. In Mainland China, most reading materials designed for children are combined with auxiliary Pinyin that appears above the characters. In addition, Pinyin provides a way of looking up characters and words in Chinese dictionaries. That is, children can teach themselves not only the pronunciation but also the meaning of a Chinese character with the aid of Pinyin. Therefore, proficient Pinyin knowledge helps children to learn new characters in their daily life.

Second, Pinyin knowledge boosts phonological awareness and tone awareness, both of which are significantly correlated with reading (McBride-Chang et al., 2010; Shu et al., 2008). As an alphabetic coding system, Pinyin represents Chinese characters with an onset, a rime, and a tone. A Pinyin spelling test, in essence, reflects the ability to manipulate phoneme units. Children spell a Pinyin word correctly based on a good understanding of its onset, rime, and tone. Conversely, an onset deletion test and a tone discrimination test aim to segment a Pinyin word into separate phonemes and a tone. From this perspective, sufficient Pinyin knowledge makes the phonological manipulation more transparent and straightforward.

As a unique phonetic tool in Mainland China, Pinyin is an auxiliary tool of learning to read at the start of formal instruction, providing a platform where children have more opportunity to learn new characters. Furthermore, Pinyin boosts children's phonological awareness and tone awareness, and affects the way that children process the phonology of Chinese. Therefore, Pinyin is a reliable predictor of reading in Chinese.

RAN has been reported as a strong predictor of reading in numerous studies across languages (English: Parrila et al., 2004; Norwegian: Lervag et al., 2009; Chinese: Li et al., 2010; English, Spanish, Czech, & Slovak: Caravolas et al., 2012). The role of RAN may be interpreted as a measure of the efficiency of phonetic retrieval from visual information. In other words, RAN reflects one's visual and phonetic processing ability, both of which are closely associated with word reading.

In the present study, only numeric RAN was assessed as potential predictor. Future research is needed to explore non-alphanumeric RAN (i.e. colour-RAN or object-RAN) as a predictor of reading to confirm whether non-alphanumeric RAN is tapping into the mechanism of visual and phonological processing. According to Lervag et al. (2009), non-alphanumeric RAN is a unique predictor of early reading beyond phoneme awareness. It may be interesting if non-alphanumeric RAN is examined in future Chinese studies.

Although vocabulary has not been found to be an important predictor of reading beyond phonological information in English studies (Ball & Blachman, 1991; Duff & Hulme, 2012), the present study highlights the role of vocabulary in Chinese reading skills. This finding resonates with previous Chinese studies that reported vocabulary as a concurrent and longitudinal predictor of reading in kindergarten children (Wang et al., 2015) and primary school children aged 8 years (Hu, 2012), and extends this to the age group of 6 to 8 years old. One explanation for the significant relationship between vocabulary and reading is that vocabulary has an indirect effect on word recognition by building associations between visual form and sound of a word. As grapheme-phoneme correspondence in Chinese is opaque and irregular, paired associate learning may be a useful strategy for learning to read new words in Chinese. Having a clear understanding of the meaning of a word may contribute towards memorizing the word per se. Individuals can imagine a vivid scene or event in order to help them to memorize an unfamiliar word based on a clear definition of it (Laing & Hulme, 1999). Based on this clear definition, an isolated word can be associated with a network of information, and so it will be more easily memorized. The vocabulary test in the present study assessed the extent to which words are understood, which may be an important indicator of how easily children memorize a word.

2.4.1.2. Phonological Awareness and Visual Skills as Predictors of Reading in Early Stage of Development

It is well established that phoneme awareness plays a crucial role in learning to read across alphabetic languages (Caravolas et al., 2012; Lervag et al., 2009; Ricketts et al., 2007). However, a number of studies from Hong Kong have demonstrated that phoneme awareness was not a significant predictor of reading (McBride-Chang et al., 2008; Tong & McBride-Chang, 2010); only syllable awareness appears to predict reading ability in Chinese (Lin et al., 2010; McBride-Chang & Burgess, 2005). This is because syllables correspond to characters, but phonemes are not explicitly represented in Chinese orthography. In the present study, our results showed a different pattern in that both tests of syllable and onset deletion and onset deletion were significant predictors of reading. The inconsistency with the findings in Hong Kong can be explained by the fact that children in Mainland China are taught Chinese Pinyin at the start of formal instruction. As Pinyin represents Chinese characters in phoneme units, children who learn Pinyin have more opportunity to practise phoneme manipulation. The manipulation of phonemes helps children to remember phonetic information of a character and this is of benefit in early educational development. However, too much meaningless phonetic information would carry a significant burden on memory capacity. Children therefore begin to rely on other strategies (e.g. semantic information) to organize phonetic information at a later stage of development. One limitation of the syllable deletion test in the present study is that syllable deletion in some extent overlaps morpheme deletion in Chinese. Future studies are needed to use nonwords to test children's ability of syllable deletion. In nonwords, syllables are meaningless and they are not morphemes.

Similar to phonological awareness, visual skills were early indicators of learning to read in the present study. This is consistent with previous findings that visual skills were a longitudinal predictor of reading beyond syllable deletion and RAN in kindergarten children (McBride-Chang et al., 2005), but failed to predict reading after Grade 3 (Siok & Fletcher, 2001). As Siok and Fletcher (2001) argued, children's educational level affects the relationship between visual skills and reading in Chinese: younger children are inclined to holistic processing and rote memory making visual skills important for learning to read, while proficient readers tend to rely less on visual skills but more on orthographic or morpheme skills. Unlike alphabetic languages, Chinese characters that evolved from pictures are composed of complex strokes. Therefore, children that have little orthographic knowledge or rules of characters tend to use graphic processing to identify characters. Each character is like a picture, or a set of pictures. For example, 人 /ren2/ (person) looks like a person with two legs; 从 /cong2/ (follow) means one person follows another person. Due to this feature of Chinese orthography, beginner readers can benefit from using a whole-character strategy to process visual forms in print. However, the purely visual processing of characters has its limits. First, not all Chinese characters can be imagined as a picture (e.g. characters with abstract meanings). Second, visual processing of characters, in essence, is memorizing a character by analysing its radicals. This provides an effective way to learn characters in the early grades, but it is of relatively low efficiency. Therefore, proficient readers do not rely on elementary visual information, but organize the isolated visual information into systematic orthographic knowledge and morpheme knowledge.

In summary, phonological awareness and visual skills are precursors of Chinese reading. Beginners are more likely to utilize phonetic and visual cues to learn new words, while proficient readers tend to find other advanced strategies.

2.4.1.4. Morphological Awareness as a Predictor of Reading in the Late Grades

As previous findings reported, morphological awareness was not a significant predictor of reading in Chinese in the early grades with phonological awareness (Hu, 2012) or visual skills (Li et al., 2010) controlled. It was found to be a concurrent and longitudinal predictor of reading after Grade 2 in our study. Using morphological strategies, children can guess the meaning of an unfamiliar Chinese word according to certain morphological information. For example, if one knows that 水 (water) 瓶 (bottle) is a bottle containing water and what 奶 (milk) is, one will guess that 奶 (milk) 瓶 (bottle) means a bottle containing milk. It is clear that morphological manipulation is an advanced and efficient reading strategy, while visual and phonetic processing is transparent but limited. Therefore, children may tend to use visual and phonetic processing in the early stages of literacy development, and begin to use morphological strategies for reading in the later stages.

2.4.2. Concurrent and Longitudinal Predictors of Spelling in Chinese

Similar to word reading, Pinyin knowledge and RAN predicted spelling concurrently and longitudinally; visual discrimination significantly predicted spelling at early stage of spelling. However, the pattern of prediction of spelling is different from reading in vocabulary, phonological awareness, and morphological awareness. Vocabulary, which was one of the most robust predictors of reading, played a limited role in Chinese spelling. Phonological awareness concurrently predicted spelling at T1 and T3, and longitudinally predicted spelling across all the time points. Morphological awareness concurrently predicted spelling at late stage (T2 to T4), but failed to longitudinally predict at any time points.

2.4.2.1. Pinyin Spelling and RAN as Reliable Predictors of Spelling

The present study highlighted Pinyin spelling as the most robust predictor of spelling in Chinese. Pinyin spelling at each time point was the most robust concurrent and longitudinal predictor of spelling across 5 time points. This extended the work of Pan et al. (2011) which showed that Pinyin spelling at age 6 was a longitudinal predictor of spelling at age 9 and 10. An explanation for the relationship between Pinyin spelling and Chinese spelling is that the cognitive skills required in Pinyin spelling and word spelling are similar. Although Pinyin spelling refers to alphabetic languages while word spelling refers to strokes and radicals, both demand phonetic and motor skills. When children learn to spell, they are using skills in visual, phonetic, and motor processing. From this perspective, Pinyin spelling is naturally the most robust predictor of word spelling.

In addition to Pinyin spelling, RAN from T2 to T5 was a reliable concurrent and longitudinal predictor of spelling in the present study. This confirmed findings of Yeung et al. (2011) and Li et al. (2012) which respectively demonstrated RAN to be a concurrent and longitudinal predictor of spelling in Chinese. The predictive effect of RAN on spelling can be explained that the elementary classroom teaching in Chinese writing relies heavily on rote memorization. This teaching method is strongly associated with the ability to build arbitrary relationships between visual forms and pronunciation (Yeung et al., 2012). However, RAN at T1 was not a significant predictor of spelling. It is possible that there were more variables at T1 than subsequent time points and those variables (e.g. rapid Pinyin reading and rapid Pinyin letter reading) share variance with RAN, which led to the non-significant effect of RAN at T1 on spelling.

In summary, Pinyin spelling and RAN, which share much in common with word spelling, are reliable predictors of learning to spell in Chinese.

2.4.1.2. Limited Roles of Vocabulary, Phonological Awareness, and Morphological Awareness as Predictors of Spelling

Although vocabulary played a robust role in predicting Chinese reading, the predictive power of vocabulary was limited in spelling. This is in line with previous findings (Pan et al., 2011; Tong et al., 2009) which reported vocabulary was not a reliable predictor of spelling in Chinese at aged 7 and 8, and extends this to children aged 6-8 years.

In contrast to the pattern seen for reading, phonological awareness and morphological awareness did not show different predictive effects at different stages of spelling development. Phonological awareness was a reliable longitudinal predictor of spelling, but this prediction was unreliable for concurrent data. It is inconsistent with a previous study in Hong Kong children (Tong et al., 2009), confirming our prediction that the pattern of phonological awareness as a predictor of Chinese literacy skills is different between Hong Kong and Mainland China. It is possible that Pinyin changes the way children derive phonological information from orthography. Morphological awareness concurrently predicted spelling from T3 to T5, but failed to predict spelling at any longitudinal time points. This is in line with a previous study (Yeung et al., 2013) which found concurrent but not longitudinal prediction of morphological awareness for spelling in Grade 1 and Grade 2. These findings suggested that the relationship between phonological awareness and spelling is causal, but the relationship between morphological awareness and spelling is not causal.

The limited predictive effect of vocabulary, phonological awareness and morphological awareness can be explained by the way in which children learn to spell in Chinese. In formal literacy instruction in Chinese schools, children learn to spell from copying. A teacher writes a character on the blackboard, tells the children the pronunciation of the character, and then children copy it on their paper. Therefore, learning to spell in Chinese involves visual, phonetic, and motor processing. Spelling, a process of output, therefore places heavier demands on memorization than does reading (input). Although vocabulary (Ricketts et al., 2007; Wang et al., 2015), phonological awareness (Chow et al., 2005) and morphological awareness (Li et al., 2010) were predictors of learning to read, they explain little variance in spelling after the effects of Pinyin spelling and RAN are controlled.

2.5. Conclusions

This study confirms that Pinyin spelling and RAN are reliable predictors of reading and spelling in Chinese. Vocabulary is one of the most robust predictors of reading, but has limited predictive power for spelling. Visual discrimination plays an important role in early, but not later, literacy development in Chinese. Phonological awareness was precursors of reading, while morphological awareness was more important in later grades. For spelling, phonological awareness was a reliable longitudinal predictor of spelling, but had limited concurrent prediction; morphological awareness was a concurrent predictor of spelling at late stage, but failed to longitudinally predict spelling at any time points. These findings fit well with predictions from previous studies, and extend them to children aged 6-8 years. Practically, these findings suggest schools pay more attention to children's Pinyin spelling ability which may have a great effect on children's developing literacy skills. In addition, RAN may be a convenient measure for schools to identify children who are at the risk of reading or/and spelling difficulties.

Chapter Three

Paired Associate Learning Tasks as Predictors of Chinese Literacy Skills

3.1. Introduction

Paired-associated learning (PAL) tasks have been used in numerous studies to tap the mechanisms of learning to read and spell in alphabetic languages (English: Hulme, Goetz, Gooch, Adams & Snowling, 2007; Litt, de Jong, Bergen, & Nation, 2013; Norwegian: Lervag & Hulme, 2009). These tasks assess the ability to learn associations between paired stimuli (either of the same modality e.g. verbal-verbal pairs, or cross-modally e.g. visual-verbal pairs); and performance on these tasks is strongly related to reading. One explanation for this relationship is that learning letter-sounds requires learning the associations between visual shapes and verbal stimuli (Hulme et al., 2007), and letter knowledge is a critical predictor of reading in alphabetic languages (Caravolas et al., 2013; Parrila et al., 2004). As associations between phonology and orthography in Chinese are more arbitrary than in alphabetic languages, it is interesting to explore the mechanisms of reading in Chinese using PAL tasks. This chapter examines 4 types of PAL (visual-verbal, visual-visual, verbal-visual, and verbal-verbal) as potential predictors of learning to read and spell in Chinese. The findings will have implications for theories of learning to read in Chinese.

PAL tasks have been used extensively to explore the deficits in reading shown by children with dyslexia (Vellutino, Scanlon, & Spearing, 1995; Vellutino, Steger, Harding & Phillips, 1975). In these previous studies, children with dyslexia showed significantly poorer performance than age-matched children on visual-verbal PAL (i.e. learning to associate a visual shape with a verbal stimuli), but performed as well as their counterparts on visual-visual PAL (i.e. learning to associate a visual stimuli with another visual stimuli). Thus, dyslexia is not associated with problems in learning associations per se but is specifically associated with a difficulty in learning associations that have a verbal component. Poor performance on visual-verbal PAL is therefore likely due to the underlying phonological deficits seen in dyslexics (Mayringer & Wimmer, 2000; Messbauer & de Jong, 2003). Further work by Litt and Nation (2014) extends this finding by including two additional PAL tasks: verbal-visual

PAL (i.e. learning to associate a verbal stimuli with a visual shape); and verbal-verbal PAL (i.e. learning to associate a verbal stimuli with another verbal stimuli). Children with dyslexia (aged 8 to 12 years) showed significant deficits on verbal output tasks (visual-verbal and verbal-verbal), but not on visual output tasks (visual-visual and verbal-visual) compared to age-matched children without dyslexia. These findings demonstrate the importance of the phonological component of PAL, and a specific relationship with verbal output processes.

The relationship between PAL and reading is also seen in studies of typically developing children, and appears to be independent of other critical underlying skills including phoneme awareness and RAN (Hulme et al., 2007; Litt et al., 2013; Windfuhr & Snowling, 2001). Windfuhr and Snowling (2001) tested 75 children aged from 7;01 to 11;11 years using tests of visual-verbal PAL, vocabulary, phonological awareness (phoneme deletion and rhyme oddity), and verbal short-term memory. Hierarchical multiple regressions showed that visual-verbal PAL was a significant predictor of reading after controlling for all other variables

including nonword reading. It was inferred from this that the critical role of PAL in reading is independent of phonological decoding.

Warmington and Hulme (2012) extended this to examine the role of visual-verbal PAL in reading beyond the contribution of rapid automatic naming (RAN). Both RAN and visual-verbal PAL are thought to reflect the retrieval of phonological information from visual stimuli: visual-verbal PAL taps nascent associations of visual and phonological stimuli; RAN taps how fast one retrieves learned visual-verbal associations from memory. In this study, seventy-nine children aged 7 to 11 years were given tests of visual-verbal PAL, RAN, phoneme deletion, and reading. Path analyses showed that both visual-verbal PAL and RAN were unique predictors of word reading accuracy and reading speed with all other constructs controlled. This confirms the critical role of visual-verbal PAL in learning to read in English, independent from phonological skills and RAN.

There is some evidence that the relationship between PAL and reading is specific to cross-modal learning. Hulme et al. (2007) examined visual-verbal PAL, visual-visual PAL, verbal-verbal PAL, and phoneme deletion as potential foundations of reading in English. Visual-verbal PAL and phoneme deletion were both unique predictors of reading with the other two PAL tasks controlled. Neither visual-visual PAL ($r = .23$, $p > .05$) nor verbal-verbal PAL ($r = .38$, $p < .05$) were significant predictors, leading the authors to suggest a cross-modal learning hypothesis for the relationship between reading and PAL. This is, however, called into question by a recent study (Litt et al., 2014) which examined four PAL tasks (visual-verbal, visual-visual, verbal-visual, and verbal-verbal) in 64 children aged 7 to 11 years. According to the cross-modal hypothesis, both visual-verbal and verbal-visual PAL should be significantly related to reading. However, a set of regression models showed that only visual-verbal PAL ($r = .34$, $p < .01$) and verbal-verbal PAL ($r = .37$, $p < .01$) were significant predictors of reading accuracy (with phoneme deletion and RAN controlled). In contrast, there was no relationship between reading and performance on either visual-visual PAL ($r = .10$, $p > .05$) or verbal-visual PAL ($r = .06$, $p > .05$). This contradicts the cross-modal mapping hypothesis and suggests that the critical feature of PAL is verbal output which taps the access and retrieval of phonological representations.

A study of reading in Norwegian (Lervag & Hulme, 2009) suggests that the relationship between PAL and reading differs according to the consistency of the orthography. In contrast to English (which has an irregular orthography), Norwegian has a regular orthography. Lervag and Hulme (2009) conducted a large-scale longitudinal study in Norway with 228 first grade children (average age: 6;04 years) including tests of visual-verbal PAL, RAN, phoneme awareness, letter knowledge, short term memory, IQ, and verbal abilities. Visual-verbal PAL was not a longitudinal predictor of reading. Thus, learning arbitrary associations between visual forms and phonological output are more important for reading in an irregular than regular orthography.

Though a number of studies have examined PAL as a predictor of reading in alphabetic languages, few have explored the role of PAL in Chinese literacy. One previous study in Chinese (Li et al., 2009) compared the performance of dyslexic children with a typically developing age matched group on visual-visual PAL and visual-verbal PAL. In line with a study in English (Litt & Nation, 2014), there were no differences between the groups on visual-visual PAL, but children with dyslexia performed significantly poorer on visual-verbal PAL. Moreover, Li et al. (2009) assessed several cognitive skills (i.e. phonological awareness, morphological awareness, RAN, and verbal short-term memory) to identify the unique predictors of dyslexia. Logistic regressions showed that performance on tasks tapping morphological awareness, RAN, and visual-verbal PAL reliably discriminated between dyslexic and normal readers. Thus, as in studies of reading in English, visual-verbal PAL appears to be significantly related to reading in Chinese.

In contrast to reading in alphabetic languages, a study by Huang and Hanley (1995) suggests that PAL tasks that involve a visual component may also be related to reading in Chinese. In this study, correlations between visual-visual PAL and reading were strong (.70-.76, $p < .001$) in Chinese readers; in contrast, there was no relationship between visual-visual PAL and reading in English (.20, $p > .05$). Thus, visual-visual PAL appears to play a more important role in reading in Chinese (a logographic language) than in English.

PAL studies in Chinese are relatively rare, and none have examined 4 types of PAL (visual-verbal, visual-visual, verbal-visual, and verbal-verbal) as potential predictors of learning to read and spell in Chinese. This chapter looks at the influence of PAL in Chinese literacy skills beyond the contributions of the cognitive skills that were unique predictors of reading and spelling in Chapter 2. It is predicted that both visual-verbal PAL and verbal-visual PAL will be critical foundations for reading and spelling in Chinese.

3.2. Method

3.2.1. Participants

A total of one hundred and twenty children (71 boys) aged 6;10 to 10;02 years (mean = 8;01, SD = 0;07) participated in this study. This group were a subset of participants in the 2-year longitudinal study. All were native Mandarin speakers from Beijing, China.

3.2.2. Design

Children were assessed on a set of tests measuring cognitive skills, reading ability, and PAL. Testing was conducted individually over five sessions administered approximately one week apart. Assessments of cognitive skills and reading ability were conducted in Session 1. Each of the remaining sessions included one of the four PAL tasks. The order of PAL tasks was counterbalanced.

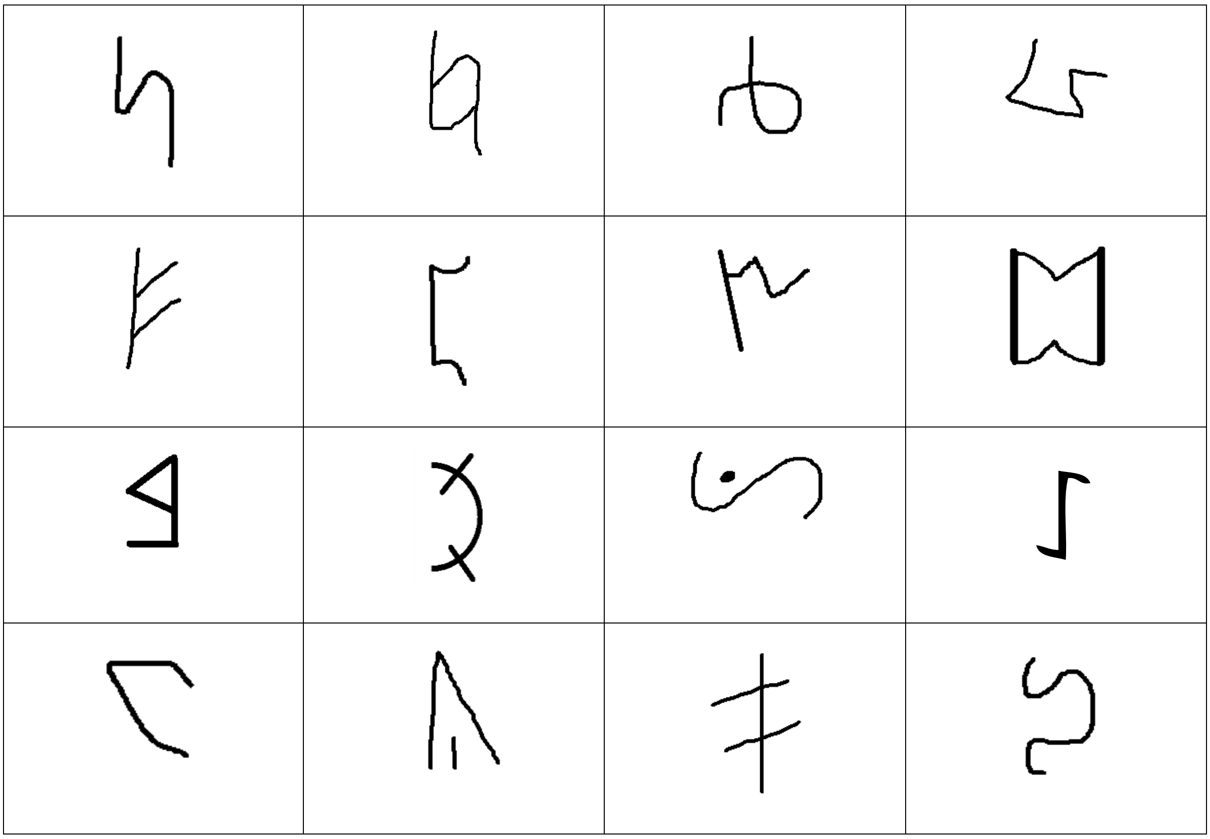
3.2.3. Materials and Procedure

3.2.3.1. Stimuli

3.2.3.1.1. Visual Stimuli

Visual stimuli were 16 abstract shapes used by Litt and Nation (2014). Two of these shapes were modified as they looked similar to Chinese characters. All shapes were listed in Table 3.A. Fifteen Mandarin speaking adults were asked to rate the difficulty of drawing each of the shapes. The visual stimuli were then assigned to four sets matched for difficulty of drawing (F (3, 12) =.013, p=.998).

Table 3.A. Sixteen abstract shapes used in PAL tasks.



3.2.3.1.2. Verbal Stimuli

The verbal stimuli were 16 nonsense single-syllables constructed by changing the tones of real Chinese syllables. Verbal stimuli were always presented aurally; children were not provided with their written forms. Fifteen Mandarin speaking adults were asked to rate the difficulty of verbalizing each of the syllables. The verbal stimuli were then assigned to four sets matched on difficulty of verbalizing (F (3, 12) =.007, p=.999).

The visual and verbal stimuli were used to create 4 PAL conditions: visual-verbal, visual-visual, verbal-visual, and verbal-verbal. Children learned four stimulus-response pairs in each condition. Each condition included 1 practice block and 5 test blocks, and each block included 4 trials. In each condition, the stimulus–response pairs were fixed so that all participants learned the same pairings within each condition. The order of the pairs was randomized in every trial. The number of correct responses was recorded.

3.2.3.2. PAL Tasks

3.2.3.2.1. Visual-visual PAL

In the practice block, an experimenter presented each of the 4 pairs of shapes at a time, and told the child “This shape goes with this shape”. After removing the response item, the experimenter asked the child to draw it to ensure that they could accurately reproduce it. In the test blocks, the child was asked to draw a shape that went with the given shape. Full feedback was given: Each correct response was praised, and incorrect responses were corrected by showing the child the correct picture.

3.2.3.2.2. Visual-verbal PAL

First, the child was asked to repeat aloud each of the nonsense syllables. Only when the experimenter was satisfied with the child’s pronunciation of each syllable did the learning procedure begin. In the practice block, an experimenter presented one shape at a time and told the child that this shape went with a nonsense single-syllable (e.g., this shape goes with /shui1/). Then the experimenter asked “What goes with this shape?” to which the child would respond with the corresponding syllable. In the test blocks, the child was asked what went with the given shape. Full feedback was given: Each correct response was praised, and incorrect responses were corrected by telling the child the correct syllable.

3.2.3.2.3. Verbal-visual PAL

In the practice block, the experimenter said a nonsense syllable and presented a shape, and told the child that this syllable went with the shape (e.g., /ban2/ goes with the shape). After removing the shape, the experimenter gave the nonsense syllable (e.g., “What goes with /ban2/), and asked the child to draw the response item to ensure that they could be accurately reproduced. In the test blocks, the child was asked to draw the shape that went with the given syllable. Full feedback was given: Each correct response was praised, and incorrect responses were corrected by showing the child the correct picture.

3.2.3.2.4. Verbal-verbal PAL

First, the child was asked to repeat aloud each of the nonsense syllables. Only when the experimenter was satisfied with the child's pronunciation of each syllable did the learning procedure begin. In the practice block, the experimenter said each of the 4 pairs of syllables, and told the child the two syllables were a pair (e.g., "/qun3/ goes with /gai2/"). The experimenter then provided only one syllable and asked the child to provide its pair (e.g., "What goes with gai2?"). In the test blocks, the child was asked what went with the given syllable. Full feedback was given: Each correct response was praised, and incorrect responses were corrected by telling the child the correct syllable.

3.2.3.3. Literacy Tests and Cognitive Tests

3.2.3.3.1. Chinese Word Reading

This task was modified from a two-character word-reading test used by McBride-Chang et al (2003). To increase the difficulty of the task, 40 new two-character words were added into the test (190 items in total). These new words were randomly selected from the book *Chinese Textbook* (2004, 2005) in Grade 4 to 5. Words were presented to increase in difficulty and testing was discontinued after 15 consecutive errors. Each correct answer was awarded 1 point (max. 190).

3.2.3.3.2. Semantic-only Reading

This task presented 30 two-character words which were simple characters or only had semantic radicals, randomly selected from the book *Chinese Textbook* (2004, 2005) in Grade 4 to 5. Children were asked to try to read all words. Each correct answer was awarded 1 point (max. 30).

3.2.3.3.3. Semantic-phonetic-regular Reading.

This task included 30 two-character words. All the words were phonograms, and the pronunciations of phonetic radicals were completely the same as those of the words. These new words were randomly selected from the book *Chinese Textbook*

(2004, 2005) in Grade 4 to 5. Children were asked to try to read all the words. Each correct answer was awarded 1 point (max. 30).

3.2.3.3.4. Semantic-phonetic-irregular Reading

Thirty two-character words were presented. All the words were phonograms, but the pronunciations of phonetic radicals were not completely the same as those of the words (they may differ in onset, rime or tone). These new words were randomly selected from the book *Chinese Textbook* (2004, 2005) in Grade 4 to 5. Children were asked to try to read all the words. Each correct answer was awarded 1 point (max. 30).

3.2.3.3.5. Chinese Word Spelling

Children were asked to spell 48 two-character words (taken from McBride-Chang et al., 2003) presented aurally. Each correct character was awarded 1 point (max. 96). All errors in writing were penalised.

3.2.3.3.6. Onset Deletion.

There were three parts to the onset deletion task: a 7-trial single-syllable onset deletion test; a 7-trial two-syllable onset deletion test; and a 13-trial complex multiple-syllable onset deletion test (McBride-Chang et al., 2003). In the single-syllable onset deletion test, children were required to repeat the syllable to make sure that they heard it, and then they were asked to delete an initial phoneme from each syllable. For example, after repeating 泼 /po1/, children were asked to delete an initial phoneme when saying 泼 /po1/. The answer should be 喔 /o1/. In the two-syllable onset deletion test, children were required to repeat the two-syllable word to make sure that they heard it clearly, and then they were required to delete an initial phoneme from this two-syllable word. For example, after repeating 申请 /shen1qing3/, children were asked to delete an initial phoneme when saying 申请 /shen1qing3/. The answer should be /en1qing3/. In the complex multiple-syllable onset deletion test, children were required to repeat the multiple-syllable word to make sure that they heard it clearly, and then they were required to delete an initial phoneme from each syllable. For example, after repeating 申请 /shen1qing3/, children were asked to delete an initial phoneme of each syllable when saying 申请 /shen1qing3/. The answer should be /en1ing3/. Each correct answer was awarded 1 point (max. 27). The test was discontinued if a child provided 4 incorrect answers in any single part (i.e. if a child provided 4 incorrect answers in Part 1, he/she would not proceed to Part 2 or Part 3).

3.2.3.3.7. Morphological Construction.

Morphological awareness was assessed using a morphological construction task (McBride-Chang et al., 2003). In this task, children listened to 2 spoken sentences. The first sentence described a familiar word as a morphological cue. The second sentence described a novel object or concept for which children were required to construct a compound word based on a morphological cue. For example, 'If a ball played with a foot is called '足球' (football), what should we call a ball which is played with the mouth?' The answer should be '嘴球' (mouthball). The test was discontinued when the child failed to provide correct answers on 4 consecutive trials. Each correct answer was awarded 1 point (max. 32).

3.2.3.3.8. Visual Discrimination

The visual shapes were modified from Gardner's visual test (Gardner, 1996). On each trial, a target shape was presented alongside five alternative choices on a computer screen. Children were required to select which one of the five shapes was the same as the target shape. Distractor shapes were selected to look very similar to the target. Children were allowed 6 seconds to respond on each trial. Each correct answer was awarded 1 point (max. 25).

3.2.3.3.9. RAN

In this task, children were presented with a 5*5 matrix on paper of five digits: 1, 2, 5, 6, and 8 (Denckla & Rudel, 1976). Children were required to name the digits from left to right and from top to bottom as rapidly and accurately as possible. Response time was recorded in seconds.

3.2.3.3.10. Pinyin Spelling

The Pinyin words were randomly selected from the book *Xinhua Chinese dictionary* (2011). Children heard the spoken form of Pinyin words and were asked to write them down. Each correct word spelled correctly was awarded 1 point (max. 20). Any error on onset, rime, or tone was penalized.

3.2.3.3.11. Vocabulary

Vocabulary was assessed using a 53-item test from McBride-Chang et al. (2003). Children were required to give a verbal definition of the meaning of each word they heard. The score for each trial was 0, 1, or 2 according to the accuracy of the explanation (following McBride-Chang et al., 2003). Only verbal responses were scored. The maximum score of this test was 106.

3.3. Results

3.3.1. Descriptive Statistics

Table 3.1 presents the means, standard deviations (SD), and range of scores on all measures. All measures were well distributed without floor or ceiling effects.

Table 3.1. Means, Standard Deviations, and Ranges for the All the Measures

Measure	Mean	SD	Range
Age[a]	97.02	7.49	82.07 - 121.50
Chinese word reading (190)	114.71	39.73	17 - 188
Semantic-only reading (30)	16.31	6.44	2 - 30
Semantic-phonetic-regular reading (30)	15.92	8.49	0 - 30
Semantic-phonetic-irregular reading (30)	12.20	7.55	0 - 30
Chinese word spelling (96)	41.01	17.44	10 - 83
RAN[b]	10.92	2.71	6.10 - 19
Pinyin spelling (26)	18.17	6.17	1 - 26
Visual discrimination (25)	20.40	2.42	10 - 25
Onset deletion (27)	18.46	7.55	0 - 27
Morphological awareness (32)	24.18	4.84	12 - 32
Vocabulary (106)	61.40	22.36	20 - 106
Verbal-verbal PAL(20)	5.16	3.82	0 - 17
Verbal-visual PAL (20)	12.47	4.18	2 - 20
Visual-verbal PAL (20)	12.00	4.31	1 - 19
Visual-visual PAL (20)	9.83	3.91	1 - 19

Note. N = 120.

Numbers in parentheses represent the maximum score for each measure. Measures are recorded in raw scores. RAN is the time to complete the task.

[a] In months. [b] In seconds.

A repeated measures analysis of variance (ANOVA) showed significant differences between scores on the different PAL tasks ($F=122.07$, $p< .001$, $\eta^2= .51$). Performance on verbal-visual PAL was significantly better than that of visual-visual PAL ($t=6.17$, $p<.001$); performance on visual-verbal PAL was significantly better than that of verbal-verbal PAL ($t=17.38$, $p<.001$); and performance on visual-visual PAL was significantly better than that of verbal-verbal PAL ($t=10.78$, $p<.001$). There were no differences between visual-verbal PAL and verbal-visual PAL ($t=-1.08$, $p=.284$).

3.3.2. Correlations

Table 3.2.1 displays the simple correlations between word reading, semantic-only reading, semantic-phonetic-regular reading, and semantic-phonetic-irregular reading. All tests of reading showed strong correlations with each other (correlations ranged from .770 to .885, $p< .001$). To simplify further analyses, we conducted a factor analysis and derived a single factor score for each subject. The factor scores ranged from -2.07 to 1.97 (SD= .98).

Table 3.2.1. Correlations between Word Reading, Semantic-only Reading, Semantic-phonetic-regular Reading, and Semantic-phonetic-irregular Reading

	1	**2**	**3**
1.Chinese word reading	--		
2.Semantic-only reading	.847***	--	
3.Semantic-phonetic-regular reading	.843***	.875***	--
4.Semantic-phonetic-irregular reading	.770***	.837***	.885***

Table 3.2.2 displays the simple correlations among measures and the partial correlations with age controlled. All cognitive skills and PAL tasks were significantly correlated with tests of reading (word reading factor scores) and spelling ability (correlations ranged from .247 to .593, $p< .05$) with the exception of visual-visual PAL and word spelling ($r=.027$, $p> .05$). PAL tasks were significantly correlated with each

other (correlations ranged from .219 to .442, $p < .05$). After controlling for age, the general pattern of correlations remained the same. Correlations between visual-visual PAL and word reading factor scores became stronger, and correlations between verbal-verbal PAL and literacy skills became weaker. Correlations between the four PAL tasks were all significant, ranging from .258 to .407.

Table 3.2.2. Correlations between Age, Word Reading Factor Scores, Chinese Word Spelling, RAN, Pinyin Spelling, Visual Discrimination, Onset Deletion, Morphological Construction, Vocabulary, and PAL Tasks.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Word Reading Factor Scores	--	.628***	-.335***	.518***	.274**	.458***	.549***	.488***	.272**	.422***	.528***	.329***
2.Chinese word spelling	.704***	--	-.442***	.557***	.106	.409***	.414***	.252**	.275**	.399***	.380***	.120
3.RAN	-.354***	-.430***	--	-.323***	-.169	-.373***	-.368***	-.138	-.242**	-.073	-.262**	-.112
4.Pinyin spelling	.563***	.589***	-.342***	--	.183*	.367***	.373***	.063	.265**	.359***	.380***	.036
5.Visual discrimination	.323**	.194*	-.188*	.223**	--	.282**	.396***	.123	.067	.186*	.040	.210*
6.Onset deletion	.544***	.532***	-.389***	.428***	.329***	--	.403***	.401***	.328***	.292**	.397***	.271**
7.Morphological awareness	.584***	.465***	-.384***	.411***	.422***	.452***	--	.341***	.122	.201*	.281**	.298**
8.Vocabulary	.593***	.471***	-.181*	.185*	.201*	.516***	.405***	--	.171	.293**	.341***	.264**
9.Verbal-verbal PAL	.342***	.361***	-.264**	.312***	.111	.389***	.173*	.269**	--	.397***	.407***	.284**
10.Verbal-visual PAL	.395***	.341***	-.075	.353***	.187*	.278**	.202*	.265**	.391***	--	.378***	.339***
11.Visual-verbal PAL	.566***	.440***	-.282**	.418***	.084	.448***	.322***	.407***	.442***	.373***	--	.258**

12.Visual-visual PAL	.247*	.027	-.095	.003	.182*	.200*	.258**	.162*	.243**	.333***	.219**	--	
13.Age	.410***	.574***	-.123	.259**	.189*	.390***	.236***	.511***	.248**	.025	.240**	-.123	

Note: N = 120   Partial correlations controlling for age are above the diagonal. Simple correlations below.

+p<.1; *p<.05; **p<.01; ***p<.001

3.3.3. Modelling Relations among Measures of Reading, Spelling, and PAL Tasks

To evaluate which PAL tasks were unique predictors of reading and spelling in Chinese, two simultaneous regression models were conducted with reading (word reading factor scores) and spelling as the dependent variables. Age and scores on the 4 PAL tasks were the independent variables. All independent variables were entered into each model, and nonsignificant variables with the smallest contribution were dropped iteratively to leave a simplified model in which all predictors were statistically significant. The models are shown in Figure 3.1 (reading) and Figure 3.2 (spelling) below. Solid arrows represent statistically significant predictive relationships with other predictors in the model controlled. The value above the dependent variable represents the proportion of variance explained by the variables in the model.

Patterns of predictors of reading and spelling were the same: performance on visual-verbal, and verbal-visual PAL were significant predictors of reading (F (3,116) =31.399, $p< .001$) and spelling (F (3,116) =35.399, $p< .001$) after controlling for age. For reading, visual-verbal PAL, verbal-visual PAL, and age (controlling for the other predictors in the model) accounted for 19%, 8%, and 14% of the variance. For spelling, visual-verbal PAL, verbal-visual PAL, and age (controlling for other predictors in the model) accounted for 7%, 9%, and 32% of the variance in Chinese word spelling.

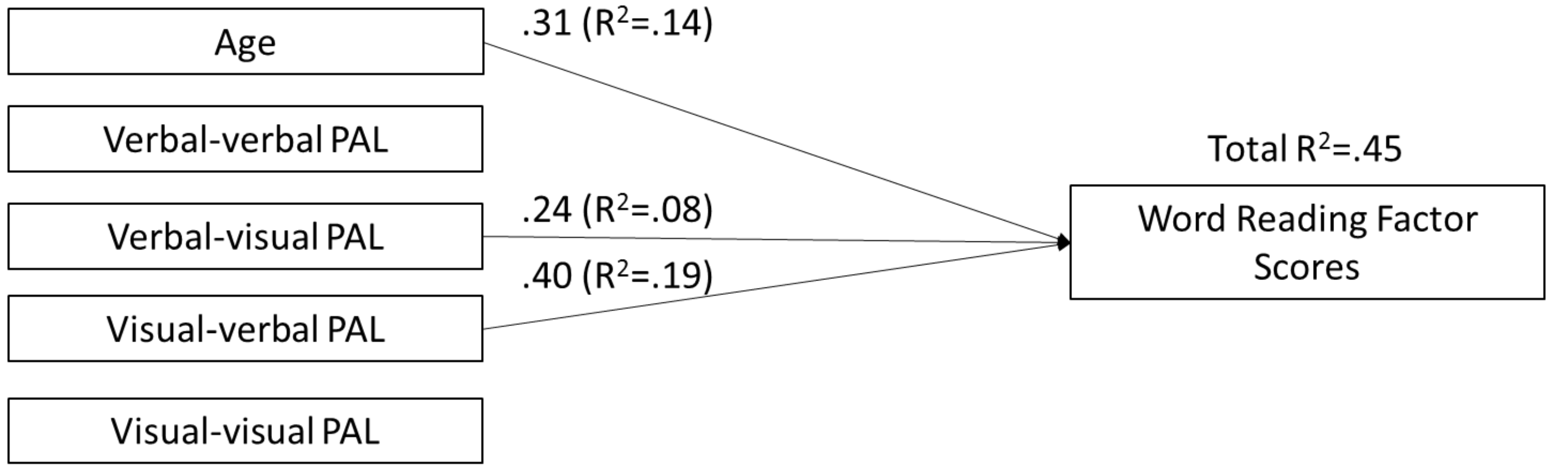


Figure 3.1. Path diagram showing predictors of combined word reading. Path weights are standardized regression coefficients. R^2 values are unique contributions from each variable, and total R^2 value is contribution from all significant variables. Non-significant effects were omitted from the model and are not shown in the diagram.

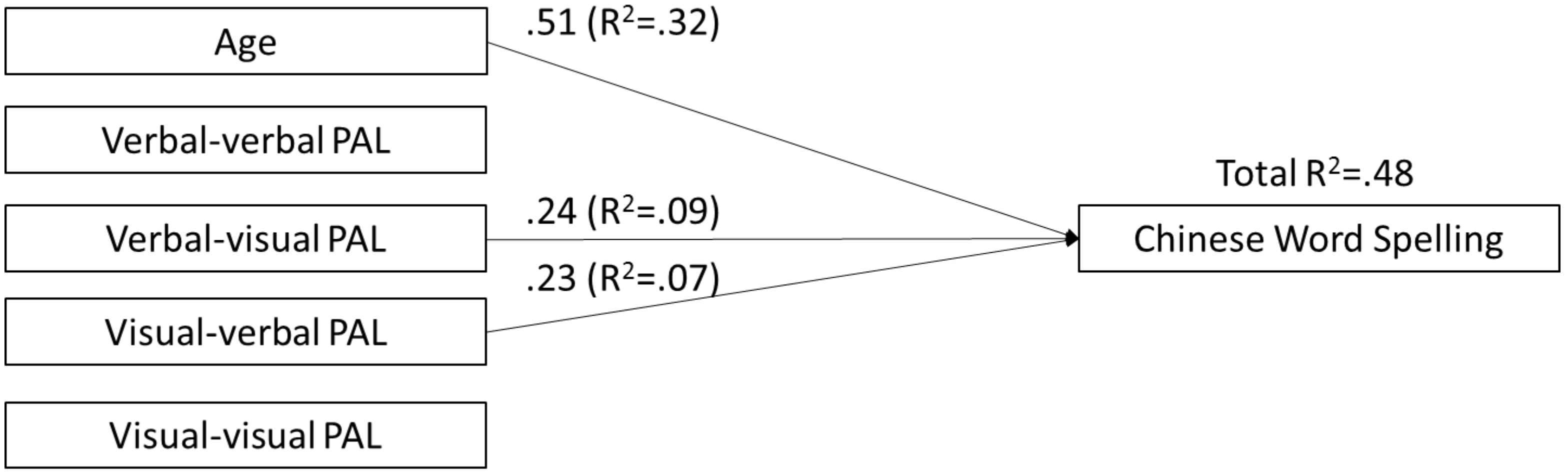


Figure 3.2. Path diagram showing predictors of Chinese word spelling. Path weights are standardized regression coefficients. R^2 values are unique contributions from each variable, and total R^2 value is contribution from all significant variables. Non-significant effects were omitted from the model and are not shown in the diagram.

3.3.4. Modelling Relations among Measures of Reading, Spelling, PAL Tasks, and Cognitive Skills

To assess the most important predictors of reading and spelling in Chinese, we used two sets of simultaneous regression models with word reading (word reading factor scores) and spelling as dependent variables. Visual-verbal PAL, verbal-visual PAL, age, and cognitive skills were independent variables. First, all independent variables were entered into two sets of simultaneous regression models. In each model, the non-significant predictors with the smallest contribution were dropped iteratively to leave a model in which all predictors were statistically significant. The models are shown below in Figure 3.3 (reading) and Figure 3.4 (spelling).

Four variables were significant predictors of reading: Pinyin spelling, morphological awareness, vocabulary, and visual-verbal PAL ($F(4,115) = 52.251$, $p < .001$); together these predictors accounted for 65% of the variance in reading. In the model, Pinyin spelling, morphological awareness, vocabulary, and visual-verbal PAL (controlling for other predictors) respectively accounted for 16%, 11%, 20%, and 9% of the variance in reading.

Four variables were significant predictors: age, RAN, pinyin spelling, and verbal-visual PAL ($F(4,115) = 47.663$, $p < .001$) accounting for 62% of the variance in spelling. In the model, age, RAN, pinyin spelling, and verbal-visual PAL (controlling for other predictors in the model) respectively accounted for 34%, 13%, 16%, and 8% of the variance in Chinese word spelling.

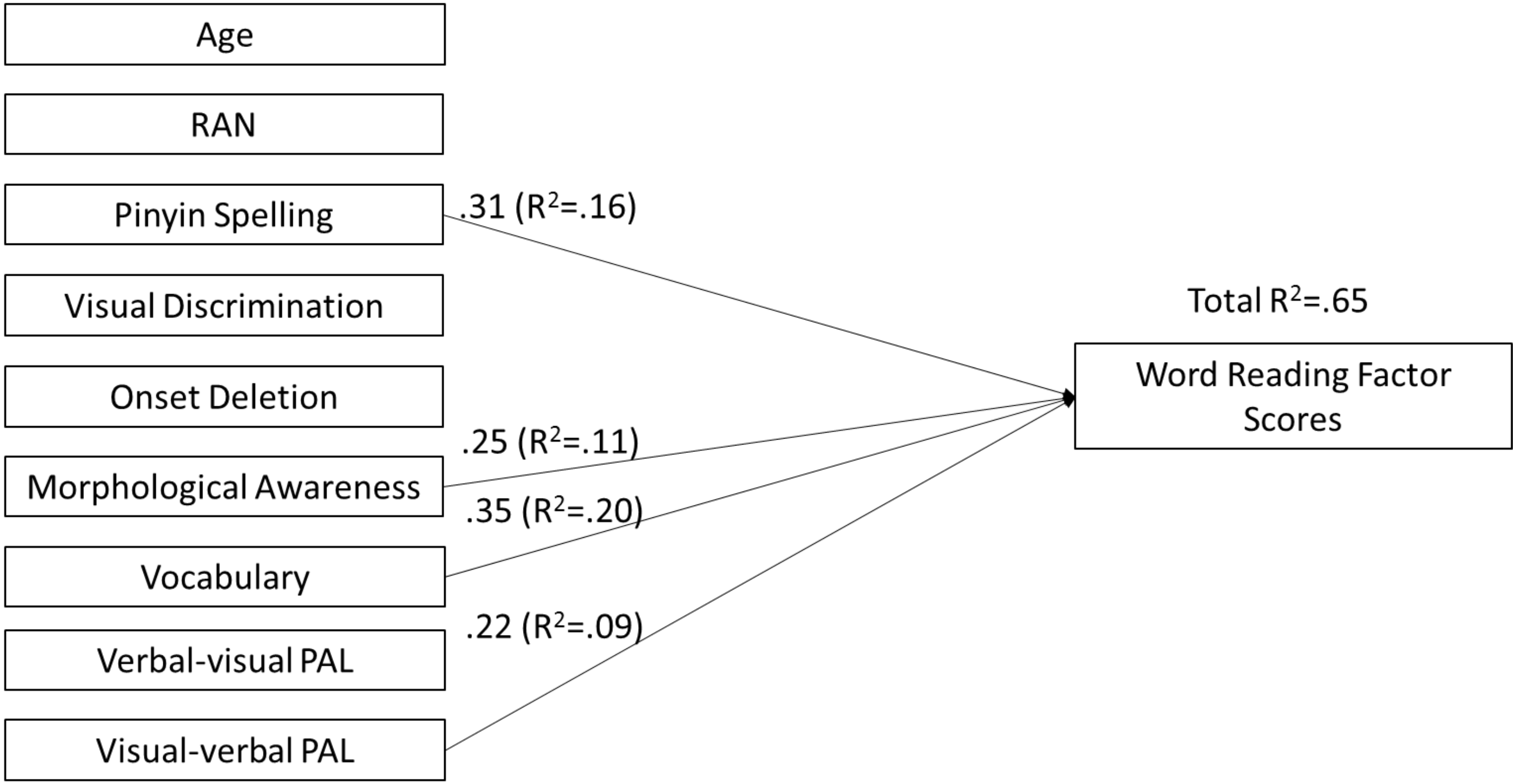


Figure 3.3. Path diagram showing predictors of combined word reading. Path weights are standardized regression coefficients. R^2 values are unique contributions from each variable, and total R^2 value is contribution from all significant variables. Non-significant effects were omitted from the model and are not shown in the diagram.

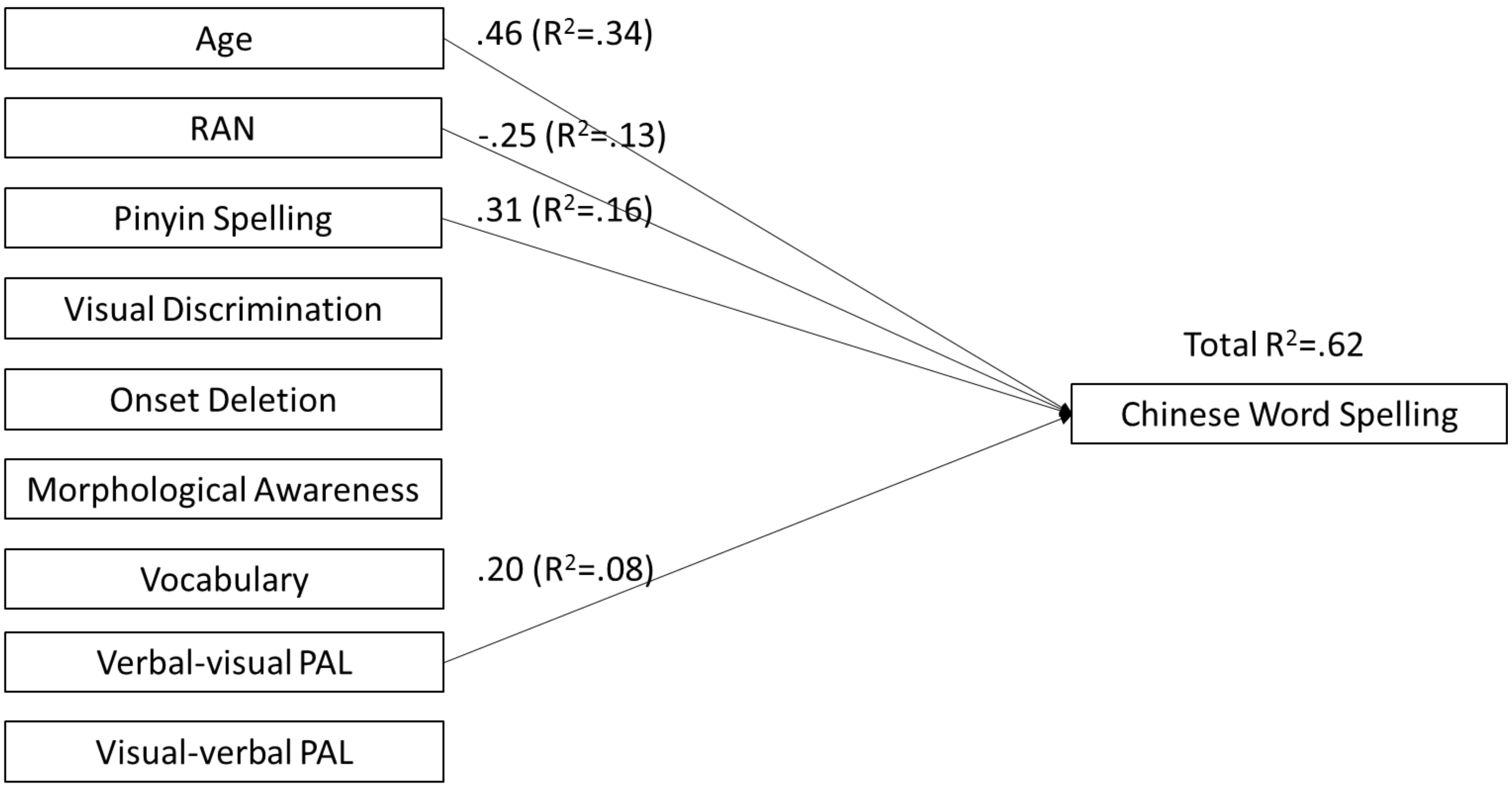


Figure 3.4. Path diagram showing predictors of Chinese word spelling. Path weights are standardized regression coefficients. R^2 values are unique contributions from each variable, and total R^2 value is contribution from all significant variables. Non-significant effects were omitted from the model and are not shown in the diagram.

3.4. Discussion

The aim of the present study was to assess the role of four PAL tasks (visual-verbal, visual-visual, verbal-visual, and verbal-verbal) as predictors of learning to read and spell in Chinese. Both visual-verbal and verbal-visual PAL were unique predictors of reading and spelling in Chinese with age and other PAL tasks controlled. Neither visual-visual nor verbal-verbal PAL were unique predictors of Chinese literacy skills. It is notable that the lack of prediction between the verbal-verbal task and literacy skills might be due to the low scores (only 5/20 correct), so future studies are needed to provide more training trials in verbal-verbal PAL to avoid floor effect. Furthermore, visual-verbal PAL was a unique predictor of reading, and verbal-visual PAL was a unique predictor of spelling, beyond the contribution of critical cognitive skills. These findings suggest that cross-modal learning mechanisms are important for learning to read and to spell in Chinese. Furthermore these cross modal learning mechanisms have influences on reading and spelling development after a range of other cognitive skills (RAN, Pinyin spelling, visual discrimination, onset deletion, morphological awareness, and vocabulary) have been controlled.

3.4.1. PAL Tasks and Cognitive Skills as Predictors of Reading in Chinese.

Visual-verbal PAL was a unique predictor of Chinese word reading. This finding is in line with some previous findings from different languages (English: Hulme et al., 2007; Chinese: Li et al., 2009). This predictive relationship remained significant even when controlling for a set of cognitive skills that are important for reading including RAN, Pinyin spelling, visual discrimination, morphological awareness, and vocabulary.

These results are somewhat inconsistent with a previous study in English (Litt et al., 2013). Litt et al. (2013) found that only verbal output tasks were significantly correlated with reading while visual output tasks were not significantly related to reading. In the present study, relationships between reading and all 4 PAL conditions were significant and both verbal-visual and visual-verbal tasks were significant predictors of reading when controlling for age (though only visual-verbal PAL remained significant when other cognitive skills were included in the analysis). These findings suggest that visual skills play a more important role in learning to read Chinese than in learning to read English. It is possible that Chinese is a logographic system which places heavier demands on visual skills

Visual-verbal PAL was a significant predictor of reading after controlling for other cognitive skills that are important for reading. This relationship may be explained by similarities between visual-verbal PAL and learning to read. Visual-verbal PAL simulates the way children learn to read a new word at the early stage of literacy development: when learning to read, children are presented with a visual shape (a word) and must learn to associate it with a verbal response (the pronunciation of the word). In written Chinese, associations between orthography and phonology are relatively arbitrary, especially for simple characters. As little semantic or phonetic information can be found in simple characters, learning these is analogous to visual-verbal PAL. As Li et al. (2010) reported, kindergarten children tend to use a 'logographic strategy' to learn to read a new word; i.e. they identify a character as an overall shape (most characters that kindergarten children learn to read are simple characters). Each simple character is like an abstract shape (e.g. 日) for a beginner. Learning to read them is therefore similar to learning associations between verbal stimuli (e.g. /ri4/) and visual shapes (e.g. 日). Numerous studies have demonstrated the importance of radical knowledge for reading in Chinese (Siok & Fletcher, 2001; Tong et al., 2009). Most radicals are derived from simple characters (e.g. the radical 亻 is derived from the character 人 /ren2/ *person*). Knowledge of simple characters therefore directly affects one's knowledge of radicals. Visual-verbal PAL which plays an important role in simple-character reading may therefore have an important effect on learning to read compound-characters that are composed of more than one radical.

Along with visual-verbal PAL, Pinyin spelling, morphological awareness, and vocabulary were significant unique predictors of reading in this study. This is generally consistent with findings from the longitudinal study reported in Chapter 2, with the exception of RAN which was also a significant concurrent predictor of reading in a similar age group of children. In the current study, RAN was no longer a significant predictor of reading when visual-verbal PAL was included in the model. This inconsistency with the longitudinal study can be explained RAN and visual-verbal share much variance as both of them reflect the phonological retrieval from visual forms (the correlation coefficient between RAN and visual-verbal was -.282, $p < .01$).

3.4.2. PAL Tasks and Cognitive Skills as Predictors of Spelling in Chinese.

The pattern of predictors of spelling was different from that of reading in Chinese. Age, RAN, Pinyin spelling, and verbal-visual PAL were significant predictors of spelling. Verbal-visual PAL reflects a process that is similar to that involved in spelling in that the child hears a verbal stimulus (hears a spoken word) and draws an abstract shape (spells the word). Beyond the contribution of verbal-visual PAL, Pinyin spelling and RAN accounted for significant variance to spelling. This finding is in line with the results from the longitudinal study reported in Chapter 2 in which Pinyin spelling and RAN were the most robust predictors of spelling in Chinese.

Verbal-verbal, verbal-visual, and visual-verbal PAL were significantly correlated with spelling after controlling for age. However, the partial correlation between visual-visual PAL and spelling was not significant. It is interesting that visual-visual PAL was not significantly correlated with spelling, but the correlation between verbal-verbal PAL and spelling was significant. This suggests that Chinese spelling is not an automatic skill developed from copying but rather demands verbal processing.

3.5. Conclusions

Visual-verbal and verbal-visual PAL are significant predictors of learning to read and spell in Chinese. Moreover, visual-verbal PAL is a significant predictor of reading beyond Pinyin spelling, morphological awareness, and vocabulary; and verbal-visual PAL predicts spelling alongside RAN, pinyin spelling, and age. These findings fit well with the cross-modal hypothesis of Hulme et al. (2007), and suggest that cross-modal associative learning is important for the development of reading and spelling in Chinese.

Chapter Four

The Causal Role of Phonological and Semantic Knowledge in Learning to Read Words in Chinese

4.1. Introduction

Reading is a process that maps the pronunciation of a word from its visual form; learning to read is to build mappings from print to sound. Several theoretical hypotheses have been put forward to explain the reading system. Plaut, McClelland, Seidenberg, and Patterson (1996) proposed a parallel-distributed processing (PDP) model, showing two routes in the reading system: one is a direct route from orthography to phonology; the other route is mediated by semantic information. Due to its triangular configuration, it is referred to as the *triangle framework*. Similarly, Coltheart (2005) proposed a dual-route framework (DRC) which postulated two routes from orthography to pronunciation: a lexical route and a non-lexical route. The lexical route is for processing irregular words and involves individuals' orthographic, phonological, and semantic lexicon. The non-lexical route is for processing regular words based on rules of grapheme-phoneme conversion (GPC). These models indicate the key roles of phonology and semantic knowledge in reading. According to the lexical quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2002), whether a word can be easily remembered depends how much information (e.g. phonology & semantics) is provided. A word with good lexical quality which incorporates a wide range of linguistic knowledge is more likely to be remembered.

A large number of studies have demonstrated the critical role of phonological skills in learning to read in English (Furnes & Samuelsson, 2011; Parrila et al., 2004). The importance of semantics (i.e. vocabulary) appears to be much weaker. As Strain, Patterson, and Seidenberg (1995) reported, semantic information had great effect on reading words that were of low-frequency and irregular in spelling. Ricketts et al. (2007) reported similar findings that vocabulary was a significant predictor of irregular word reading, but did not predict children's ability to read regular words in English. These findings are consistent with the hypothesis of the triangle framework. According to Plaut et al. (1996), the direct orthography-phonology route is more likely to be activated when grapheme-phoneme mappings are consistent (i.e. when reading regular words), while the semantic mediation route is more likely to be activated when mappings are inconsistent (i.e. irregular or exception words). Therefore, compared with regular words, semantic mediation plays a more important role in exception word reading.

In addition to correlational studies, a growing number of researchers have begun to use training studies to assess the effect of phonological or/and semantic knowledge on word learning in English (Duff & Hulme, 2012; McKague, Pratt, & Johnston, 2001; Ouellette & Fraser, 2009; Share, 1999). Ouellette and Fraser (2009) recruited 35 children (average age: 9;07 years), and presented them with 10 nonwords: 5 with semantic pre-exposure (hearing the definitions of each word), and 5 without semantic pre-exposure. After being presented with each word one by one, the children were asked to identify the nonwords from real words. Nonwords with semantic pre-exposure were correctly identified more frequently than those without semantic pre-exposure. It was suggested that semantic information provided children with a stronger representation when learning the new nonwords. Similarly, a number of training studies have demonstrated that semantic information plays critical roles in learning to spell words in English (Wang, Castles, Nickels, & Nation, 2011; Wang, Nickels, Nation & Castles, 2013).

However, results differed in studies by Nation and Cocksey (2009) and Duff and Hulme (2012). Nation and Cocksey (2009) examined the relationship between phonological knowledge, sematic knowledge, and reading ability. It was found that phonological knowledge played an important role in learning to read, whereas semantic knowledge had little effect on children's (average age: 7 years) reading ability. Duff and Hulme (2012) taught 18 children (average age: 6;01 years) to read 12 non-words: 4 words were learned with phonological pre-exposure, 4 words were presented with phonological and semantic pre-exposure, and 4 words were learned with no pre-exposure. Children learned to read more nonwords that were presented with phonological pre-exposure than no pre-exposure, however, semantic plus phonological exposure did not lead to better word learning than phonological exposure alone. Thus, whilst it has been well documented that phonological information is a foundation of word learning in English, the importance of semantic information is still in question.

Given the visual form of Chinese characters, mappings from print to sound in Chinese are more arbitrary than those in English. The *triangle framework* (Plaut et al., 1996) would therefore suggest that the semantic mediation route may be more easily activated when learning to read in Chinese. It is possible that semantic information plays a more important role in Chinese than it does in English. A previous study (Zevin, 2013) explored the effect of phonological and semantic impairments on the development of reading skills in English and Chinese. It was found that phonological impairments affected learning to read in both English and Chinese, while semantic weaknesses only impaired Chinese word reading ability. Moreover, the Chinese word learning trajectories (Zevin, 2013) indicated that the division of labour between phonological and semantic skills was roughly equal in learning to read in Chinese.

A large number of studies (including the longitudinal study reported in Chapter 2) have shown that phonological awareness and vocabulary are longitudinal predictors of Chinese reading (Li et al., 2012; Lin et al., 2010; Wang et al., 2015). However, few studies have used an orthographic learning paradigm to examine the causal influences of phonological and semantic information on reading ability in Chinese. The purpose of this chapter is to evaluate the causal influences of phonological and semantic information on learning to read Chinese words using a word learning study. It is predicted that both phonological and semantic information contribute to learning to read unfamiliar words in Chinese.

4.2. Method

4.2.1. Participants

Participants were native Mandarin speakers from Beijing, China consisting of 48 children (28 boys) in Grade 1 (mean age = 7;02, SD = 0;04) and 48 children (28 boys) in Grade 2 (mean age = 8;02, SD = 0;04). Children were attending a typical state school and all children from a class were included in the study if their parents gave consent; thus the children can be considered to be a representative sample spanning the typical range of reading and language skills. Each child was given a graded test of Chinese word reading consisting of 150 two-character words (McBride-Chang et al., 2003). Testing was discontinued after 15 consecutive errors. Scores on this test ranged from 19-143 words correct (Grade 1) and 79-149 words correct (Grade

2). Norms for this test are not available but it is clear that a wide range of reading abilities are represented in the sample.

4.2.2. Materials (Orthographic Learning Stimuli)

Twelve low-frequency, late-acquired Chinese words were selected to be taught to the children. These were words which the children were not expected to be familiar with (see Table 4.1 below). All the words were selected from those tested in college entrance examinations. Before training, each child was asked to read and define the 12 words. None of the children were able to read any of the words, and very few accurate definitions were provided (of the 96 children, 11 children defined one of the words; 7 children defined two of the words).

Table 4.1. Training Items

Item	**Pronunciation**	**Meaning**	**Word class**
功勋	/gong1xun1/	Feat, achievement	Noun
悭吝	/qian1lin4/	Stingy	Adjective
皴裂	/cun1lie4/	Chap	Verb
窥觑	/kui1qu4/	Peep	Verb
孱弱	/chan2ruo4/	Frail	Adjective
踯躅	/zhi2zhu2/	Walk to and fro	Verb
静谧	/jing4mi4/	Quiet	Adjective
蟾蜍	/chan2chu2/	Toad	Noun
执拗	/zhi2niu4/	Stubborn	Adjective
髑髅	/du2lou2/	Skull	Noun
罹难	/li2nan2/	Die in a disaster/accident	Verb
裨益	/bi4yi4/	Benefit	Noun

4.2.3. Design and Procedure

The training and testing procedure is based closely on that of Duff and Hulme (2012) and is summarised in Table 4.2. There were three learning conditions: No pre-exposure; Phonological pre-exposure; and Phonological + Semantic pre-exposure. Children were tested individually in three 20-minute training sessions across three consecutive days. Words were divided randomly into 3 sets of 4 words. These word sets were rotated across conditions so that each word occurred equally often in the 3 conditions. All children were taught all words in each condition.

Table 4.2. Summary of the Training and Testing Procedure by Pre-exposure Condition

Time point	Condition	Procedure				
Session 1	N	—	—	—	—	
	P	Phonological pre-exposure	Phonological pre-exposure	Repetition trials	Reinforcement trials	
	P+S	Phonological pre-exposure	Semantic pre-exposure	Repetition trials	Reinforcement trials	
Session 2	N	—	—	—	—	—
	P	Reinforcement trials	Phonological pre-exposure	Phonological pre-exposure	Recall trials	Reinforcement trials
	P+S	Reinforcement trials	Phonological pre-exposure	Semantic pre-exposure	Recall trials	Reinforcement trials
Session 3	N	—	Orthographic learning			
	P	Reinforcement trials	Orthographic learning			
	P+S	Reinforcement trials	Orthographic learning			

Note: N = No pre-exposure condition; P = Phonological pre-exposure condition; P+S = Phonological and Semantic pre-exposure condition

In Session 1 and Session 2, children were pre-exposed to 8 words in the two pre-exposure conditions (Phonological and Phonological + Semantic). The remaining 4 words were not pre-exposed (No pre-exposure). In Session 1, all 8 words initially received phonological pre-exposure. Four of these words then received additional phonological pre-exposure (Phonological pre-exposure condition), while the other four words received additional semantic pre-exposure (Phonological + Semantic pre-exposure condition). This pre-exposure phase was completed with four repetition trials. In Session 2, pre-exposure was repeated as per Session 1, and this time completed with four recall trials. In Session 3, children were taught to read (orthographic learning phase) all 12 target words.

The oral pre-exposure was reinforced at four time points (see below): at the end of Session 1, the beginning of Session 2, the end of Session 2, and the beginning of Session 3. Words were taught in a random order on each trial.

4.2.3.1. Pre-exposure Procedures

Various procedures were used to familiarize children with phonological and semantic information about the training words. In total, children encountered (i.e., heard or said) each word 52 times in both the Phonological and Phonological + Semantic pre-exposure conditions before learning to read them.

4.2.3.1.1. Phonological Pre-exposure

Eight of the 12 words underwent phonological pre-exposure. The training for each word was as follows:

1. The experimenter said the word; the child repeated it (twice).
2. The experimenter said the word; the child listened to it.
3. Syllable discrimination task: The child selected which of two words had the same initial syllable as the target word (e.g., which of 缠绕 /chan2rao4/ and 乘除 /cheng2chu2/ has the same initial syllable as 蟾蜍 /chan2chu2/).
4. Phonological recall: The child was asked to recall the target word. Correct responses were praised, and incorrect responses corrected.

4.2.3.1.2. Phonological + Semantic Pre-exposure

After the Phonological pre-exposure was completed, 4 of the 12 words underwent additional semantic pre-exposure as follows:

1. The experimenter gave the meaning of the word, which included four semantic cues (e.g., A toad is an animal which looks like a frog with bumpy skin. It lives in the water during its childhood and tends to live on land as an adult).
2. The experimenter inserted the word into a defining sentence containing two of the semantic cues mentioned at Step 1; the child repeated the sentence.
3. The experimenter inserted the word into a new defining sentence containing the two remaining semantic cues mentioned at Step 1; the child repeated the sentence.
4. Sentence construction: The child was asked to construct a novel sentence using the target word.
5. The experimenter provided the four semantic cues for the word, and the child was asked to recall the target word. Correct responses were praised, and incorrect responses corrected.

4.2.3.1.3. Repetition and Recall Trials

The pre-exposure phase in Session 1 concluded with repetition trials. Items in the Phonological pre-exposure condition underwent phonological repetition trials: on each trial, the experimenter said each of the 4 words and the child repeated them in turn. The items in the Phonological and Semantic pre-exposure condition underwent semantic repetition trials. On each of these trials, the experimenter said one of the 4 words and gave its definition and the child repeated what the experimenter said. For both conditions, there were 4 repetition trials (4 attempts at each of 4 words), with words presented in a random order on every trial.

The pre-exposure phase in Session 2 concluded with recall trials. Children were asked to recall all 4 words in the Phonological pre-exposure condition. For items in the Phonological + Semantic pre-exposure condition, children heard each of the 4 words (presented in random order) and were asked to provide the relevant definition for each word. In both conditions, there were 4 trials (four attempts at recalling each of the four words/definitions). Correct responses were praised, and incorrect responses corrected.

4.2.3.1.4. Reinforcement Trials

Reinforcement trials occurred at the end of Session 1, the beginning of Session 2, the end of Session 2, and the beginning of Session 3. Children were asked to recall the pronunciations of all 8 words that had been pre-exposed (i.e., “Can you remember any of the words you learnt?”) and to give the meanings of the 4 words in the Phonological + Semantic pre-exposure condition (e.g., “Can you remember what that word means?”). Correct responses were praised, and incorrect responses corrected by the experimenter. These trials represent a form of retrieval practice which is known to facilitate long-term learning (Karpicke & Roediger, 2008)

4.2.3.2. Orthographic Learning

Children were taught to read the 12 words aloud in Session 3. On each trial, children were presented with the 12 words in a random order, each printed on a card, and were asked to read each one aloud. Correct responses (defined as both syllables of the word pronounced correctly with the correct tone) were awarded 1 point. Incorrect responses were corrected by the experimenter. Children completed 6 learning trials (6 attempts at reading each of the 12 words aloud). Word cards were shuffled between trials to randomize the order of presentation. Orthographic learning in this study was assessed purely by a measure of reading accuracy (spelling, which is frequently used as a measure of orthographic learning in studies in English, was not assessed here as it would have been too difficult a task for these children in Chinese).

4.3. Results

Table 4.3 shows the means and standard deviations of words read correctly by condition and grade on each learning trial. This is presented graphically in Figure 4.1. It is clear that children were able to correctly read more words with phonological pre-exposure than with no pre-exposure, and that phonological + semantic pre-exposure led to greater word learning than phonological pre-exposure alone. Children’s performance improved across trials, and children in Grade 2 performed better than children in Grade 1.

Table 4.3. Means and Standard Deviations of Reading Performance on Words Presented in Each Condition over 6 Learning Trials

	No Pre-exposure				Phonological Pre-exposure				Phonological + Semantic Pre-exposure			
Trial	**Grade 1**		**Grade 2**		**Grade 1**		**Grade 2**		**Grade 1**		**Grade 2**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
1	.21	.459	.71	1.129	.63	.789	1.15	1.148	.96	.967	2.04	1.184
2	.58	.821	1.23	1.207	1.23	1.309	1.87	1.178	1.48	1.238	2.58	1.164
3	.96	.922	1.63	1.347	1.56	1.319	2.23	1.341	1.79	1.148	2.60	1.086
4	1.21	1.071	2.15	1.368	1.73	1.267	2.67	1.059	1.98	1.313	2.94	1.060
5	1.46	1.184	2.19	1.266	1.83	1.191	2.96	1.051	2.21	1.352	3.15	1.010
6	1.56	1.270	2.42	1.318	2.08	1.217	3.08	1.007	2.46	1.184	3.42	.767

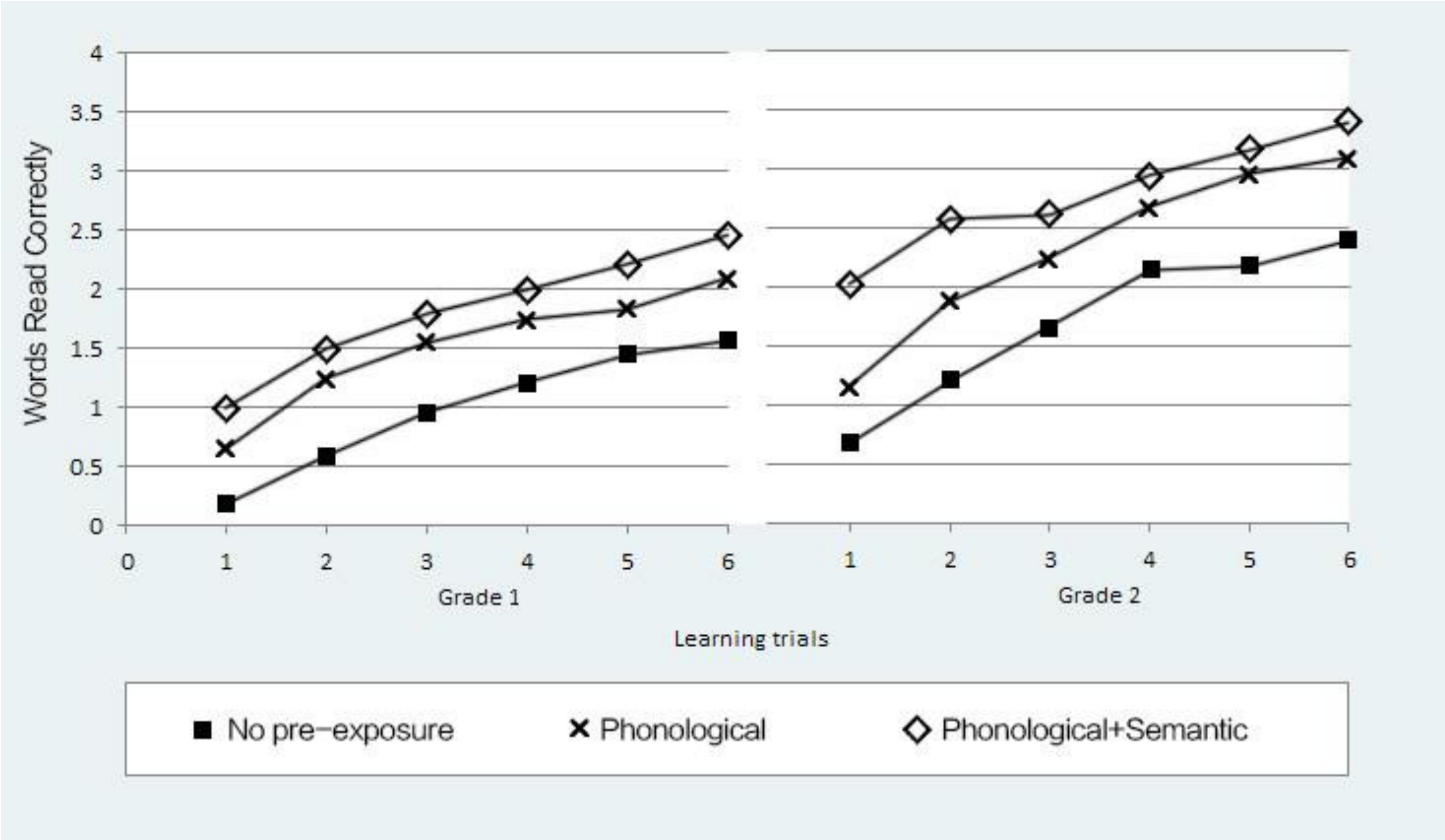


Figure 4.1. Average number of words read correctly on each of 6 learning trials as a function of pre-exposure condition and Grade (maximum score per trial = 4).

As Grade 1 and Grade 2 show similar trends across the learning trials in Figure 4.1, we collapsed data across grade. Figure 4.2 indicates the reading performance of all children across 6 leaning trials. Children correctly read more words with phonological pre-exposure than with no pre-exposure, and additional semantic pre-exposure led to better word learning than phonological pre-exposure alone. The difference between conditions maintained to a roughly constant degree across all trials.

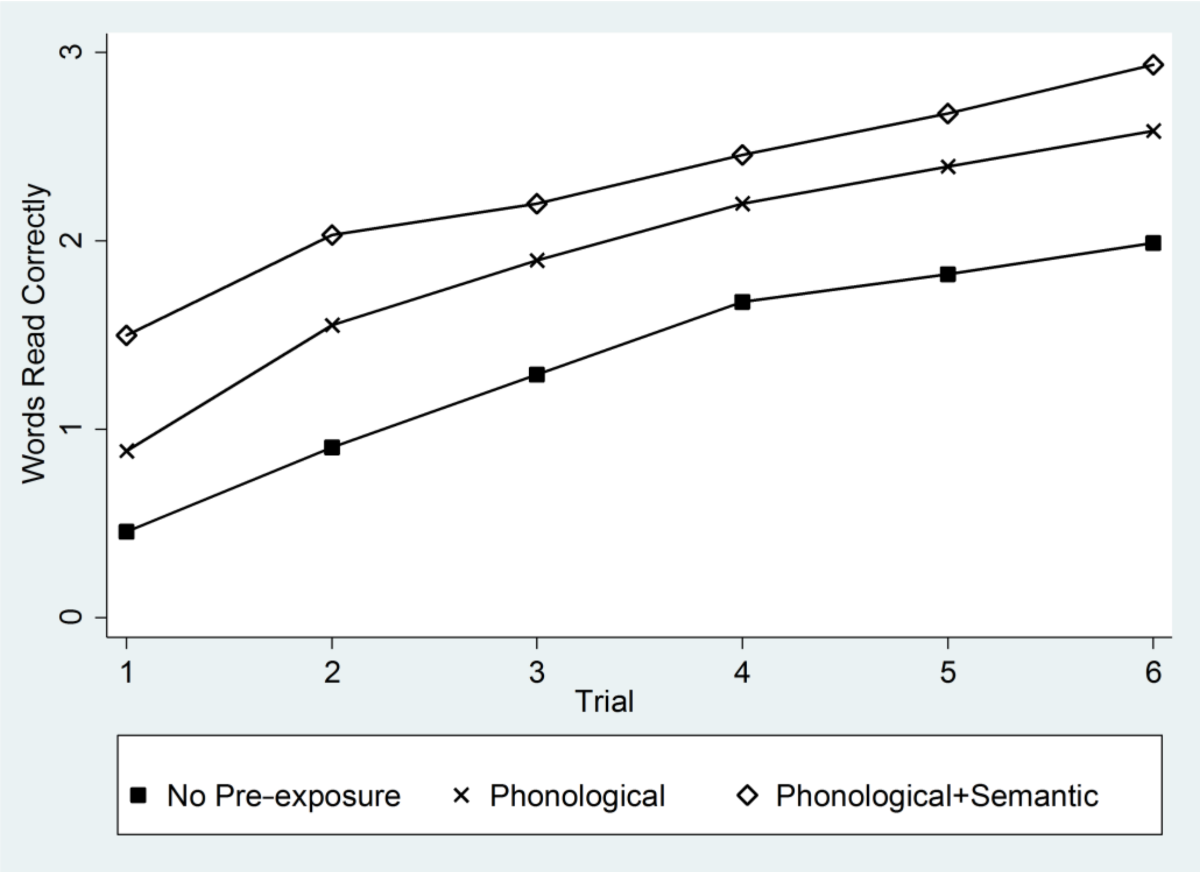


Figure 4.2. Average number of words read correctly on each of 6 learning trials as a function of pre-exposure condition (maximum score per trial = 4).

To evaluate the effect of phonological and semantic pre-exposure on word learning, data were analysed using a cross random effects logistic regression model (xtmelogit in Stata 13.01). This model compared the difference between trials, grade, and learning condition (two dummy codes: [a] no pre-exposure vs. phonological pre-exposure; [b] no pre-exposure vs. phonological and semantic pre-exposure). Items and participants were treated as crossed random effects in the model. Overall, the learning trajectories across trials were characterized by a significant linear (OR=2.80, 95% CI [2.33, 3.38], $z = 10.88$, $p < .001$), and quadratic trend (OR= 0.93, 95% CI [0.91, 0.95], z = -5.70, p < .001). Children's performance showed a steep increase across the first 2 trials, and then tended to increase at a lower rate for the later trials. Children in Grade 2 performed significantly better than children in Grade 1 (OR=4.50, 95% CI [2.63, 7.70], z = 5.50, p < .001). Phonological pre-exposure led to significantly greater reading accuracy than no pre-exposure (OR=2.41, 95% CIs [2.07, 2.82], z= 11.12, p < .001). Phonological + semantic pre-exposure also led to greater reading accuracy than no pre-exposure and this condition showed a larger effect (OR= 4.76, 95% CIs [4.05, 5.59], z=19.06, p < .001). It is clear that additional semantic pre-exposure provided significant benefits for learning to read compared with phonological pre-exposure alone given no overlap between the confidence intervals for each condition.

To examine the interactions between conditions, and linear and quadratic trends of each trial, we added the interaction variable into the model. There were no significant improvements in fit, suggesting that children's performance across trials are equivalent across conditions. The same method was used to examine the interaction between grade and condition. Again, this had no significant effect on the fit of the model, showing that children's performance across conditions and trials are equivalent between the two grades.

4.4. Discussion

This orthographic learning study assessed the causal role of phonological and semantic information in learning to read unfamiliar words in Chinese. The results support the importance of phonological information for word learning, and show that semantic information provides additional benefit to word learning beyond phonological information. The results fit well with our hypotheses, and support the findings of the longitudinal study (Chapter 2) and other previous longitudinal studies (e.g. Song et al., 2015; Zhang et al., 2013) which demonstrate that phonological and semantic skills are critical foundations of learning to read in Chinese.

The present study replicated the experimental design of Duff and Hulme (2012), but shows different findings to their study. In their study of word learning in English, Duff and Hulme (2012) showed that phonological pre-exposure significantly benefited nonword learning in English; additional semantic pre-exposure did not provide additional benefit. Results of the present study also support the key role of phonological information in word learning, but go further to demonstrate the importance of semantic information for learning to read in Chinese. These findings are consistent with Zevin (2013) who reported that phonological and semantic deficits equally affect children's reading ability in Chinese, whereas only phonological deficits affect children's reading ability in English. This is in line with the data presented in Figure 4.2: the difference between phonological pre-exposure and no pre-exposure is roughly equal to the difference between semantic + phonological pre-exposure and phonological pre-exposure.

The current findings show that phonological information is a foundation for learning to read and semantic information plays different roles in word learning across different languages (i.e. a greater role in Chinese word reading than in English). These findings are in line with the theoretical framework of Plaut et al. (1996). There are two routes from orthography to phonology: a direct route without the process of meaning and an indirect route mediated by meaning. According to the results of the present study, both routes of processing exist in learning Chinese words. As the triangle framework of reading indicates, the semantic mediation route is more likely to be activated when mappings from print to sound are unreliable. Therefore, semantic information is more important for learning to read in Chinese where print-sound mappings are more unreliable than in English.

The findings of the present study are also consistent with both the lexical quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2002) and the dual-route framework (Coltheart, 2005). Oral pre-exposure helped children establish good-quality lexical phonological and semantic representations of the unfamiliar words, which made it easier to remember the words in the learning stage. With reference to the dual-route framework, oral pre-exposure strengthened the lexical route (a route for processing irregular words that can be identified from familiar visual forms), and therefore increased children's learning ability.

The present study also has implications for teaching. Given that both phonological and semantic information have a causal effect on learning to read in Chinese, familiarizing children with a word's pronunciation and meaning before teaching children to read it is likely to support learning. This could be achieved through interesting oral pre-exposure activities (e.g. telling stories) which refer to phonetic and semantic information of the new words. These activities are likely to not only motivate and engage children but also help them to learn to read new words.

4.5. Conclusions

This study used an orthographic learning study to demonstrate the importance of both phonological and semantic knowledge in learning to read new words in Chinese. Phonological information is a foundation of learning to read in Chinese, and additional semantic information provides further support for word learning. These results fit well with the triangle framework proposed by Plaut et al. (1996), and suggest practical strategies to support new word learning in school.

Chapter Five

Evaluating the causal effect of Pinyin knowledge on Chinese literacy skills.

5.1. Introduction

Hanyu Pinyin, or Pinyin, is a unique writing system which uses the Latin alphabet and lexical tone marks to represent the standard pronunciation of Chinese characters. It was first officially issued by the People's Republic of China in 1958, and was designated as a compulsory course in primary school in Mainland China from then on (Xinhua News Agency, 2008). The International Organization for Standardization 7098 (ISO7098) accepted Pinyin as an international standard in 1982 (ISO 7098:1982).

Chinese is a logographic orthography. The pronunciation of a character is opaque in the orthography. Each character has a corresponding syllable with a tone. Pinyin, as an alphabetic coding system, makes each phoneme of a syllable transparent to learners. It is taught as an auxiliary tool for learning Chinese, which standardizes children's pronunciation of a single character.

A Pinyin word consists of an onset, a rime, and a tone symbol. The onset is an initial consonant (of a Chinese syllable). The rime is a simple or compound vowel (of a Chinese syllable), sometimes with a terminal [n] or [ng]. The Chinese Pinyin system is composed of 21 onsets, 35 rimes and 4 lexical tone marks (Institute of Linguistics, Chinese Academy of Social Science, 2004). Each onset has one or two letters (e.g. z & zh); each rime has one to four letters (e.g. a, ao, iao, & iang). Each onset and rime has a unique pronunciation, which does not reliably map to orthography (e.g. the pronunciation of *zh* is not the combination of *z* and *h;* the pronunciation of *ia* is the combination of *i* & *a*).

Lexical tone is also an important component of Pinyin. There are four pitches of tones in Mandarin: high level (Tone 1), rising (Tone 2), falling-rising (Tone 3), and falling (Tone 4). A syllable with different tones may indicate different meanings (e.g. /cai/ with Tone 1 means guess; /cai/ with Tone 3 means colourful).

Knowledge of Pinyin, measured by Pinyin reading and/or spelling tests, is a significant concurrent and longitudinal predictor of Chinese literacy. Siok and Fletcher (2001) found that for children from Grade 2 to 4, the speed of Pinyin reading was a significant concurrent predictor of Chinese word reading after controlling for age, phonological awareness, visual skills, orthographic skills, and homophone discrimination. Lin et al. (2010) showed that Pinyin spelling measured at 6;05 years significantly predicted Chinese word reading measured one year later, even after controlling for age, IQ, syllable deletion, phoneme deletion, Pinyin letter reading, and early reading ability. Pinyin knowledge also predicts Chinese word spelling: According to Pan et al. (2011), Pinyin spelling tested at age 6 was a longitudinal predictor of word reading at age 7 to 10, and a robust predictor of word spelling at age 9 and 10. Controls in this study included age, IQ, vocabulary, RAN, syllable deletion, and reading ability measured at age 5.

Previous studies therefore demonstrate that Pinyin knowledge is a reliable predictor of Chinese literacy skills. The longitudinal study reported in Chapter 2 firmly supports these previous studies: Pinyin spelling was identified as one of the strongest concurrent and longitudinal predictors of Chinese reading and spelling. Taken together, these longitudinal studies suggest a possible causal relationship between Pinyin knowledge and learning to read in Chinese.

The best way to test causal relationships is by using training studies: if there is a causal relationship between Pinyin knowledge and literacy then improvements in Pinyin knowledge should lead to improvements in Chinese literacy. As yet there are no training studies available which speak to this question. This chapter reports a 5-week Pinyin training study, in which children receive either Pinyin training or training in math (control condition). The aim of the present study was to evaluate the effect of Pinyin training on Chinese reading and spelling. It was predicted that children who received Pinyin training would show significantly greater improvements in reading and spelling than those in the math training group.

Although there are no existing Pinyin training studies, numerous studies have evaluated the effect of training other cognitive skills on Chinese literacy skills (Chow, McBride-Chang, Cheung, & Chow, 2008; Wu, Anderson, Li, Wu, Li, Zhang, & Chen, 2014; Zhou, McBride-Chang, Fong, Wong, & Cheung, 2013). Therefore, if Pinyin training leads to gains in literacy in the present study, it is necessary to further explore whether Pinyin training directly affects children's literacy skills or whether such effects are mediated by other cognitive skills. Conversely, if Pinyin training has no effect on literacy, the assessment of other cognitive skills could help to identify improvements in other skills that are due to daily classroom teaching. Thus, the present study included several cognitive skills that are significant predictors of Chinese literacy skills (as reported in Chapter 2), so that we could look at the effect of Pinyin training on these cognitive skills.

5.2. Method

5.2.1. Participants

Sixty-two first year primary school children aged from 6;06 to 8;03 years (Mean=7;02; SD=0;04) participated in this study. All were native Mandarin speakers, studying in one public primary school in Beijing, China. None of the children had been diagnosed with dyslexia. Children were from 2 whole classes in the same school. One class were allocated to receive Pinyin training: this group included 31 children (16 boys) aged from 6;07 to 8;03 years (Mean=7;02; SD=0;04). Children from the other class (N=31) were allocated to the math training group: this group were aged from 6;06 to 7;07 years (Mean=7;01; SD=0;04). The two groups were matched for age ($t(1,61) = -.38$, $p=.71$).

5.2.2. Design

Children were allocated into 2 age-matched groups. Group 1 received training in reading and spelling Pinyin; Group 2 received mathematics training (including addition, subtraction, and numeric comparison activities). The training was delivered by the author (L. Zhou) in sessions of approximately 20-25 minutes, four times a week for 5 weeks (20 sessions in total). All children completed a set of tests of cognitive skills, literacy ability and mathematics ability before (T1) and immediately after (T2) the training. Maintenance of gains was assessed by a further test session (T3) completed 4 weeks after training ended.

5.2.2.1. Pinyin Training

At the time of training children had been taught Pinyin for 6 months in school. As such they already had some Pinyin knowledge. Typical teaching of Chinese literacy focuses on character reading and spelling in the second semester of school year. Pinyin is taught as an aid to learning characters in the first semester, but is not reinforced in the second semester. In line with this the longitudinal study reported in Chapter 2 found children's average scores on Pinyin spelling at the beginning of the second semester was roughly 15 out of 20 and showed no real gains (an increase by less than 1) in the next 6 months. The Pinyin training reported here was designed to reinforce learning from the first semester and correct common errors in Pinyin reading and spelling. Table 5.1 below provides an overview of the training sessions.

Table 5.1. Overview of Pinyin Training

Number of unit	**Content**
Unit 1	Read the entire list of onsets and rimes; practice 4 types of tone; indicate the position of a tone symbol in a Pinyin word
Unit 2 & Unit 3	Read + Spell: Pinyin words with a rime of üe; Pinyin words with onsets of l and n
Unit 4 & Unit 5	Read + Spell: Pinyin words with rimes of ui & iu; Pinyin words with onsets of l, n, j, q, & x
Unit 6 & Unit 7	Read + Spell: Pinyin words with rimes of ia, iao, ian, iang, & iong; Pinyin words with onsets of j, q, & x
Unit 8 & Unit 9	Read + Spell: Pinyin words with rimes of ua, uan, & uang；Pinyin words with onsets of h & g
Unit 10	Read + Spell: Pinyin words with rimes of ou, ao, ai, an, & en；Pinyin words with onsets of b, p, m, f, d, t, n, l…
Unit 11	Read + Spell: Pinyin words with rimes of uo；Pinyin words with onsets of m and n
Unit 12 & Unit 13	Read + Spell: Pinyin words with rimes of in & ing; Pinyin words with onsets of z, c, s, zh, ch, & sh
Unit 14 & Unit 15	Read + Spell: Pinyin words with rimes of ang, eng, & ong; Pinyin words with onsets of p, q, b & d
Unit 16 to Unit 20	Read the entire lists of onsets and rimes; practice 4 types of tone; indicate the position of a tone symbol in a Pinyin word. Mini-test: children were asked to write 15 Pinyin words. Common errors were targets for teaching in the next unit.

5.2.2.2. Math Training

The age-matched math training group was the control group. The math training group was designed to compare the effect of Pinyin training with a group who had received training that was unrelated to language skills.

Children in the second semester of Grade 1 have begun to learn addition and subtraction with numbers 1-20. The teaching programme reported here focused on numerical comparison and calculation. An overview of the teaching programme is provided below in Table 5.2.

Table 5.2. Overview of Math Training

Number of units	Content
Unit 1 to Unit 10	Part 1 (10 mins): The teacher randomly selected two cards showing a digit from 1 to 100, and asked children to identify the bigger number (10min). Part 2 (10 mins): The teacher showed a card displaying a math problem and asked children to calculate it (e.g. 7+9=; 13-8=). In both parts, strategies for numerical comparison and calculation (e.g. compare numbers from tens to ones) were taught, and corrective feedback was given.
Unit 11 to Unit 20	Part 1: Children were asked to do a numerical comparison mini-test within 1 min. Part 2: Children were asked to do a calculation mini-test within 5min. Corrective feedback was given for both mini-tests. The remaining time was to go through the answers and review the calculation strategies taught before.

5.2.3. Measures

5.2.3.1. Literacy Measures

5.2.3.1.1. Chinese Word Reading (T1-T3)

This task included 150 two-character words (McBride-Chang et al., 2003). Words were presented to increase in difficulty and testing was discontinued after 15 consecutive errors. Each correct answer was awarded 1 point (max. 150).

5.2.3.1.2. Chinese Word Spelling (T1-T3)

Children were asked to spell 48 two-character words (taken from McBride-Chang et al., 2003) presented aurally. Each correct character was awarded 1 point (max. 96). All errors in writing were penalised.

5.2.3.2. Math Measures

5.2.3.2.1. Numerical Comparison (T1-T3)

Children were presented with 20 items which required them to compare 2 numbers. Children were allocated 30 seconds to identify the larger number in each pair and to indicate this by writing "<" or ">" between the numbers. Each correct answer was awarded 1 point (max. 20).

5.2.3.2.2. Addition Task (T1-T3)

Children were allocated 1 minute to calculate and write the answers to 30 addition problems. These calculations were on numbers between 1 and 20. The difficulty of each problem is similar: a digit plus a digit equals a two-digit number (e.g. 5+7=; 7+9=).Each correct answer was awarded 1 point (max. 30).

5.2.3.2.3. Subtraction Task (T1-T3)

Children were allocated 1 minute to calculate and write the answers to 30 subtraction problems. These calculations were on numbers between 1 and 20. The difficulty of all problems were similar: a two-digit number minus a single digit gives a single digit answer (e.g. 12-7=; 18-9=).Each correct answer was awarded 1 point (max. 30).

5.2.3.3. Proximal Measures

5.2.3.3.1. Pinyin Reading (T1-T3)

Twenty Pinyin words were randomly selected from the book *Xinhua Chinese dictionary* (2011). Children were asked to read these 20 Pinyin words. Each correct answer was awarded 1 point. Any error on onset, rime, or tone symbol was penalized (max. 20).

5.2.3.3.2. Pinyin Spelling (T1-T3)

Twenty Pinyin words were randomly selected from the book *Xinhua Chinese dictionary* (2011). Children heard the spoken form and were asked to write them down. Each correct word spelled correctly was awarded 1 point (max. 20). Any error on onset, rime, or tone was penalized (max. 20).

5.2.3.4. Distal Measures

5.2.3.4.1. Onset Deletion (T1-T2)

The onset deletion task consisted of 3 parts: 1) a 7-trial single-syllable onset deletion test; 2) a 7-trial two-syllable onset deletion test; and 3) an 8-trial complex multiple-syllable onset deletion test (McBride-Chang et al., 2003). In all parts children were asked to repeat the syllables first to make sure they had heard it correctly. In the single-syllable onset deletion test, they were asked to delete an initial phoneme from each syllable. For example, after repeating 泼 /po1/, children were asked to delete an initial phoneme when saying 泼 /po1/. The answer should be 喔 /o1/. In the two-syllable onset deletion test, children were required to delete an initial phoneme from this two-syllable word. For example, after repeating 申请 /shen1qing3/, children were asked to delete an initial phoneme when saying 申请 /shen1qing3/. The answer should be /en1qing3/. In the complex multiple-syllable onset deletion test, children were required to delete an initial phoneme from each syllable. For example, after repeating 申请 /shen1qing3/, children were asked to delete an initial phoneme of each syllable when saying 申请 /shen1qing3/. The answer should be /en1ing3/. Each correct answer was awarded 1 point (max. 22). The test was discontinued if a child provided 4 incorrect answers in any single part (i.e. if a child provided 4 incorrect answers in Part 1, he/she would not proceed to Part 2 or Part 3).

5.2.3.4.2. Morphological Construction (T1-T2)

Morphological awareness was assessed using a morphological construction task (McBride-Chang et al., 2003). In this task, children listened to 2 spoken sentences. The first sentence described a familiar word as a morphological cue. The second sentence described a novel object or concept for which children were required to construct a compound word based on a morphological cue. For example, 'If a ball played with using the foot is called '足球' (football), what should we call a ball which is played with using the mouth?' The answer should be '嘴球' (mouthball). The test was discontinued when the child failed to provide correct answers on 4 consecutive trials. Each correct answer was awarded 1 point (max. 27).

5.2.3.4.3. Visual Discrimination (T1-T2)

This task asked children to discriminate between visual shapes. The visual shapes were modified from Gardner's test (Gardner, 1996). On each trial, a target shape was presented alongside five alternative choices on a computer screen. Children were required to select which one of the five shapes was the same as the target shape. Distractor shapes were selected to look very similar to the target. Children were allowed 6 seconds to respond on each trial. Each correct answer was awarded 1 point (max. 20).

5.2.3.4.4. RAN (T1-T2)

In this task, children were presented with a 5*5 matrix on paper of five digits: 1, 2, 5, 6, and 8 (Denckla & Rudel, 1976). Children were required to name the digits from left to right and from top to bottom as rapidly and accurately as possible. Response time was recorded in seconds.

5.2.3.4.5. Vocabulary (T1-T2)

Vocabulary was assessed using a 53-item test from McBride-Chang et al. (2003). Children were required to give a verbal definition of the meaning of each word they heard. The score for each trial was 0, 1, or 2 according to the accuracy of the explanation (following McBride-Chang et al., 2003). Only verbal responses were scored (max. 106).

5.3. Results

Table 5.3 presents the means, standard deviations (SD) and marginal mean differences in improvement between groups for all measures for the Pinyin training (intervention) and math training (control) groups. All measures were well distributed without floor or ceiling effects.

To compare children's abilities before the training, a set of paired-samples t-tests were performed. It was found that there were no significant difference between two groups in any measures at T1 (all p's>.05).

To evaluate group differences at immediate post-test (T2) and maintenance test (T3), we performed a series of regression (ANCOVA) models. In each model the pre-test (T1) score on the outcome measure was used as a covariate and group was dummy coded (0= Pinyin training; 1 = maths training). Marginal mean differences at T2 and (when tested) at T3 are reported. As indicated in Table 5.1, there were significant group differences on addition, onset deletion and morphological construction at T2, on Chinese word spelling at T3, and on Pinyin spelling at T2 and T3. Pinyin training improved children's abilities on measures of onset deletion and Pinyin spelling. Children's addition ability, morphological construction, and Chinese word spelling were found to be improved in math training group. The two groups showed no other significant differences at any time point.

Table 5.3. Means, Standard Deviations, and Marginal Mean Difference in Improvement between Groups for the Measures at Pre-test (T1), Immediate Post-test (T2), and Maintenance Test (T3)

	T1				T2				T3				
	Intervention		Control		Intervention		Control		Intervention		Control		Marginal mean difference in improvement between groups [95% CI]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Chinese word reading (150)	59.68	37.96	65.13	32.60	68.45	37.40	73.71	32.00	76.00	36.06	79.84	30.77	T1-T2: .009 [-3.16, 3.18] p= .995; d=.0003 T1-T3: -.1.10 [-6.19, 4.00] p= .67; d=-.03
Chinese word spelling (96)	15.13	4.68	14.68	5.39	20.06	4.52	20.16	5.79	26.90	5.46	28.94	6.84	T1-T2: .42 [-1.48, 2.32] p= .66; d=.08 T1-T3: 2.42 [.16, 4.68] p= .04; d=.45
Numerical comparison (20)	13.74	4.78	13.87	4.04	16.94	3.27	17.39	3.36	16.16	4.82	17.29	4.07	T1-T2: .41 [-1.09, 1.90] p= .59; d=.10 T1-T3: 1.08 [-1.04, 3.20] p= .31; d=.27
Addition (30)	16.32	6.67	17.84	6.13	18.16	6.34	21.32	5.61	23.35	5.35	23.94	5.38	T1-T2: 2.03 [.17, 3.90] p= .03; d=.33

													T1-T3: -.34[-2.24, 1.56] p= .72; d=-.06
Subtraction (30)	14.10	5.33	15.39	6.64	15.97	5.29	15.42	6.76	17.87	5.32	17.90	8.48	T1-T2: -1.51 [-3.63, .61] p= .16; d=-.23 T1-T3: -1.00 [-3.68, 1.68] p= .46; d=-.15
Pinyin reading (20)	15.58	3.81	16.19	3.17	18.35	2.37	18.23	3.10	17.77	3.52	17.68	2.82	T1-T2: -.52 [-1.36, .32] p= .22; d=-.16 T1-T3: -.47 [-1.69, .75] p= .44; d=-.15
Pinyin spelling (30)	17.87	6.28	19.58	6.87	24.52	6.56	20.35	6.65	22.26	6.84	20.87	6.30	T1-T2: -5.67 [-7.29, -4.05] p< .001; d=-.83 T1-T3: -2.81 [-4.69, -.93] p= .004; d=-.41
Visual discrimination (20)	17.03	3.76	17.02	2.62	18.19	1.72	17.87	2.00	N/A	N/A	N/A	N/A	T1-T2: -.33 [-1.26, .61] p= .49; d=-.13
Onset deletion (22)	9.61	7.95	10.55	7.94	15.19	6.18	13.90	7.65	N/A	N/A	N/A	N/A	T1-T2: -1.98 [-3.93, -.02] p= .048; d=-.25
RAN	12.16	2.65	11.013	2.24	10.94	2.20	10.51	1.94	N/A	N/A	N/A	N/A	T1-T2:.15 [-.72, 1.02] p= .73; d=.07

Morphological construction (27)	22.55	4.34	21.29	4.81	24.23	2.49	25.06	2.00	N/A	N/A	N/A	N/A	T1-T2: 1.23 [.33, 2.14] p= .008; d=.26
Vocabulary (106)	44.74	16.85	44.19	17.44	50.19	17.90	51.71	16.14	N/A	N/A	N/A	N/A	T1-T2: 2.04[-.44, 4.52] p= .11; d=.12

Note. N = 62

Numbers in parentheses represent the maximum score for each measure. Measures are recorded in raw scores. RAN is the time to complete the task (in seconds).

5.4. Discussion

This training study was designed to assess the possible causal influence of Pinyin knowledge on Chinese literacy and related cognitive skills. In the present study, Pinyin training was compared to an active treatment control (math training). Children in the Pinyin training group significantly improved in Pinyin spelling measured immediately after training (medium effect size, d= -.83); these gains were maintained 4 weeks after training (d= -.41). Children in the math training group made small (d= .33) but significant gains in addition at post-test. These results indicate that the training programmes were effective at improving targeted skills. Furthermore, Pinyin training improved children's ability on a measure of onset deletion, which was demonstrated to be a robust concurrent and longitudinal predictor of Chinese literacy skills in first year primary school children (see Chapter 2). Pinyin training did not, however, lead to greater gains in Chinese word reading or spelling. In contrast, children in the math training group showed small but significant gains in morphological construction at post-test and in Chinese word spelling on the maintenance test conducted four weeks after training. These findings were unexpected and inconsistent with the prediction that Pinyin training improves children's Chinese literacy skills.

There is no reason to expect that gains in morphological construction or spelling seen in the math training group were a result of the training they received in this study. Potentially these differences are due to differences in classroom teaching. Each group of children were from a whole class, children in the two groups were therefore exposed to some differences in daily teaching. It is possible therefore that the small improvements seen in morphological awareness and spelling skills in the math training group are a consequence of the instruction from their teachers. In the present study, a researcher was not allowed to take up time of several classes simultaneously, so the researcher conducted each training within a whole class. Future studies should allocate children randomly to groups within a classroom to rule out this factor. According to previous studies, morphological training significantly improves kindergarten children's reading ability in Chinese (Chow et al., 2008; Zhou et al., 2013). The improvement in Chinese word spelling found in the math training group might therefore be due to the gains in morphological skills. Future research is needed to compare the effects of Pinyin training and morphological awareness training on Chinese literacy skills in primary school children.

Another important finding was that Pinyin training improved children's phoneme awareness (as measured by an onset deletion task). This is in line with previous findings that Pinyin leaning can boost phoneme awareness (Cheung et al., 2001; McBride-Chang et al., 2010). As discussed in the introduction, phonemes are not represented in Chinese orthography which is a logographic writing system. Pinyin is composed of several phonemes, thus making each phoneme transparent to the beginners. However, the improvement of phonological skills did not lead to gains in Chinese literacy skills. This is consistent with a previous study of Zhou et al. (2013) conducted with kindergarten children in which phonological training (which referred to rime, tone, and syllable awareness) did not improve children's reading skills in Chinese.

This training study is the first to evaluate the effect of Pinyin training on Chinese literacy skills. Pinyin knowledge is one of the most robust predictors of learning to read and spell in Chinese, and it is surprising that gains in Pinyin knowledge did not transfer to gains in Chinese reading and spelling, at least in the time period studied here. There are three potential explanations for this. Firstly, the length of the training (5 weeks) might be insufficient to lead to gains in Chinese literacy skills. The effect of Pinyin training on Chinese reading and spelling may be seen after longer periods of training. Secondly, the sample size was relatively small (N=31 in each condition), and children in the intervention and control group were from two whole classes. The lack of random assignment to group means that the results are easily affected by variations in children's regular school teaching. Future studies should employ random allocation within classrooms. Thirdly, children had already received teaching in Pinyin for 6 months at the start of the study, and were scoring highly on measures of Pinyin knowledge at pre-test. Our original aim of this Pinyin training was to reinforce children's Pinyin knowledge, so we began the study after children learned Pinyin for one semester. Although children in the Pinyin training showed improvement in Pinyin spelling, their Pinyin reading ability had less room to improve. Future studies of Pinyin training should focus on children who are at earlier stages of learning Pinyin.

5.5. Conclusion

Pinyin training delivered over a short period (5 weeks) led to gains in Pinyin spelling and onset deletion relative to an active treatment control (math training). However, these gains did not transfer to measures of Chinese literacy; in contrast, children in the control group showed greater gains in Chinese spelling 4 weeks after training. Potentially, results were affected by group differences in daily literacy instruction; further research should employ random allocation to groups within classrooms.

Chapter Six

Summary and Conclusions

6.1. Research Background and Aims

The ability to read and spell are critical for academic achievement and for daily life. It is well documented that phoneme awareness, letter knowledge, and RAN are longitudinal predictors of learning to read and spell in English (Furnes & Samuelsson 2011; Muter et al., 2004; Parrila et al., 2004), and in other alphabetic languages (Caravolas et al., 2012; 2013). A number of studies have demonstrated the causal influence of phoneme awareness and letter knowledge on English literacy skills using a training study in typical children or children with reading difficulties (Ball & Blachman, 1991; Burgoyne, Duff, Snowling, Buckley, & Hulme, 2013; Hulme et al., 2012; Mengoni, Nash, & Hulme, 2014). Compared with phoneme skills, children rely less on semantic information in learning to read in English: semantic information accounts for learning to read exception words (Ricketts et al., 2007) and makes little contribution to learning to read novel words beyond phonological information (Duff & Hulme, 2012). These findings support relationships between phoneme awareness, letter sound knowledge, RAN and literacy skills in alphabetic languages.

The Chinese orthography is very different to alphabetic orthographies in terms of phonetic components and visual form. Unsurprisingly, current studies demonstrate a different pattern of predictors in learning to read and spell in Chinese compared to English. These findings indicate the importance of syllable awareness (Li et al., 2012), morphological awareness (Yeung et al., 2013), visual skills (Tong et al., 2011), RAN (Lo et al., 2015), and vocabulary (Tong et al., 2009) in Chinese literacy skills. A significant limitation to this body of work is that most reading and spelling studies in Chinese have been conducted in Hong Kong. People in Hong Kong and Mainland China use different official scripts (HK: traditional scripts; Mainland China: simplified scripts). Furthermore, Pinyin, an auxiliary phonetic tool which represents characters with Roman letters making phonemes transparent to Chinese learners, is taught in formal literacy instruction in Mainland China, but not in Hong Kong. As a consequence, it cannot be assumed that findings from studies conducted in Hong Kong can be generalised to literacy development in Mainland China. Research is needed to establish the cognitive foundations of learning to read and spell in Chinese for children in Mainland China.

Previous studies conducted in Mainland China are limited in terms of sample size, age range, and the range of cognitive skills examined. In addition, few studies have explored the causal role of cognitive predictors of literacy using training studies. The purpose of this thesis was to examine the relationships between Chinese literacy skills and a comprehensive set of cognitive skills including phonological awareness, tone awareness, morphological awareness, visual skills, RAN, Pinyin knowledge, and vocabulary. Four studies were reported. The first of these (Chapter 2) reports a large-scale 2-year longitudinal study to examine a range of cognitive skills as predictors of learning to read and spell in primary school children aged 6 to 8 years old. To further explore the learning mechanisms involved in Chinese reading, Chapter 3 reports findings from a paired-associate learning study. In addition to these, a phonetic/semantic training study (Chapter 4) and a Pinyin training study (Chapter 5) are reported to explore the causal influence of phonetic, semantic, and Pinyin knowledge in Chinese literacy skills. Findings from these studies are of theoretical importance and have practical implications for literacy instruction and for the identification of children at risk of reading difficulties in Mainland China.

6.2. Summary of Research Methods, Findings, and Implications

6.2.1. Predictors of Reading and Spelling

Chapter 2 reports a 2-year longitudinal study conducted with 302 children, starting in their first year of primary school. This study included measures of syllable and onset deletion, tone discrimination, morphological construction, visual discrimination, visual memory, RAN, Pinyin letter reading, Pinyin reading, Pinyin spelling, and vocabulary as potential predictors of learning to read and spell in Chinese. Children were tested 4 times at half-year intervals. A subset of children (N=155) were followed up 6 months after the final assessment at T5.

Path analysis showed that Pinyin spelling was a unique concurrent and longitudinal predictor of reading and spelling in Chinese across all time points. Even beyond the autoregressor, Pinyin spelling significantly predicted later reading and spelling. This is consistent with previous findings of studies by Lin et al. (2010) and

Pan et al. (2011) which identified Pinyin spelling as a longitudinal predictor of reading in Chinese. The present study extends those findings from reading to spelling.

RAN has been found to be a reliable predictor of literacy skills in alphabetic languages (Caravolas et al., 2012, 2013; Furnes & Samuelsson, 2011; Parrila, Kirby & McQuarrie, 2004) and in Chinese (Lo et al., 2015; Yeung et al., 2011). In line with previous findings, RAN was also a concurrent and longitudinal predictor of Chinese literacy skills in the longitudinal study (though this relationship was not consistent at all-time points).

Vocabulary was a robust concurrent and longitudinal predictor of reading, but showed a limited role in predicting spelling. In contrast, phonological awareness was a concurrent and longitudinal predictor in the early stages of learning to read in Chinese, but played a limited role in later grades. This pattern shows strong similarities with previous studies in Chinese (reading: Hu 2012; spelling: Pan et al., 2011; Tong et al., 2009) and suggests that children learning Chinese rely less on phonological awareness and more on vocabulary, particularly in the later stages of reading development. This pattern is different to that seen in studies of reading in English: phonological awareness is a critical foundation for English literacy skills, while vocabulary is a significant predictor of exception word learning only (Muter et al., 2004; Ricketts et al., 2007).

Similar to phonological awareness, visual discrimination skills were also found to be both concurrent and longitudinal predictors of reading in the early grades. In contrast, morphological awareness predicted reading in the later grades only. These findings are in line with previous studies in Chinese (visual discrimination: Siok & Fletcher, 2001; morphological awareness: Yeung et al., 2013). Consistent with the pattern found for reading, visual discrimination was an early predictor of spelling in Chinese. This findings are important given that little previous research has assessed the role of visual skills in Chinese spelling in primary school children.

It is interesting that phonological awareness and morphological awareness showed a different predictive pattern in spelling compared to reading. Whereas phonological awareness was a reliable longitudinal but not a concurrent predictor of spelling, morphological awareness was a concurrent but not a longitudinal predictor of spelling. Studies that have examined phonological awareness as a predictor of spelling in Chinese are rare, but these findings are nevertheless in line with a previous study which also found morphological awareness to be a concurrent but not a longitudinal predictor of spelling in Chinese (Yeung et al., 2013).

Overall, the findings from this longitudinal study are consistent with the pattern seen in previous studies of reading and spelling in Chinese, and highlight the importance of Pinyin spelling, RAN, and vocabulary for the development of literacy skills in Chinese. This pattern is different from that seen in studies of alphabetic languages. RAN appears to be a robust predictor of reading and spelling across different languages. Phonological awareness is a critical foundation of literacy skills for learners in alphabetic languages, while Chinese learners rely more on vocabulary. Findings of this study have implications for identifying children who are at risk of dyslexia, and provide guidance for how best to teach reading and spelling in Chinese. Compared with other cognitive skills, Pinyin spelling, vocabulary, and RAN are ideal indicators which are reliable and can be easily tested to identify children with reading difficulties. Longitudinal data in the present study show a predictive relationship between Chinese literacy skills and a set of cognitive skills. Primary schools should therefore be encouraged to pay more attention to developing and reinforcing Pinyin spelling and vocabulary skills, given that improvements in these skills may be of benefit to children's literacy development. Given the changing roles of phonological, visual and morphological skills in literacy development over time, it is important to provide sufficient support for phonological and visual skills for young children, and to reinforce morphological skills for children in the later grades.

6.2.2. Examining the Learning Mechanisms of Reading and Spelling Using PAL

Reading and spelling demand long-term accumulation of learning. Visual-verbal PAL and verbal-visual PAL respectively simulate the way children learn to read and spell a new word.

Previous studies have demonstrated a critical role of visual-verbal PAL for learning to read in English (Hulme et al., 2007; Warmington & Hulme, 2012). Due to the features of Chinese orthography (a logographic language), associations between phonology and orthography in Chinese are more arbitrary than those in English. It is therefore useful to explore the learning mechanisms of Chinese literacy skills with PAL tasks.

Chapter 3 reported findings from a study of 120 first and second year primary school children who completed 4 PAL tasks (visual-verbal, visual-visual, verbal-visual, and verbal-verbal), and tests of reading, spelling, and cognitive skills. Path analysis showed that both visual-verbal and verbal-visual PAL were unique predictors of reading and spelling in Chinese with age and other PAL tasks controlled. These findings support the hypothesis of cross-modal learning mechanisms proposed by Hulme et al. (2007), and extend this hypothesis from reading to spelling. Furthermore, a set of cognitive skills (RAN, Pinyin spelling, visual discrimination, onset deletion, morphological awareness, and vocabulary) that were significant predictors of reading and spelling in the longitudinal study (Chapter 2) were included in the path analysis models. Visual-verbal PAL, Pinyin spelling, morphological awareness, and vocabulary were unique predictors of reading; verbal-visual PAL, age, RAN, and Pinyin spelling were unique predictors of spelling. These results are in line with previous findings in Chinese (Li et al., 2009) and English (Hulme et al., 2007), highlighting the importance of cross-modal learning mechanisms for learning to read and to spell in Chinese beyond a wide range of cognitive skills.

6.2.3. The Causal Influence of Phonetic and Semantic Information in Learning to Read

As Duff and Hulme (2012) reported, phonetic information plays a critical role in learning to read new words in English, but semantic information did not show an additional benefit beyond phonetic knowledge. Chapter 4 reports a study which aimed to assess the effect of phonetic and semantic information on learning to read in Chinese using a training and testing procedure following the paradigm Duff and Hulme (2012).

A total of 96 first and second year primary school children were taught to read 12 unfamiliar Chinese words in 3 within subject conditions: Phonetic oral pre-exposure, Phonetic + Semantic oral pre-exposure, and no pre-exposure (control condition). Children learned significantly more words following Phonetic + Semantic pre-exposure than in the other conditions. A significant difference was also found between Phonetic pre-exposure and the control condition. These results fit well with hypotheses of current models of reading (namely the triangle model (Plaut et al., 1996), dual-route model (Coltheart, 2005), and lexical quality (Perfetti, 2007; Perfetti & Hart, 2002) models) but contrast with those reported in a previous study by Duff and Hulme (2012).

The present study highlights the importance of semantic information in learning to read in Chinese and suggests that semantic information plays a more important role when the mappings from orthography to phonology are less reliable. Findings from this study suggest that primary schools should make use of interesting oral pre-exposure activities (e.g. telling stories) for children to highlight phonological and semantic information about new words to be learned. These activities are likely to benefit the subsequent learning of unfamiliar words.

6.2.4. Evaluating the Effect of Pinyin Knowledge on Chinese Literacy Skills

The longitudinal data (reported in Chapter 2) demonstrated an effect of Pinyin spelling on learning to read and spell in Chinese. To further evaluate the effect of Pinyin knowledge, Chapter 5 reports a 5-week Pinyin training study conducted in two classes with first year primary school children. One class received Pinyin training, and the other received math training for the same length of time. It was predicted that children in the Pinyin training group would make significantly greater gains in literacy skills than children in the math training group.

Training was effective at improving targeted skills: Pinyin training significantly improved children's Pinyin spelling ability; math training significantly improved their addition skills. Furthermore, Pinyin training improved children's phoneme awareness. However, these improvements did not transfer to children's literacy skills. In contrast, children in the math training group showed small but significant gains in Chinese word spelling assessed four weeks after training. These findings were inconsistent with predictions. Potentially the children, who were from two separate classes, were exposed to different daily teaching in addition to our training programmes which led to these differences.

This training study failed to demonstrate a causal effect of Pinyin training on Chinese literacy skills. Limitations of the study were insufficient length of training (only 5 weeks) and lack of random assignment to groups. Future research should conduct a longer Pinyin training programme at earlier stages of Pinyin instruction, employing random allocation to groups.

6.3. Conclusions and Future Plans

This thesis provides evidence for the role of a set of cognitive skills in learning to read and spell in Chinese. The 2-year longitudinal study examined those cognitive skills as predictors of measures of Chinese literacy. Our findings show strong consistency with previous studies in Chinese, but differ from the findings in English particularly in terms of the role of phonological awareness and vocabulary (Duff &Hulme, 2012; Hatcher et al., 2004; Muter et al., 2004; Ricketts et al., 2007). Phonological awareness, recognized as a foundation of English literacy skills (Anthony & Lonigan, 2004; Durand et al., 2005; Goswami, 1993), was found to be a significant predictor of Chinese literacy skills at early stage of development. In contrast, vocabulary which only predicts children's reading ability of exception word in English (Ricketts et al., 2007), showed a robust effect on reading in Chinese. Along with phonological awareness, a large body of research has found letter knowledge plays an important role in learning to read in English (Foorman, Francis, & Liberman, 1991). Correspondingly, several studies have reported that orthographic skills (radical skills) were significant predictors of reading in Chinese (Li et al., 2012; Tong et al., 2009). Future research is needed to examine orthographic skills as predictors of Chinese literacy skills beyond the cognitive skills that were significant predictors in the present longitudinal study.

Although predictors of reading and spelling in Chinese were found to be different from those in English, the two languages may depend partly on the same learning mechanisms. The PAL study reported that both visual-verbal and verbal-visual PAL were unique predictors of Chinese literacy skills after controlling for age and other PAL tasks. This study replicated the paradigm of a study in English by Hulme et al. (2007) and the findings have theoretical implications, supporting hypothesis of cross-modal learning mechanisms. Even beyond the cognitive skills that were significant predictors in the longitudinal study, cross-modal learning mechanisms emerged as critical foundations of learning to read and spell in Chinese.

Two training studies were conducted to assess the causal effect of phonological skills, vocabulary and Pinyin knowledge on the development of Chinese literacy. The phonetic/semantic training study demonstrates that phonetic information is critical to learning to read new words, and pre-exposure to semantic information has additional benefits for new word learning beyond phonetic information. These findings are consistent with the triangle model, dual-route model, and lexical quality of learning to read (Coltheart, 2005; Perfetti & Hart, 2002; Plaut et al., 1996). Future studies can further explore the role of semantic information on words varying in imageability and word composed of different types of characters (regular or irregular phonetic-semantic characters).

Pinyin training had a significant effect on children's Pinyin spelling ability, but these improvements in Pinyin spelling did not transfer to measures of Chinese literacy skills. The failure of this study may be attributed to the lack of random assignment. Future research is needed to reassess the role of Pinyin training using a random assignment design, and to further explore the causal effect of other language skills using training studies.

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