A Holistic Examination of Word Reading in Lower Grade Chinese Students: a One-year Longitudinal Study

By

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Statement of Originality

I, WANG, Lei, hereby declare that I am the sole author of the thesis and the material presented in this thesis is my original work except those indicated in the acknowledgement. I further declare that I have followed the University's policies and regulations on Academic Honesty, Copyright and Plagiarism in writing the thesis and no material in this thesis has been submitted for a degree in this or other universities.

Abstract

Factors from ecological, psychological, and cognitive domains have all been found to be important in learning to read words. However, previous studies mainly examined the effects of the cognitive factors on reading development, and few have incorporated factors from all three domains and examined their interactions in contributing to reading development. To conduct a comprehensive examination of the reading development of the Chinese lower graders, this study included factors from the ecological, psychological, cognitive domains and examined the relationships between the factors from different domains and word reading in Chinese lower grade students under the framework of the Componential Model of Reading (CMR).

In this study, 194 children (mean age = 86.20, SD = 4.92; 119 boys, 75 girls) were measured in grade one (Time 1). Of these 194 children, 175 (mean age = 103.13, SD = 4.27; 108 boys, 67 girls) were measured again when they were in grade three (Time 2). In addition, 9 boys (mean age = 100.67, SD = 4.67) who were not measured at Time 1 joined the study at Time 2. At both times, the ecological component was composed of the home literacy environment and family socioeconomic status, the cognitive component was composed of vocabulary, working memory, morphological awareness, and phonological awareness, and the psychological component was represented by the children's interest in reading. The outcome variable word reading was composed of word reading fluency and word reading accuracy.

The results showed that: 1) the factors for each component (i.e., cognitive, psychological, ecological) significantly loaded onto the respective component, and

each component was significantly correlated with word reading (except the ecological component and word reading at Time 2); 2) the cognitive and the psychological components contributed directly to word reading, while the ecological component only contributed indirectly to word reading via the mediations of the other two components; 3) comparing the models at the two time points, the path from the ecological component to the cognitive component at the second time was stronger; 4) the cognitive component at Time 1 contributed to word reading at Time 2 via the mediation of word reading at Time 1, and the longitudinal indirect effects of ecological component were nonsignificant; 5) the Time 1 ecological component and word reading were found to predict the Time 2 psychological component.

Taken together, these findings emphasized the importance of the factors from all three domains to reading development, validated and extended the CMR in Chinese lower grade students. The results also underscored the complexities of reading development with the emergence of the interactive, indirect, and bidirectional relationships between the components and word reading.

Keywords: Chinese children, word reading, lower grade students, ecological factors, psychological factors

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List of Abbreviations

CFI	comparative fit index
CMR	componential model of reading
COVID-19	Coronavirus disease 2019
DCCS	Dimensional Change Card Sort
EF	executive function
HLE	home literacy environment
MA	morphological awareness
MLR	maximum likelihood robust
PA	phonological awareness
PIRLS	progress in international reading literacy study
PISA	program for international student assessment
RAN	rapid naming
RMSEA	root mean square error of approximation
SES	socioeconomic status
SRMR	standardized root mean square residual
SVR	simple view of reading

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Chapter 1: Introduction

Reading is an important skill for children to learn. It serves as a key to understanding the world, as most knowledge is written in words. Moreover, reading ability influences children's academic performances in primary school and beyond, and contributes to their cognitive development (Boland, 1993; Cunningham & Stanovich, 1998). Because of its importance in child development, many studies have investigated the topic of reading development. Most of these have examined it from the perspective of the cognitive domain. For illustration, I conducted a literature search and categorized the research perspectives of the resulting studies into cognitive (e.g., vocabulary, morphological awareness, working memory), ecological (e.g., literacy environment at home), and psychological (e.g., reading motivation) domains. Specifically, the search covered peer-reviewed journal articles dated from 2000 to 2020 in PsycARTICLE and PsycINFO databases using the keywords *child* and *word reading,* focusing on the studies with participants aged 6- to 12-years, in primary school. There were 122 resulting studies, of which 113 (92.6%) examined children's word reading from the cognitive domain. Only 9 studies (7.4%) were from the psychological or ecological domains. Although this was not a complete literature search that included all the relevant literature, the result provided a snapshot of the prevalence of the cognitive perspective and the lack of an ecological or psychological perspective in the reading literature.

However, some studies have found that ecological components (e.g., family socioeconomic status, home literacy environment) and psychological components (e.g., reading interest, temperament) do make significant contributions to reading development (e.g., Burgess, 1997; Chiu, McBride-Chang, & Lin, 2012; Katzir, Lesaux, & Kim, 2009; Molfese, Modglin, & Molfese, 2007; Wigfield & Guthrie, 1997). Previous studies have found that these two components explained 8% to 30% of the variance of the reading outcomes in primary school children (e.g., Howard et al., 2014; Katzir et al., 2009; Sikiö et al., 2018; Torppa et al., 2019). In other words, the numbers of reading studies from these two perspectives is disproportionately low, compared to their contribution to reading development. Moreover, most studies have only considered components from one domain (e.g., only including the cognitive factors). The indirect relations between factors from multiple domains and reading outcomes were thus less studied. This can be a limitation since components from different domains may not work independently but interact with each other in contributing to reading development (Bronfenbrenner, 1986). For example, a rich home-literacy environment (i.e., an ecological factor) may be beneficial to children's vocabularies (a cognitive factor), and the improved vocabulary in turn can facilitate their reading abilities (e.g., Zhang et al., 2019). As a result, previous studies may have underestimated the contribution of components from ecological and psychological domains by not accounting for their indirect influences. More comprehensive studies that incorporate components from multiple domains and structural paths (direct and indirect) are needed for a better understand of reading development. Therefore, the

present study aimed at incorporating components from multiple domains and examining their interactions in contributing to the reading development.

One of the starting points for this comprehensive investigation was the lower grade students. This is because the bulk of reading development happens in the lower grades of primary school. For example, using the scores of seven standardized reading achievement tests, Bloom, Hill, Black, & Lipsey (2008) found, in children from the United States, that reading ability increased most in the lower grades and gradually slowed in momentum throughout the primary years. This is also in accordance with the structure of the Chinese curriculum in China, with the lower grade students learning a large portion of new characters, while the number of new characters decreases in higher grades (Shu, Chen, Anderson, Wu, & Xuan, 2003). Moreover, reading ability in the lower grades is highly associated with reading ability in the higher grades. This is supported by the examples of Pan et al. (2011) (*r*s = 0.76 to 0.86 for character reading in grade one and character reading in higher grades) and Wagner et al. (1997) (*r*s = 0.62 to 0.84 for word reading in grade one and word reading in higher grades). In contrast, the association between reading competence in kindergarten and primary school is lower, e.g., *r*s = 0.27 to 0.32 for character reading in kindergarten and in primary school (Pan et al., 2011); *r*s = 0.27 to 0.69 for word reading in kindergarten and in primary school (Wagner et al., 1997). These results suggest that the start of formal schooling has a large impact on children's reading abilities. In addition, children in mainland China only began their literacy learning when they entered primary school (Li & Rao, 2005), which may be one of the reasons

for the highly correlated reading performances found in Chinese children within the primary school period but not across kindergarten and primary school. In sum, the development of reading ability in the lower grades lays the foundation for reading ability in the higher grades. Thus, in this study, I examined reading development in lower grade students.

Word reading was chosen as the reading outcome in this study for three reasons. First, this study focused on the reading development of lower grade Chinese students; their major task in the Chinese course is character and word learning (The Ministry of Education of People's Republic of China, 2011). Second, word reading serves as a foundation to attain higher reading ability, such as sentence and passage comprehension (Gough & Tunmer, 1986; Perfetti, 2017). Previous studies have consistently found the relationship between word reading and reading comprehension (e.g., Adlof, Catts, & Little, 2006; Kim, 2017; Perfetti, 2007; Yeung, Ho, Chan, Chung, & Wong, 2013). Third, because Chinese has an opaque orthography (i.e., few and inconsistent phonological cues in Chinese), Chinese word reading demands more word-level knowledge (e.g., semantic knowledge) comparing to word reading in alphabetic languages (McBride, 2016a). Understanding both word form and meaning is required for successful decoding in Chinese (Zhou, Duff, & Hulme, 2015). In other words, Chinese word reading examines multiple dimensions (e.g., semantic, phonological) of word-level knowledge (Liu, Li, & Wong, 2017).

This study aimed to include both accuracy and fluency measures of word reading for the word-reading skill. According to the Lexical Quality Theory (LQT), both

accuracy and fluency are representations of lexical quality, which in turn contributes to reading comprehension (Perfetti, 2007). Similarly, both decoding accuracy and fluency were included in the Simple View of Reading (SVR) model (Hoover & Gough, 1990). Word-reading fluency was also found to correlate with reading comprehension in children across languages (e.g., Cheng et al., 2017; Fuchs, Fuchs, Hosp, & Jenkins, 2001; Kim, Park, & Wagner, 2014), as predicted by the two models. Moreover, word-reading fluency was found to predict reading comprehension in Chinese children after accounting for word-reading accuracy (e.g., Joshi et al., 2012; Yeung et al., 2016).

To summarize, previous studies have focused largely on the relationships between cognitive factors and reading outcomes, while the relationships between psychological factors, ecological factors, and reading outcomes have received less attention. Studies of the indirect and reciprocal relationships between components in different domains and reading are also lacking. However, cognitive factors are not the sole influencers of reading outcomes, and factors from multiple domains may not contribute to reading independently but interact with each other to affect reading ability. In addition, reading ability may also exert its influence on these components. For a comprehensive and nuanced understanding of the reading development in lower grade Chinese students, this study incorporated factors from the cognitive, psychological, ecological domains, and examined the direct, indirect, and reciprocal relationships between these factors and word reading by tracking a group of students from grade one to grade three.

Chapter 2: Literature Review

2.1. Theoretical Framework of This Study

The framework of this study is the Componential Model of Reading (CMR) (Aaron, Joshi, Gooden, & Bentum, 2008). This is a comprehensive theory that includes factors from the cognitive, psychological, and ecological domains (i.e., components). Specifically, the cognitive component was based on the Simple View of Reading (SVR; Gough & Tunmer, 1986), thus word recognition and comprehension were included. For the psychological component, factors such as reading motivation, reading interest, learned helplessness, and learning style were proposed. For the ecological component, factors such as home environment, culture, parental involvement, classroom environment, and dialect were proposed (Aaron et al., 2008). The validity of CMR has been verified in children who are learning to read different languages, including Chinese children (e.g., Chiu et al., 2012; Høien-Tengesdal & Høien, 2012; Joshi et al., 2012; Li et al., 2020).

It should be noted that the CMR was broadly conceptualized, which means that the factors in each component are susceptible to change depending on the focus and scope of the study. For example, while some studies with the CMR framework have chosen word reading and comprehension as the cognitive factors (e.g., Aaron et al., 2008; Joshi et al., 2012), others have introduced more linguistic skills such as phonological and morpho-syntactic skills as the cognitive factors (Ortiz et al., 2012). This is also true for the psychological and ecological components, with different studies focusing on different factors. For example, home language (whether the children speak a

minority language) and socioeconomic contexts were included as the ecological factors in the study by Kieffer and Vukovic (2012), where they investigated the sources of reading difficulties in a group of children from urban schools in the United States. In contrast, Chiu et al. (2012) included countries' gross domestic products per capita as one of the ecological factors (along with other ecological factors at the family and school levels) because their study examined the sources of reading difficulties in children across different countries. In the next several sections, the components of each domain and their relationships with reading will be discussed, followed by a discussion of the relationships of components across different domains.

2.2. Cognitive Component and Word Reading

In accordance with the Simple View of Reading (SVR) (Gough & Tunmer, 1986), CMR includes word recognition and comprehension as the two factors in the cognitive component (Aaron et al., 2008). These two factors contribute to reading comprehension, which is the reading outcome in both SVR and CMR. However, when the model is applied to younger children, the reading outcome may need to be changed based on their literacy development. This in turn calls for the replacement of the cognitive factors. For example, Ortiz et al. (2012) used a mix of word-study skills (e.g., phonetic analysis), word reading, and reading comprehension as the reading outcome when applying the CMR to a group of kindergarten children from the United States. Accordingly, a set of emergent literacy skills was included as the cognitive factor, including vocabulary, letter knowledge, and phonological awareness. In other

words, the choice of reading outcome and the cognitive component should consider the children's abilities and development. Because this study aimed to investigate the reading development of lower grade students from China, word reading was selected to be the reading outcome. Thus, the cognitive factors that are the most relevant to word reading will be reviewed in this section.

These factors are categorized as domain-specific metalinguistic awareness and domain-general cognitive abilities. This dichotomy conforms to the theoretical perspective that divides the abilities into two categories; the domain-general abilities (e.g., working memory) contribute to children's achievement across academic subjects, and the domain-specific abilities contribute to their achievement in specific academic subjects. This perspective has been utilized in numerous studies, and both domain-general and domain-specific abilities were found to be associated with reading ability (e.g., Bull, Espy, & Wiebe, 2008; Chu, VanMarle, & Geary, 2016; Geary, 1993; Kim, 2017).

2.2.1. Domain-specific metalinguistic awareness

Learning to read is a specialized skill that involves processes such as identifying the written form of the word and retrieving its meaning and sound. These processes are unique to literacy learning and thus domain-specific skills need to be built upon them. Due to the differences in the characteristics of languages and their corresponding writing systems (e.g., morphology, orthography), the importance and the constructs of the specific subskills are different across literacy learning in different languages (e.g.,

Kuo & Anderson, 2006; McBride-Chang et al., 2005). In this section, the domain-specific metalinguistic awareness that is important in learning to read Chinese will be discussed.

Morphological awareness Morphological awareness (MA) is the "knowledge about pairing sound and meaning in a language and the word-formation rules that guide the possible combination of morphemes" (Kuo & Anderson, 2006). MA has been found consistently to predict word reading in both alphabetic languages (e.g., Carlisle, 2000; Deacon et al., 2018; Levesque et al., 2017) and Chinese (e.g., Chen et al., 2009; Dulay et al., 2021; McBride-Chang et al., 2003; Tong et al., 2009; Yeung et al., 2013).

MA is considered to be especially important in learning to read Chinese due to the characteristics of this language (e.g., McBride, 2016a; Wu et al., 2009). Specifically, morpheme, syllable, and character are almost in one-to-one-to-one correspondence in Chinese, which elevates the importance of morpheme (and syllable) in this language. In addition, there are numerous homophones and homographs in Chinese (average over five homophones for every syllable) (McBride-Chang et al., 2003), so children are more likely to resort to the meaning unit of the language (e.g., morpheme) in learning to read, as it is difficult to discern words through sound (e.g., Liu & McBride-Chang, 2010).

Moreover, the morphology of Chinese is transparent in form and meaning. Specifically, in almost all cases the forms of the constitute morphemes stay the same irrespective of the words they resided (i.e., few transformations in pronunciation and orthography) (Kuo & Anderson, 2006). The compounding words in Chinese (in which

compounding morphology is the most prevalent morphology) are mostly understandable through analysis of the morphemes (e.g., Chen et al., 2009; McBride-Chang et al., 2003). For example, *mask* in Chinese is 口罩 (/kou3 zhao4/, mouth-cover); the meaning of this is easily deducible from the constitute morphemes and word structure (subordinate structure in this example). The transparency of the morphology further increases the importance of MA in learning to read Chinese.

In accordance with the characteristics of Chinese, MA is divided into two major dimensions, namely, lexical compounding awareness and homophone/homograph awareness (Liu & McBride-Chang, 2010). Lexical compounding awareness refers to the knowledge of the rules that combine morphemes into words in Chinese. This is related to the fact that more than 75% of the words in Chinese are composed by combining two or more morphemes, so this dimension of MA is important for Chinese children to understand words (Chen et al., 2009). Homophone/homograph awareness is the ability to differentiate morphemes with the same sound, which is related to the fact that Chinese has a lot of homophones. Research has shown that both dimensions of MA are related to word reading in Chinese children (e.g., Cheng, Zhang, Wu, Liu, & Li, 2016; Liu & McBride-Chang, 2010; Liu, McBride-Chang, Wong, Shu, & Wong, 2013; Zhao et al., 2019).

Lexical compounding awareness was found to predict word reading in previous studies (e.g., Dulay et al., 2021; Liu et al., 2013). Some researchers have suggested that it can improve word reading in three ways. First, the structure knowledge provides extra cues for remembering the words. Second, it helps children to

understand and differentiate the meanings of the words. Third, it helps them to guess the approximate meaning of the new words (Liu et al., 2013).

Homophone/homograph awareness has also been found to be important in word reading. Given the prevalence of homophones and homographs in Chinese, the ability to discern the meanings of homophones and homographs is crucial for the mapping between sound and meaning, which in turn may improve the mapping of meaning onto the orthographic form (Yeung et al., 2013). In addition, homophone/homograph awareness helps children to evade (or at least be aware of) the potential distractions among morphemes with the same pronunciation, which could improve their vocabulary development and in turn contribute to their word reading (Liu et al., 2013).

Phonological awareness Phonological awareness (PA) is the ability to operate phonological parts of spoken words (Oakhill & Kyle, 2000). PA has been found to contribute to reading in Chinese children, especially in young children (e.g., Pan et al., 2016; Ruan, Georgiou, Song, Li, & Shu, 2018; Shu, Peng, & McBride-Chang, 2008). There are three levels of PA in Chinese, that is, syllable awareness, onset/rime awareness, tone awareness. Each of these represents the ability to manipulate the corresponding phonological unit. Of these three levels, syllable awareness and tone awareness seem to have larger contributions to reading in Chinese children. For example, Shu, Peng, and McBride-Chang (2008) found that syllable and tone awareness (but not rime awareness) explained character recognition in Chinese preschool children after controlling vocabulary and rapid naming. Similarly,

McBride-Chang et al. (2008) found that syllable awareness and tone awareness were related to Chinese word reading in Chinese early readers, whereas onset awareness was only related to English reading for the same group of children. The prominent roles of syllable awareness and tone awareness are related to the characteristics of Chinese.

Because syllable, morpheme, and character have an almost one-to-one-to-one correspondence in Chinese, the ability to segment and manipulate syllables in words (i.e., syllable awareness) helps children to recognize morphemes in spoken language, which in turn facilitates the mapping of morphemes into characters (Pan et al., 2016). On the other hand, tone is an essential feature of the Chinese language; it differentiates morphemes with the same phonological structure (McBride-Chang et al., 2008). For example, the four tones of the syllable /pin/ each represent different morphemes (characters), that is, /pin1/ 拼 (spell), / pin2/ 贫 (poor), / pin3/ 品 (taste), / pin4/ 聘 (employ). Thus, tone awareness also facilitates the recognition of morpheme and contributes to reading development.

In contrast, onset/rime awareness has relatively less impact on reading development in Chinese children, as shown in the studies by Shu et al. (2008) and McBride-Chang et al. (2008). The reason may be that Chinese is not divisible at the onset/rime level and does not require phoneme awareness to read (Shu et al., 2008). Nevertheless, onset/rime awareness may help Chinese children learning the language in two aspects. First, children in mainland China and Taiwan use phonetic alphabet (i.e., *Pinyin* and *Zhuyin Fuhao* respectively) to code the pronunciation of character. Both phonetic

alphabets break down the pronunciation of character into smaller phonetic units and emphasize the distinction between onset and rime. Therefore, the phoneme awareness may support learning of a phonetic alphabet, which then improves word reading for children from these two regions (e.g., Lin et al., 2010). Second, many Chinese characters have phonetic radicals which indicate their pronunciation. Shu et al. (2003) found that 26% of these characters share the same onsets or rimes with their phonetic radicals. Thus, onset/rime awareness may help children to read these semi-regular characters through the phonetic radicals. Because both phonetic alphabets are introduced when children enter the primary school, and semi-regular characters (most of them are low frequency characters) with informed phonetic radicals are introduced gradually to primary school children (Shu et al., 2003), the influence of onset/rime awareness on character reading may take some time to take effect. In other words, only when children have acquired enough print experience and knowledge of the phonetic alphabet can they benefit from onset/rime awareness. In supporting this view, Li et al. (2012) discovered that rime awareness was not associated with character reading in kindergarten children but was related uniquely to character recognition in primary school children in their sample.

Vocabulary knowledge Vocabulary knowledge is an important component that contributes to reading development. (e.g., Muter, Hulme, Snowling, & Stevenson, 2004; Ouellette, 2006; Tong, Tong, & McBride, 2017; Yeung, Ho, Chan, & Chung, 2016). Because vocabulary knowledge represents the semantic understanding of words, it may contribute to reading by facilitating the connections between

phonology, orthography, and semantic representations (Li & Kirby, 2015; Ouellette & Beers, 2010). Moreover, because MA provides a way to learn new words (i.e., learning them through the awareness of morphemes and morphology), MA and vocabulary are closely related (e.g., Liu et al., 2013; Spencer et al., 2015; Spencer, Quinn, & Wagner, 2017; Tong et al., 2017). Both levels of MA in Chinese, that is, lexical compounding awareness and homophone awareness, were found to be correlated with vocabulary, with homophone awareness more closely related to vocabulary since it taps existing morpheme knowledge (Liu et al., 2013).

There are two facets of vocabulary knowledge, that is, vocabulary depth and breath. The depth refers to the degree of understanding of acquired words and the breath refers to the number of acquired words (Spencer et al., 2017). In measuring vocabulary depth, researchers often ask children to define words presented aurally by the experimenter (e.g., Cain & Oakhill, 2014; Ouellette & Beers, 2010), whereas the measure of vocabulary breath often requires children to select the picture from the alternatives that corresponds to a word presented aurally by the experimenter ,or to name pictured nouns and verbs (e.g., Ouellette, 2006; Ouellette & Beers, 2010; Proctor, Silverman, Harring, & Montecillo, 2012). It should be noted that the measurement of vocabulary depth also taps into the breath of vocabulary and vice versa (Ouellette, 2006). In the study by Ouellette (2006), both the depth and the breath of vocabulary were found to predict irregular word reading in grade four students from Canada who predominately spoke English.

Because the written Chinese is extremely opaque in that the pronunciations of the characters and the words are rarely deducible from the orthography alone (McBride, 2016a), more semantic knowledge is needed about learning to read Chinese compared to learning to read alphabetic languages (Zhou et al., 2015). Therefore, the depth of vocabulary may be more relevant in the reading development of Chinese children. Previous studies that examined this mainly used the vocabulary depth to account for the vocabulary variables (e.g., Kim et al., 2020; McBride-Chang et al., 2005; Tong et al., 2017).

Orthographic knowledge Orthographic knowledge refers to the understanding of the orthographic regularities in a language (Castles & Nation, 2006). Previous studies have examined orthographic knowledge in Chinese at two levels. The first level is the knowledge about the positional regularities of radicals (for radicals have regular positions in characters) and the configuration of character (Tong et al., 2009). For example, the radical 亻 is always located on the left side of the character, whereas the radical 攵 always appears on the right. This knowledge about the internal structures and the positions of radicals is important for character recognition (Shu et al., 2003) and was found to correlate with reading ability in young Chinese children (K3 to grade one students) (e.g., Ho, Chan, Chung, Lee, & Tsang, 2007; Tong et al., 2009). Typically, in the test on this level of the orthographic awareness, experimenter presented visual symbols to the children. Some of these symbols conform to the character structural rules while others do not. Children are asked to judge whether they are real characters (e.g., McBride-Chang & Ho, 2005; Tong et al., 2009).

The second level is the knowledge about the function of phonetic and semantic radicals. For example, the semantic radical in the left part (i.e., 氵) of the character 河 (/he2/, river) means water, which indicates the meaning of the whole character (river). The orthographic knowledge of semantic radicals can support the meaning deduction for unfamiliar characters. Similarly, the knowledge of phonetic radicals is conducive to reading new characters. For example, the right side of the character 妈 (/ma1/, mother) is the phonetic radical 马 (/ma3/, horse), which shares the same syllable with the character. Although the utility of the phonetic radicals may be reduced by the irregularity of phonetic radicals, as the majority of characters (about 60%) that contain the phonetic radicals do not share the pronunciations with the radicals (Shu et al., 2003).

Nevertheless, this level of orthographic knowledge is related to reading ability in Chinese primary school children. For example, Ho et al. (2003) found that knowledge about the function and sound of phonetic radicals was significantly correlated with word reading in Chinese primary school students. To test this orthographic knowledge, the authors required the children to choose the pictures that depicted the meaning of the semantic radicals from the alternatives (i.e., semantic radical knowledge), or select the characters that may have the same pronunciation as the phonetic radicals (i.e., phonetic radical knowledge) (Ho, Ng, & Ng, 2003; Yeung et al., 2013). It was suggested that the orthographic knowledge in Chinese children progresses from the first level to the second level developmentally (Ho et al., 2003), and it may have an bidirectional relation with reading experience (McBride, 2016b).

Rapid naming Rapid naming (RAN) is the ability to pronounce a serial of basic and familiar visual symbols (e.g., digits, letters, simple characters) as quickly as possible (Georgiou, Parrila, Cui, & Papadopoulos, 2013). In the RAN test used in their study, the children were required to name a list of familiar visual stimuli (e.g., digits, simple characters, and colors) as quickly as possible. RAN has been found to be associated with reading across languages (e.g., Georgiou, Parrila, & Liao, 2008; Manis, Seidenberg, & Doi, 1999; Norton & Wolf, 2012 for a review; Pan et al., 2011). In Chinese, RAN has been found to predict word reading in primary school children (e.g., Georgiou et al., 2008; Pan et al., 2011; Wei, Georgiou, & Deng, 2015). In explaining the relationship between RAN and reading fluency, some researchers have suggested that it is because both tasks require serial processing and pronunciation of specific names (Georgiou et al., 2013). With regard to the association between RAN and reading accuracy, some researchers have suggested that this is due to the "nature of arbitrary mapping of higher level of orthography and phonology" common to both tasks (Pan et al., 2011, p. 904).

One meta-analysis study investigated the moderators of the relationship between RAN and word reading in Chinese children (Song, Georgiou, Su, & Shu, 2016). The study found that RAN was significantly more associated with word reading fluency than word-reading accuracy. The researchers provided three possible reasons for this result. First, both RAN and fluency test demand fast replies, and this speed component contributes to the elevated correlation between the two tests. Second, word-reading fluency tests usually use high-frequency words as stimuli, and this

retrieval process of these familiar words from long term memory is like the retrieval process of familiar stimuli (e.g., digits, colors) in the RAN test. Third, both word reading fluency test and the RAN test involve the processing of parafoveal information when naming the stimulus. Moreover, the study found that age did not moderate the relationship between RAN and reading in Chinese children.

2.2.2. Domain-general cognitive abilities

As a learned skill, reading also requires domain-general abilities. These abilities are important not only in reading development, but also in the development of other skills (e.g., mathematics). In this section, two of the most relevant domain-general cognitive abilities (i.e., executive function and visual spatial attention) for Chinese children's reading development will be discussed.

Executive function Executive function (EF) refers to a series of mental processes such as anticipation, goal selection, planning, initiation of activity, self-regulation, mental flexibility, deployment of attention, and utilization of feedback that account for the goal-oriented behavior (Anderson, 2002). EF is commonly divided into four components: working memory, inhibition, updating, and shifting (Baddeley, 2003; Miyake et al., 2000). Working memory is the ability to hold and manipulate information simultaneously in mental tasks; inhibition is the ability to suppress one's typical or habitual responses; updating is the ability to modify currently stored content for the reception of new information; and shifting is the ability to shift attention, strategies or responses (Cartwright, 2012; Peng et al., 2013).

Of these four components, working memory and inhibition are the most relevant to word reading in Chinese children. When reading a word, working memory is needed for the child to connect the orthographic representation with the linguistic information in the long-term memory. In this process, a child also needs the inhibition ability to suppress interfering information (e.g., homophones) (Chung & McBride-Chang, 2011). As a result, Chung and McBride-Chang (2011) found that working memory and inhibition longitudinally predicted word reading in kindergarten children in Hong Kong. The association of working memory and reading outcomes was also found in Chinese primary school children (e.g., Leong, Tse, Loh, & Hau, 2008; Yeung et al., 2013). Moreover, children with reading difficulties were found to perform below par in working memory tasks (Peng et al., 2013). Similar results were found in children speaking alphabetic languages (e.g., Sesma, Mahone, Levine, Eason, & Cutting, 2009; Welsh, Nix, Blair, Bierman, & Nelson, 2010). As for the updating and shifting, the former is related to reading comprehension, since this requires readers to constantly update the situation model and remove the irrelevant information (Carretti, Cornoldi, DeBeni, & Romanò, 2005), while the latter may tap into the general cognitive ability needed for the overall learning process, which may be the reason for the association between shifting and reading (Yeniad, Malda, Mesman, VanIjzendoorn, & Pieper, 2013).

Measurements have been developed to test the four components of EF. For working memory, the backward digit span test is commonly used. This asks children to recite backwards the number strings that are presented aurally by the experimenter (e.g.,

Chung & McBride-Chang, 2011; Xue et al., 2013). For the inhibition task, they are asked to respond while inhibiting the prepotent responses (e.g., Stroop color-naming task) (e.g., Cartwright, 2012; Chung & McBride-Chang, 2011; Yang et al., 2019). For the measurement of updating ability, researchers often use the n-back task (e.g., Im-Bolter et al., 2006; Peng et al., 2013). In this task, children are asked to listen to or watch a string of digits or words, with each stimulus presented for a short time before the next one. They are then asked to respond whether the current stimulus matches the stimulus presented several trials before (e.g., whether the current digit is the same as the digit presented in the second to last trial). Finally, shifting ability is commonly measured through the Dimensional Change Card Sort (DCCS) task, in which children are asked to categorize a set of cards according to different dimensions and rules (e.g., McKinnon & Blair, 2019; Welsh et al., 2010).

Visual spatial attention Visual spatial attention refers to the attentional processes that lead to choosing visual stimuli within a spatial location (Vecera & Rizzo, 2003). For children who are learning alphabetic languages, visual spatial attention can help them to segment words into component graphemes, which improves the quality of orthographic representation. In addition, the effectiveness in processing a series of letters facilitates the mapping from orthography to phonology, which is beneficiary in developing phonemic awareness (Gori & Facoetti, 2015). Visual spatial attention is also important for children who are learning to read Chinese for two reasons. First, Chinese characters are intricate as visual stimuli, which necessitates children having high levels of visual processing ability to discern the correct character from similar-

looking ones (e.g., 我, 找, 栽, 哉, 载). Moreover, since Chinese characters contain little information to guide pronunciation, children must be familiar with the visual form of the character when acquiring it, for they cannot spell the character out according to its pronunciation (Liu & Liu, 2020). Second, when writing in text, Chinese is closely organized with no visual boundaries between words. Thus, visual spatial attention is required to segment and recognize the words (Liu et al., 2016). As a result, visual spatial attention has been found to predict word reading in Chinese primary school children (e.g., Liu et al., 2016; Liu & Liu, 2020). Similar results have also been found in children who are learning alphabetic languages (e.g., Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Gori & Facoetti, 2015). Visual spatial attention is usually measured through the visual search task (e.g., Liu & Liu, 2020; Plaza & Cohen, 2007). In this task, children circle the target visual stimuli identified from the distractors.

To summarize, the above review of the cognitive factors has included MA, PA, vocabulary, orthographic knowledge, rapid naming, executive function, and visual spatial attention, all of which have been found to contribute to Chinese children's reading development. Although it would be ideal to incorporate all the factors into this study, the inclusion of numerous variables (there are also factors from the ecological and psychological domains) would have complicated the model, making it difficult to converge these three groups of factors. Therefore, four cognitive factors, that is, MA, PA, vocabulary, and working memory, were selected to represent the cognitive component based on their importance, inclusiveness, and interpretability.

Specifically, because this study aimed to examine the early literacy development of Chinese children, three early emerging oral language-related skills (MA, PA, vocabulary) that are the most relevant for Chinese early readers were included (e.g., Lei et al., 2011; McBride-Chang et al., 2005; Pan et al., 2016).

Orthographic knowledge and visual spatial attention were excluded because both skills are related to visual ability, hence they may not converge well with the language-related skills (i.e., PA, MA, vocabulary). In addition, a recent study (Liu & Chung, 2021) did not find the prediction of orthographic knowledge on character reading in Chinese early readers, which support the view that orthographic knowledge does not provide stable prediction to literacy development in early childhood.

Rapid naming was excluded because the task involves multiple cognitive components, such as phonological processes and working memory, which were already included as the other cognitive factors in this study. This complex nature of the task also makes its relationship with reading difficult to discern (Norton & Wolf, 2012). As for the executive function, only working memory was included in this study because shift and updating are not related closely to word reading (but are important in reading comprehension) (Carretti et al., 2005; Yeniad et al., 2013), and inhibition was tapped in the task of homophone awareness, in which the children were required to inhibit the semantic activation of the alternative morpheme with the same sound.

2.3. Ecological Component and Word Reading

Aside from the cognitive component, CMR includes factors from the ecological domain (Aaron et al., 2008). As mentioned above, because the ecological domain (as well as the psychological domain) in CMR is conceptualized broadly, studies adopting it have chosen different ecological factors, depending on the scope of the study. In general, the ecological component can be categorized into three levels: family, school, and neighborhood. This is in accordance with the Ecological Systems Theory by Bronfenbrenner (1986), in which he theorized that children's development is not only affected by the family environment, but also the systems beyond the family such as school, social networks, and neighborhoods and communities, as well as the interactions between different systems.

Although the study by Chiu et al. (2012) included a variable at the country level (gross domestic product per capita) as one of the ecological factors, the scope of the previous studies has rarely gone beyond the levels of family, school, and neighborhood, with most focusing on the family level (Aikens & Barbarin, 2008). Therefore, the review below focused on these three major levels of ecological factors, with an emphasis on the ecological factors at the family level.

2.3.1. Ecological factors at the family level

The two important ecological factors at the family level have been identified as family socioeconomic status (SES) and home literacy environment (HLE). These two ecological components have been shown to influence children's reading development

across languages and societies (e.g., Cheng & Wu, 2017; Hood et al., 2008; Liu et al., 2018; Senechal & LeFerve, 2002; Zhang et al., 2019).

Socioeconomic status (SES) SES is a broad concept that consists of family income, and parental occupation and education level. It exerts a wide influence on children's lives, such as their health, cognition, and emotions (Bradley & Corwyn, 2002), including their reading ability (e.g., Cheng & Wu, 2017; Chiu et al., 2012; Hart et al., 2013; Liu et al., 2020; Vasilyeva et al., 2018). High SES is believed to be associated with better amenities, goods, social connection, and parenting styles, which benefit children's development (Bradley & Corwyn, 2002), whereas the opposite is true for children from low SES families. For example, Bradley et al. (2001) discovered that children in the low SES families they studied were less likely to receive learning stimulation (e.g., parents were less likely to purchase books for them or take them to cultural and educational events), which was related to a lower development of their motor, social and language abilities.

The mechanism of the relation between SES and children's reading ability has been examined in previous studies. Using a large sample (over 10,000 participants) study to investigate the relationship between SES and reading development in American children, Aikens and Barbarin (2008) found that this relationship in young children was mediated by the home literacy environment (e.g., number of children's books at home), parenting style and parental participation in school activities. This agreed with the results reported by Bradley et al. (2001). Moreover, the study found that as children entered primary school, the effect of SES on their reading competence

decreased, while the school environment started to exert a larger influence on reading scores (Aikens & Barbarin, 2008). However, this decreased effect of SES when children entered the school has not been found in the Chinese context. A meta-analysis done by Liu et al. (2020) (drawing data from 78 samples, over 210 thousand participants) found that school grade did not moderate the effect of SES on academic achievement in children from mainland China.

Nevertheless, as in the western studies, SES has been found to predict literacy resources at home in young Chinese children (third-year in kindergarten), and the literacy resources subsequently predicted their vocabulary (Liu et al., 2018; Zhang et al., 2019). Cheng and Wu (2017) found that SES contributed to reading comprehension via the simple mediation of MA and the three-path mediation of vocabulary and MA in Chinese grade one students. Considering that vocabulary may be a prerequisite for MA to support reading (McBride, 2016a), as well as the pathway from SES to home literacy resources to vocabulary found by Liu et al. (2018), the mediation results reported by Cheng and Wu (2017) were in line with the result that SES facilitates home literacy environment.

Home literacy environment (HLE) By considering the conceptualization of previous studies of HLE, Phillips and Lonigan (2009, p. 147) defined it as variables associated with "literacy artifacts, functional uses of literacy, verbal references to literacy, library use, parental encouragement and value of reading, parental teaching of skills, child interest, parental modeling of literacy behaviors, parental education, and parental attitudes toward education". The Home Literacy Model has divided home-literacy

activities into two categories, that is, formal and informal (Sénéchal & LeFevre, 2002). Formal literacy activities are those related directly to the written language, such as parents teaching a child how to read and write a character, while informal literacy activities are those in which children are exposed incidentally to the written language, such as parents reading a storybook with the child (Senechal, 2006). Some studies of children learning to read alphabetic languages have found that formal literacy activities predicted children's literacy knowledge (e.g., alphabet knowledge) and reading ability whereas the informal literacy activities predicted vocabulary and reading interest (e.g., Senechal, 2006; Skwarchuk et al., 2014). Moreover, the effect of the informal literacy activities on children's reading development was found to be highly contingent on parents' language skills, whereas the effect of formal literacy activities was less influenced by parents' skills (Puglisi et al., 2017).

There is a relative scarcity of studies examining the relationship between HLE and reading abilities in Chinese primary school children, although some of the early studies found that HLE predicted Chinese primary school children's reading abilities (e.g., Shu, Li, Anderson, Ku, & Yue, 2002; Lau & McBride-Chang, 2005). For the transitional period from kindergarten to primary school in Chinese children, Zhang et al. (2019) found that formal literacy activities (e.g., teaching children to read characters) and literacy resources (e.g., the number of books for children) at home during the kindergarten years contributed indirectly to word reading in grade one via cognitive skills and emergent literacy ability (e.g., vocabulary, Pinyin knowledge). For the lower grade period in primary school, Deng et al. (2015) found that children's

word-reading ability in grade one negatively predicted the frequency of informal literacy activities in grade two. These researchers suggested that Chinese parents responded to their children's less satisfactory reading achievement at school by conducting more shared reading at home (Deng et al., 2015). To summarize, HLE is an important ecological factor for the reading development of lower grade students in China. Multiple relationships could emerge between HLE and reading ability (e.g., facilitative, compensatory) in Chinese children, which warrants a detailed examination.

2.3.2. Ecological factors at the school level

In the original CMR model, two factors school-level factors were proposed as the ecological factors, that is, classroom environment and peer influence (Aaron et al., 2012). Peer achievement, school resources (e.g., learning specialist, school satisfaction), and teacher qualifications were included as the ecological factors by Chiu et al. (2012), when they applied the CMR to primary school children from 38 countries. In this section, the broad construct of the classroom reading environment and its relationship with children's reading outcomes will be reviewed.

Classroom reading environment Like the home literacy environment, the classroom reading environment is an important ecological factor for reading development when children began formal schooling (Snowling & Hulme, 2020). The classroom environment includes factors from the method of teaching (e.g., instructional time on reading), teacher's skills and attitudes toward reading instruction, quality of textbooks

and supplemental reading materials, and the composition of the classmates (Taylor et al., 2020). Tracking a group of children from the United States, by operationalizing the early classroom reading environment as the growth of the classmates' reading scores from grade one to grade two (excluding the participants' own scores), Taylor et al. (2020) found that poor early classroom reading environments led to higher variability in reading comprehension when the children reached adolescence (7^{th} to 10^{th} grade), while good early classroom reading environments led to lower variability in reading comprehension so that the large variance of reading was accounted for by individual's genetic dispositions.

In addition to viewing the classroom reading environment as a whole, some researchers have also investigated the constituent factors and their relationships with children's reading ability. For example, Law (2013) found that parents' and children's perspectives of teachers' instructional practices (e.g., whether teachers' instructions could facilitate students' reading motivation) predicted reading proficiency in lower grade primary school Hong Kong students. More broadly, Chiu et al. (2012) found, in a cross-country study, that schoolmates' early literacy abilities, school resources (e.g., whether the school had learning specialists), school climate (e.g., teachers' job satisfaction), and school-home connections were correlated with primary school students' reading difficulties. In sum, as a learned skill, children's reading ability is influenced by the environmental variables at the school level as they begin formal schooling (Snowling & Hulme, 2020).

2.3.3. Ecological factors at the neighborhood level

Compared to the factors at the family and school levels, investigations of the effect of the ecological factors at the neighborhood level on young children's reading development have been relatively scarce. One of the initial examinations of neighborhood ecological factors was the study by Aikens and Barbarin (2008) in the United States. These researchers asked parents, school administrators, and field staff to appraise various aspects of the neighborhood conditions, such as the litter and garbage in the street, drug problems, safety issues, and the community's support for the school (Aikens & Barbarin, 2008). Their results showed that, after controlling the effects of the school and family variables, the community's support for the school and the poor physical surroundings of the school were related to the growth rate of the lower grade students' reading abilities (Aikens & Barbarin, 2008).

Recently, Little et al. (2019) found a negative effect of neighborhood variables on children's reading comprehension in grade school student from the United States. Specifically, the shelters (e.g., homeless shelter, drug rehabilitation center) in the school neighborhood exerted negative effects on the school children (e.g., anxiety for the occurrence of the violent incidents on the way to the school), so that the distance from the shelter to the school was negatively associated with children's reading abilities from third grade to tenth grade. The researchers suggested that the proximity to the shelter induced both indirect effects (e.g., increased stress) and direct effects (e.g., not attending the school for fear of violence) on the children's reading development, thus lowering their reading ability (Little et al., 2019).

In this study, only the ecological factors at the family level were included. Since this study only recruited children from one primary school, I was not able to investigate the effects of the factors at the school and the neighborhood levels. Moreover, neighborhoods in China are generally perceived as secure (Hill et al., 2016), therefore, the negative effects of debilitating neighborhood variables (e.g., distance to drug rehabilitation center) on children's reading development may be less relevant.

Two questionnaire were used at the two time points because the context of the environment were changed. Specifically, at Time 1, the children were at the beginning of formal education and literacy learning, literacy activities (e.g., shared reading) that focused on simple literacy-related interactions may be the principal component of literacy environment at home. Similar measurement was used in previous studies on grade one students from China (e.g., Zhang et al., 2019). At Time 2, the children have moved further into the formal education (in grade three), thus, more in depth literacy activities that support formal learning at school (e.g., aiding homework, listen to the children to read the text) may be essential to the children's reading development. To support this view, a recent three-year longitudinal study found that shared reading was not predictive of the children's reading ability from grade one onwards. Instead, a more literacy-focused reading comprehension activities (e.g., parents ask children to recall information from the text) was predictive of the lower graders in Canada (Georgiou et al., 2021).

2.4. Psychological Components and Word Reading

In addition to the cognitive and the ecological components, CMR also includes the psychological domain (Aaron et al., 2008). Like the ecological domain, the psychological factors selected in previous studies were related to the focus of the particular study. For instance, Li et al. (2020) adopted CMR to examine reading ability in a group of immigrant children who were learning to read English in Canada. Because the participants came from immigrant backgrounds, acculturation (i.e., adaption of the main culture and retention of one's own culture) was included as the psychological component in the study (Li et al., 2020). Ortiz et al. (2012), however, selected children's academic competence, social skills, and problem behaviors as the psychological factors to predict the reading performance of grade one primary school students in the United States.

Similar to the factors in the cognitive domain, the psychological factors can also be categorized into domain-general and the reading-specific variables. While the domain-general factors include children's overall psychological attributes, such as emotional competence, self-regulation, and attentional attributes, the reading-specific factors include attitudes, efficacy, and interest in reading. Both the general psychological attributes and the reading-specific psychological factors have been associated with reading ability in previous studies (e.g., Chapman & Tunmer, 1995; Kwok et al., 2007; Newman et al., 1998; Schiefele et al., 2012; Zhang et al., 2018). In the following section, the importance of domain-general psychological factors on

reading development in lower grade students will be discussed, followed by the introduction of the reading-specific factors.

2.4.1. Domain-general psychological factors

General psychological attributes. As mentioned above, general psychological attributes have an influence on children's reading abilities. This is particularly true for first graders who are adapting to the school environment (e.g., learning to follow classroom rules, doing homework, and meeting new friends). Some studies have shown general behavioral attributes such as self-control, emotional competence, and prosocial behaviors all to be related to academic performance in early graders (e.g., Kwok et al., 2007; Spira et al., 2005; Zhang et al., 2018). Since learning to read (and other knowledge) requires children to interact with classmates, parents, and teachers, having less social skills or/and emotional regulation abilities may lead to decreased learning-related interactions, which in turn can lead to decreased learning opportunities (e.g., Zhang & Sun, 2011).

Moreover, early graders are only at the beginning of formal literacy education, so their reading-specific psychological factors (e.g., reading interest, reading self-efficacy) may not be fully mature, for the development of these specific psychological factors needs the accumulation of teachers' feedback and their own reading experiences (Schiefele et al., 2012). In addition, at the start of literacy development, the reading-specific psychological factors may not be fully transferable to reading development. For example, even if children are highly interested in reading, their low

reading abilities can limit the propensity to read more books. However, recent studies have found that young children's interest in reading could prompt parents to conduct more literacy activities, which in turn may facilitate the children's reading growth (e.g., Pezoa et al., 2019). Therefore, the reading-specific psychological factors are also potentially important to children's reading development. The three most relevant factors are reviewed below.

2.4.2. Domain-specific psychological factors

Children's interest in reading Children's interest in reading has been related to the construct of intrinsic motivation, which propels children to read for its own sake rather than for external reasons (e.g., receiving higher grades) (Wigfield & Guthrie, 1997). Previous studies have associated reading interest with reading ability in children (e.g., Baker & Wigfield, 1999; McKenna et al., 1995). However, the association was often found to be weak (e.g., Kirby et al., 2011; Yeo et al., 2014). For example, children's reading interest predicted reading ability in lower grade primary school students from Canada, although the accounted variance was 4% at most (Kirby et al., 2011). Thus, it seems that interest in reading contributes to reading ability (e.g., through more engagement with reading activities), however, the contribution was found to be smaller than that of other factors such as phonological awareness, naming speed, and SES (Kirby et al., 2011).

In addition, interest in reading was found to be associated with HLE. For example, Yeo et al. (2014) found a strong association between these in Singapore preschool

children. Similar results were found in children who spoke French (Sénéchal, 2006) and English (Weigel et al., 2006). Although early studies (e.g., Weigel et al., 2006) hypothesized the direction of the relationship was from HLE to reading interest (e.g., more shared reading by parents brings more interest in reading in children), recent studies have shown that it may be a bidirectional relationship. For example, Boerma et al. (2018) found that parents from the Netherlands conducted more literacy activities at home when they perceived their primary school children (grade 3 to 6) to be more interested in reading. Similarly, a longitudinal study (tracked from prekindergarten to the end of kindergarten) found that children's reading interest predicted HLE in low-SES families from Chile (Pezoa et al., 2019). These results suggested that interest in reading could shape the environment to become more conducive to children's reading development.

Reading attitude Reading attitude is a system of feelings associated with reading that impels learners to approach or avoid reading activities (Alexander & Filler, 1976). It can be divided into two parts: attitudes towards leisure reading and to academic reading. The relationship between reading attitude and reading performance has been identified in previous studies. For example, the meta-analysis by Petscher (2010) found a strong correlation between the attitude and the achievement in reading in primary school children (Z_r = .44). Some researchers have suggested that children with more positive reading attitudes tend to have more successful and frequent reading experiences, which lead to higher reading achievement (Thames & Reeves, 1994). For the two kinds of reading attitude, scores on the recreational reading

attitude have been shown to be better at differentiating good and poor readers than the scores on academic reading attitude (McKenna et al., 1995). The reason may be that recreational reading attitude is related more closely to reading behaviors, whereas academic reading attitude is correlated with school subjects (Schiefele et al., 2012). Reading attitude was found to become increasingly negative with grade. For example, a study with a large sample (over 10,000 participants) found that both leisure and academic reading attitudes became progressively negative with increased grade levels (McKenna et al., 1995). Therefore, it is crucial to cultivate positive reading attitudes in the early stages of reading development (Petscher, 2010). Parental attitudes towards reading and home literacy environments were found to relate to children's reading attitudes (e.g., Beech, 1990; Scarborough & Dobrich, 1994). One way to measure reading attitude is to have children answer a series of queries about their feelings for reading-related activities (e.g., "How do you feel when you go to a bookstore?") (McKenna & Kear, 1990).

Reading self-efficacy Reading self-efficacy refers to "the extent of a person's expectation to perform well on a reading task" (Schiefele et al., 2012). Because self-efficacy influences children's choices of tasks, and their effort and persistence on the task, it has impact on their reading behaviors (Bandura, 1997). High reading self-efficacy helps children to maintain effort in achieving a reading task over a long period of time, while exceedingly high self-efficacy may be detrimental to learning to read, for children may be overoptimistic about their abilities and hence not put enough effort into studying (Schunk, 2003). Previous studies have found correlation between

reading self-efficacy and reading activities. For instance, Tercanlioglu (2001) found that reading self-efficacy was related to the amount of reading for enjoyment (r = .24). It has also been associated with reading strategies (e.g., memorization, elaboration) (Anmarkrud & Bråten, 2009).

Reading self-efficacy is acquired mainly through task performance; the success experience raises the self-efficacy and the failure experience lowers it (Schiefele et al., 2012). Moreover, self-efficacy can also be acquired through the comments of others (e.g., parents told child that he/she can do this), and the observation of others' behaviors, for instance, for classmates with similar ability levels or seeing other people finish a task will improve the self-efficacy of the viewer (Schunk, 2003).

In this study, the general psychological attributes (e.g., self-regulation, emotional competence) and reading interest were selected as the psychological factors. As mentioned above, because lower grade students in China have limited literacy experiences and are adapting to formal schooling, the general psychological attributes could be more prominent at this stage of their reading development. As for reading interest, previous studies have shown that very early readers (kindergarten children) are able to express this, which in turn prompted their parents to conduct more literacy activities (Pezoa et al., 2019), whereas the reading attitudes and reading self-efficacy of these early readers may be underdeveloped due to the limited literacy experiences, especially at the first time point (grade one). Specifically, researchers have found that lower graders held overoptimistic academic self-concept and their self-reported reading interest did not correlated with other reading-related variables (e.g., Helmke,

1999; Silinskas et al., 2020). Thus, I did not include the children's reading attitude and reading self-efficacy for the psychological component, and the reading interest was examined by a parental questionnaire in this study, as the participants in this study were lower grade students.

2.5. The Interplays of Components Across Domains in CMR

One of the benefits for incorporating components from multiple domains (i.e., cognitive, ecological, psychological) in CMR is that it creates an opportunity to investigate the relationships across domains. This type of investigation is lacking in previous studies, for most of them only included factors from one domain. However, factors from different domains do not contribute to reading independently; rather, they interact with each other in contributing to reading development. In this section, those interplays between components will be discussed. In the following sections, the potential mediation of cognitive components for the relationship between ecological components and reading will be discussed, followed by the potential mediation of psychological components for the link between ecological components and reading.

2.5.1. The mediation of cognitive components between ecological components and reading

According to the Ecological System Theory (Bronfenbrenner, 1986), ecological components such as SES and HLE have extensive influence on children's development. However, the specific mechanisms for the relation between ecological components and children's reading outcomes remain largely unknown. One way to

investigate these mechanisms is through examining the interaction between components from different domains. Previous studies have investigated the mediation of cognitive components for the relation between ecological components and reading outcomes. These studies shed light on how the ecological component contributes to children's reading development.

For example, Senechal and LeFerve (2002) found that children's vocabulary and listening comprehension at the beginning of grade one mediated the relationship between HLE measured at kindergarten and reading outcomes at the end of grade one and grade three in Canadian primary school children. This result suggested that better HLE (e.g., parents reading more books to children) enhanced children's vocabulary and listening comprehension, which supported their reading acquisition. Similarly, the mediation of the cognitive components for the relation between ecological component and reading was also found in Chinese children. For instance, Liu (2018) found that SES predicted literacy resources (quantity of children's books at home), and the effects of literacy resources on word reading was mediated by vocabulary and phonological awareness in Chinese third-year kindergarten children (Liu et al., 2018). Similar results were found in a longitudinal study from the third year of kindergarten to grade two, where HLE measured in kindergarten was found to contribute to children's word reading at grade one and reading comprehension at grade two via the emergent literacy skills measured in kindergarten (e.g., rapid naming, vocabulary, syllable awareness) (Zhang et al., 2019). Relatedly, Cheng and Wu (2017) found that vocabulary and morphological awareness mediated the relationship between SES and

reading comprehension in Chinese first graders. Other researchers have suggested that children from higher SES families developed broader vocabularies. This vocabulary base supported their reading development both directly and indirectly by facilitating the growth of their morphological awareness (Cheng & Wu, 2017). Similarly, in a longitudinal study, Zhang et al. (2013) found that early SES (measured at age 3) contributed to children's character reading at age 9 both directly and indirectly via the early phonological awareness and vocabulary (measured at ages 4 and 5).

Thus, besides the direct contribution to reading development, ecological components also contribute to reading outcomes via the mediation of cognitive components. Moreover, the proportion of direct and indirect contributions of the ecological component to reading may be susceptible to change with reading development. A large amount of studies of home learning environments focused on kindergarten or younger children (e.g., Anders et al., 2012; Liu et al., 2018; Son & Morrison, 2010), and studies of primary school children's home literacy environments is scant (Deng et al., 2015). One reason for the deficiency of studies in primary school children may be that the relationship between ecological components and reading outcomes was shifted from direct to indirect with reading development. Indeed, both Liu et al. (2018) and Deng et al. (2015) did not find any significant correlation between home literacy experiences and word reading in Chinese lower graders. This result led to researchers concluding that home literacy practice may not be an important component once children start to receive formal schooling (Katzir, Lesaux, & Kim, 2009).

While the direct influence of the ecological component on reading may be attenuated in primary school children, the studies mentioned above indicated the potential existence of indirect relations between ecological components and reading outcomes in primary school children. One possible reason for the emergence of indirect relations is that the cognitive component may be mature enough in primary school children to mediate the effect of the ecological component on reading. In all, the change in the strength of the indirect contribution of the ecological component to word reading via the cognitive component over the lower grade period remains undiscovered.

2.5.2. The mediation of psychological component between ecological component and reading

As mentioned above, children's interest in reading was found to be associated with HLE in children in different language settings (e.g., Weigel et al., 2006; Yeo et al., 2014). In other words, the ecological variables could influence the psychological conditions of children, which in turn influence their reading development. Previous studies have also found that HLE contributes to the development of reading motivation (a large construct that includes reading interest) (e.g., Baker, Scher, & Mackler, 1997). Specifically, the positive emotional interaction between parents and children during shared reading is pivotal to the development of children's reading motivation (Sonnenschein & Munsterman, 2002). On the other hand, the relationship between reading motivation and reading abilities has been established in previous studies (e.g., Becker, McElvany, & Kortenbruck, 2010; Guthrie, Wigfield, Metsala, &

Cox, 1999; Schiefele et al., 2012). Taken together, a potential path from ecological component to reading via the mediation of the psychological component can be postulated.

SES may also interact with the psychological factor, for it has been associated with children's psychological conditions in previous studies. For instance, Brody (1999) found that mothers with limited economic resources were less likely to set higher goals for their children and cultivate competence development, resulting in poorer regulation ability and lower social competence. SES has also been negatively associated with children's aggressive and delinquent behaviors (McCoy, Frick, Loney, & Ellis, 1999). Thus, with the established relation between general behavioral attributes and reading achievement (mentioned in the section above) on the other end, it is possible that the relation between SES and reading abilities is mediated by general behavior attributes.

A better ecological component may also tame the negative effect of the less adaptive psychological factors on reading ability. For example, when parents set more rules and regulations at home (e.g., asked children to study at a specific time slot every day) and conducted more literacy instructions, there were less negative impacts of their children's ill-adaptive temperaments (e.g., disobedience) on their reading abilities (Taylor et al., 2017).

Thus, in addition to the direct paths from the three components to word reading, potential mediations of the psychological and cognitive components for the relations between the ecological component and word reading may also emerge. Taken

together, these paths could be constructed into a structural model (see Figure 1). As indicated in Figure 1, paths *b*, *c*, and *e* are direct paths from components to word reading, whereas paths *a* and *d* are parts of the indirect paths from the ecological component to word reading.

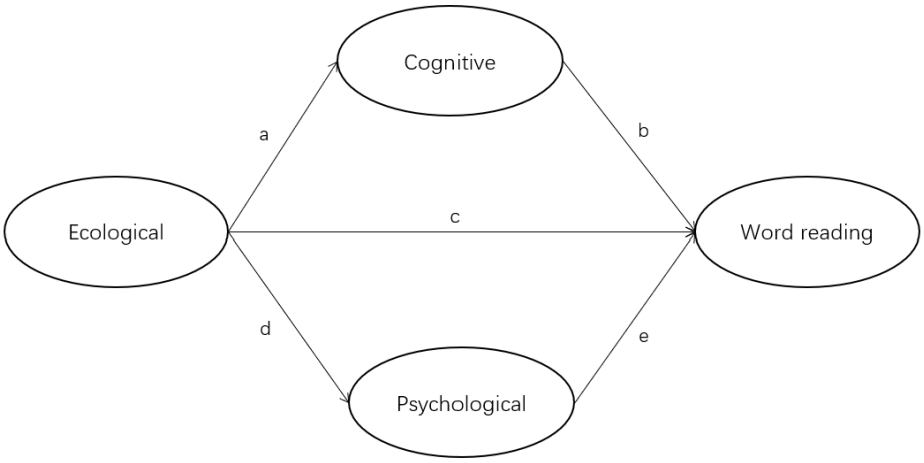

Figure 1. Hypothesized structural model between components and word reading. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component.

2.6. The Developmental and Longitudinal Relations between Components and Word Reading

The shift of the relationships between components and word reading with development was mentioned briefly in the above review. In this section, these developmental shifts between components and word reading, as well as the longitudinal relationships between components and word reading, will be discussed in detail.

2.6.1. The developmental shift of the ecological component

As mentioned before, most studies of the relationship between HLE and children's reading outcomes have focused on preschool or kindergarten children (e.g., Anders et al., 2012; Liu et al., 2018; Son & Morrison, 2010), with this relationship having been less explored and less robust in primary school students (e.g., Deng et al., 2015; Liu et al., 2018). These results indicate that ecological factors at the family level can have a reduced impact on the children's reading development.

However, it is possible that the ecological component at the school level exerts a larger effect (than the ecological factors at the family level) once children enter primary school. For example, a meta-analysis by Peng et al. (2019) found that SES exerted a larger influence on the relation between fluid intelligence and reading achievement in early development. It has been suggested that the effect of SES may be overshadowed by the school environment and children's literacy experiences with development (Peng et al., 2019). In other words, in the early developmental phases, children may benefit more from high SES environments enabling them to utilize fluid intelligence in learning to read, while the school environment and literacy experiences became more important in promoting their genetic potential (i.e., fluid intelligence) for literacy development later on. Similar results were found in the twin study by Haughbrook et al. (2017), in which school quality was found to influence the genetic variability of pre-reading skills (e.g., letter-naming fluency) in lower grade students from the United States. Thus, the ecological component may consistently exert its

influence on reading ability, with the family level factors (e.g., HLE) giving away to the school level factors (e.g., classroom environment).

In addition, the effect of the ecological component at the family level on reading ability may also shift from direct to indirect. Specifically, as the proximal components (i.e., the cognitive and psychological components) become more developed, the distal ecological component may exert its influence through their mediations. Indeed, whereas the direct relationship between home literacy experiences and word reading were not found in some studies that examined Chinese lower grade students (Deng et al., 2015; Liu et al., 2018), the indirect relationships between the ecological factors at the family level and the reading outcomes via the cognitive factors (e.g., vocabulary, PA) were found in the same group of children (e.g., Zhang et al., 2019; Zhang et al., 2013).

2.6.2. The developmental relations between the psychological and the cognitive components and word reading

Young children may possess overoptimistic self-concepts about their reading (e.g., overestimate their reading abilities). As they gain more experience with reading activities, however, their reading interest, reading self-efficacy and reading attitudes become more calibrated with the reality (Helmke, 1999). Therefore, the relationship between the psychological component and reading ability may become closer with development. In addition, with the growth of reading ability, children's reading-specific psychological factors could transfer more to their reading-related activities, which in turn improve their reading abilities. For example, reading interest may

become more relevant to reading ability as they become able to read more books on their own. Thus, the effect of reading-related psychological factors on reading ability may increase with their development.

Similarly, general psychological factors may also have an increased effect on reading ability. As children go on to higher grades, the curriculum becomes more difficult, which makes their attention and self-regulation abilities (e.g., focus on teachers' instructions during the class, strive to finish difficult homework) more relevant to their reading achievements (Newman et al., 1998). Thus, both reading-specific and general psychological factors may become more important to reading ability with children's development.

In contrast, the effect of the cognitive component may be consistent and important throughout reading development. Previous longitudinal studies have shown cognitive abilities (e.g., MA, PA, vocabulary) to be correlated moderately with reading ability throughout literacy development in Chinese children (e.g., Lei et al., 2011; Yeung et al., 2013). However, the importance of the specific cognitive factors differs across the developmental period. A cross-sectional study with primary school students in China, by Liu et al. (2017), found that PA contributed significantly to word reading only in beginning readers, whereas MA and orthographic awareness contributed significantly across grades. Another longitudinal study, by Yeung et al. (2013), found that MA (measured in grade one) was the only longitudinal predictor of word reading in grade four, with other cognitive variables (e.g., PA, rapid naming) and the autoregressive effect controlled, while rapid naming in grade one only predicted concurrent word

reading, and phonological memory in grade one negatively predicted word reading in grade four. Thus, it seems that PA is important in early reading development, while MA continues to be an essential factor in learning to read Chinese. The developmental changes for other domain-general cognitive factors (e.g., visual spatial attention, working memory) were less explored in previous studies, although they have been found to play important roles in Chinese early readers (e.g., Liu & Liu, 2020; Yang et al., 2019).

2.6.3. The longitudinal effect of the components on the growth of word reading

Learning to read is an accumulative and complex process, with factors from the early developmental phases influencing the acquisition of emergent literacy skills (e.g., MA, PA), which in turn contribute to reading ability later on. For example, in a longitudinal study Zhang et al. (2019) found that SES and HLE contributed to Chinese primary school children's emergent literacy skills (e.g., vocabulary, PA, rapid naming) at kindergarten, which in turn contributed to word reading in grade one. Similarly, Leseman and De Jong (1998) found that HLE measured in kindergarten predicted word decoding and reading comprehension in grade one, while the effects of other early ecological factors (e.g., SES, parents' literacy practices) contributed indirectly to reading achievement in grade one through the mediation of HLE and early vocabulary (measured in kindergarten) in primary school students from the Netherlands.

Ecological factors such as SES and HLE were often viewed as the antecedents of reading abilities. As a result, longitudinal studies have often included ecological factors measured at early time points when examining (or controlling) their effects on reading development (e.g., De Jong & Leseman, 2001; Li et al., 2008; Zhang et al., 2019). In these studies, the ecological factors were found to contribute to reading development directly and/or indirectly through emergent literacy skills (e.g., rapid naming), oral language skills (e.g., vocabulary), and psychological factors (e.g., reading interest), similar to the paths depicted in Figure 1 (e.g., Liu et al., 2018; Puglisi et al., 2017; Sénéchal, 2006).

Although the longitudinal effects of the ecological factors on reading ability were established in previous studies, less is known about the effects of these factors on the growth of reading ability in a given developmental period. This is because most longitudinal studies have not included the auto-regressor (i.e., early reading ability) in the model. One possible reason for the common exclusion of the auto-regressor is that it tends to eliminate the effects of other predictors in the model. For example, in the Netherlands, after accounting for word-decoding ability in grade one, early HLE did not contribute to this ability in grade three (De Jong & Leseman, 2001). Even the effects of cogntive factors (more proximal factors than ecological ones) on word reading were largely masked by the autoreggresive effects. As Yeung et al. (2013) found, only MA survived as the longitudinal predictor of word reading in Chinese primary school students.

However, the studies that excluded the auto-regressor were limited in that casual inferences, as a known predictor (early reading ability), was omitted (S. R. Burgess et al., 2002; Tabachnick & Fidell, 1989). In other words, the inclusion of the auto-regressor is necessary when examining the effects of the ecological factors on the growth of reading ability over a specific developmental span. The same applies to the examinations of the effects of the cognitive and the psychological factors. In addition, while both the direct and the indirect effects (via the cognitive and the psychological components) of the ecological factors were examined in previous longitudinal studies (e.g., Burgess et al., 2002; Vasilyeva et al., 2018; Zhang et al., 2019), few studies have scrutinized the exact developmental duration for the effects to emerge. For example, the longitudinal study by Zhang et al. (2019) measured SES, HLE, and emergent literacy skills (e.g., rapid naming, PA) at the third year in kindergarten and word reading in grade one primary school students from China. In the path model, SES and HLE were set to contribute to the concurrent emergent literacy skills, which in turn contributed to word reading longitudinally (Zhang et al., 2019). In other words, the effects of the ecological factors on the emergent literacy skills (i.e., cognitive factors) were concurrent, while the effects of the ecological and cognitive factors on word reading were longitudinal (one year).

In contrast, De Jong and Leseman (2001) found that HLE measured before children entered primary school contributed indirectly to reading comprehension in grade three via the mediation of the oral language skills (i.e., cognitive factors such as vocabulary and listening comprehension) measured at the end of grade one in the Netherlands

children. Thus, in their study, the longitudinal indirect effect of HLE on reading comprehension lasted for three years, with a one-year longitudinal effect of HLE on cognitive factors and two-year longitudinal effect of the cognitive factors on reading comprehension. In sum, while previous studies have found the longitudinal effect of ecological factors, the expressive duration for the effects (both direct and indirect) were different across studies (e.g., Crampton & Hall, 2017; Van Steensel, 2006; Weigel et al., 2006). A comparison of the durations of the effects would contribute to the understanding of reading development.

2.6.4. Bidirectional relations between components and reading outcomes

To comprehend the reading developmental process, it is necessary to look into the dynamic interactions between the components and reading outcomes. Most of the studies reviewed above have identified components and reading ability at a given time, for example, the ecological component was measured in kindergarten, the cognitive component measured in grade one, and the reading comprehension measured in grade three, which makes the studies *static* because they fail to examine how the components themselves and the reading outcomes develop and interact with each other (Cain & Barnes, 2017). Recent studies have found that the relationships between the components and reading outcomes are indeed dynamic and interactive (e.g., Cheng et al., 2016; Deng et al., 2015; Pezoa et al., 2019). In this section, these dynamic relationships will be discussed.

As mentioned before, ecological variables have often been treated as the antecedents or distal factors of reading development and thus used to predict other components (e.g., psychological component) and the reading outcomes in previous studies (e.g., De Jong & Leseman, 2001; Li et al., 2008; Zhang et al., 2019). Specifically, previous studies have found that HLE contributes to the development of children's reading interest (e.g., Sénéchal, 2006; Weigel et al., 2006). Some recent studies have found the relationship between the ecological and psychological components is not unidirectional but may be bidirectional. For example, in Chile, Pezoa et al. (2019) found that children's reading interest predicted their parents' literacy practices (e.g., shared reading) throughout the kindergarten period. Similarly, Boerma et al. (2018), in the Netherlands, found that parents conducted more literacy activities at home when they recognized their primary school children's interest in reading. Thus, it seems that children are not only the receivers of the ecological influence but also construct their environments actively to improve their reading development (Pezoa et al., 2019).

In addition to the bidirectional relationships between the components, potential bidirectional relationships may also exist between components and reading outcomes. Although most studies identified the effects of the components on reading outcomes (e.g., Kim et al., 2020; Levesque et al., 2018; Ouellette, 2006), there are also studies that found the relationships to be reversed or reciprocal. For example, a longitudinal study in Germany, by McElvany et al. (2008), found that early reading comprehension predicted later reading motivation (i.e., psychological factor), and

early reading motivation contributed indirectly to later reading comprehension with the mediation of reading amount in higher grade primary school students.

The effects of reading ability on the cognitive factors were also discovered in previous studies. For instance, the one-year longitudinal study by Dulay et al. (2021) found that early word reading predicted later vocabulary, and early MA predicted later word reading in Chinese first graders. Wu et al. (2009) suggested that MA contributes to literacy development in grade two, but the relationship turned into a bidirectional one in early third grade in Chinese primary school students. The results of these studies indicated that literacy experiences can help children to improve their language-related cognitive skills. For example, after they have learned the different characters for homophones (i.e., different morphemes with the same sound), they may be better able to differentiate the morphemes in oral language, thereby improving their vocabulary knowledge (Dulay et al., 2021). With the growth of the literacy experiences, children can also gain a better understanding of the morphology through reading, which turns the relationship between MA and reading into a reciprocal one (Wu et al., 2009).

The bidirectional relationships between ecological factors and reading outcomes in lower grade children from China were also examined in previous studies. For example, Deng et al. (2015) used the cross-lagged panel model to examine the bidirectional relationship between HLE and word reading in lower grade students. They showed that the children's word reading in grade one negatively predicted the informal literacy activities at home (e.g., the frequency of shared reading). The

researchers suggested that when the parents perceived their children were having trouble in literacy learning at school, they responded by providing more literacy activities at home (Deng et al., 2015). Thus, it seems that the relationship between the ecological component and reading may be more complex in the developmental period of primary school in China. Not only did the ecological factors (e.g., HLE, SES) contribute to the children's reading abilities, the children's reading abilities also influenced the ecological factors.

To summarize, the relationships between components and reading are dynamic and multi-directional. Even though previous studies have examined the reciprocal nature of relationships in one or two domains, no study yet has incorporated the factors from the ecological, psychological, and cognitive domains and examined the reciprocal relationships between these and with word reading in Chinese lower grade students.

2.7. The Present Study

This study investigated word-reading development in lower grade students in China by incorporating components from multiple domains and examining their dynamic interplays under the framework of CMR using a one-year longitudinal design. There were three major objectives for this study. First, it aimed to validate and extend CMR in lower grade students in China. Second, it aimed to construct a structural model (see Fig. 1 for the hypothesized model) to illustrate the relationships between components and word reading at each time point and see whether the two concurrent models were different. Third, this study aimed to examine the longitudinal effects of the

components on the growth of word reading and the reciprocal relationships between components and word reading at two time points.

Accordingly, I hypothesized that: 1) the factors from ecological, cognitive, and psychological components would converge into the respective components, and all three components would correlate significantly with word reading at two time points in the measurement models; 2) in the structural models at the two time points, the cognitive and psychological components would contribute directly to word reading, while the ecological component would contribute indirectly through the mediation of the other two components; 3) when comparing the two concurrent models, the effect of the psychological component on word reading would be increased with time, the effect of the cognitive component on word reading would be similar across the two times; 4) Time 1 components would predict the growth of word reading, Time 1 ecological component would indirectly contribute to the growth of word reading through the mediations of Time 2 cognitive and psychological components; 5) there would be reciprocal relationship between ecological and psychological components, and word reading would have reciprocal relationships with the three components. The reciprocal relationships would all be positive, except the relationship between early word reading and the ecological component, which would be negative.

The results of this study provide a comprehensive scene of the reading development in Chinese lower-grade children. Whereas most studies have examined components from one domain, this one integrated components from three domains (i.e., ecological, psychological, and cognitive). Moreover, this study examined the structural relations

among components from different domains, which is crucial in order to elucidate the overall contributions (both direct and indirect) of the components (Kim, 2017). This study aimed to extend the CMR in three aspects. First, this framework was applied to a new group of subjects (i.e., Chinese lower graders), which demanded the modification of the theory. For example, due to their developmental and language characteristics, word reading, rather than reading comprehension, was used as the reading outcome in this study. Second, as mentioned before, both direct and indirect relations among domains were investigated in this study. Third, the relationships between components and word reading were examined at two time points, which allowed for the investigation of the prediction of the early components on the growth of word reading, as well as the reciprocal relationships between components and word reading. It was intended that these examinations would enrich the model by adding the structural, longitudinal, and indirect relationships between the components and word reading. In practice, the results could provide implications for how and where to allocate resources and interventions in order to attaining better reading development for lower-grade children.

Chapter 3: Methodology

3.1. Participants

One hundred and ninety-four first grade students (119 boys, 75 girls; mean age = 86.20 months, *SD* = 4.92) were recruited from one primary school in Shenzhen, China. All participants in this study were native Chinese speakers. Of this group, 175 were tested again when they were in grade three (108 boys, 67 girls; mean age = 103.13, *SD* = 4.27). In addition, 9 boys (mean age = 100.67 months, *SD* = 4.67) who had not participated in the first wave joined the project in the second wave. The attrition was due to sick leave or school transfer. The first wave took place in March (second semester of grade one), and the second wave in September (first semester of grade three).

The parents of the children participated in both waves by completing a questionnaire on home literacy environment, family socioeconomic status, and children's reading interests and attentional conditions. There were 191 and 175 retrieved parental questionnaires in the first wave and the second wave, respectively.

3.2. Measures

3.2.1. Cognitive domain

Morphological awareness. Morphological awareness was measured by two tasks, the compounding structure awareness task and the homophone awareness task. In each item of the compounding structure awareness task (Liu & McBride-Chang, 2010), the children were asked to create a novel word for the scenario presented by the

experimenter. For example, in one item, the experimenter asked: 云彩和鲜花放在一起可以叫做什么？“What do we call the combination of rosy clouds and a fresh flower?” The best answer was 云花 (cloud-flower). The children’s answers were scored from 0 to 4. Four points were allotted for answers that contained all the crucial morphemes with the correct positions, and without any redundant morphemes; Three points were allotted for answers that were similar to the four-point answers but with redundant morphemes; two points were allotted to the answers that missed one crucial morpheme; one point was allotted to the answers that had some crucial morphemes but were positioned in wrong places; zero points were allotted for no answers or answers that did not contain any crucial morphemes. This task consisted of 31 items, and the maximum score was 124. The inter-rater reliability was .96 and .95 at the first and the second waves, respectively. Discrepancies were resolved through discussion. In each item of the homophone awareness task (McBride-Chang et al., 2003), the experimenter presented three words aurally. The first one was the target word, and the latter two were alternatives. The three words contained one common syllable, but only one of the alternatives contained the syllable that shared the morpheme in the target word. Children were asked to answer this word. For example, in one item, the target was 子女 (/zi3 nv3/, son-daughter, children), two alternatives were 子弹 (/zi3 dan4/, pellet-bullet, bullet) and 子孙 (/zi3 sun1/, son-grandson, offspring), and the answer was 子孙 (/zi3 sun1/, son-grandson, offspring). This task consisted of 33 items and one point was given for each correct answer. The scores of the two

morphological awareness tasks were first standardized and then averaged into one score of morphological awareness.

Phonological awareness. Phonological awareness was examined through four tasks: syllable deletion, onset deletion, rime deletion, and tone detection. In each item of the syllable deletion task (McBride-Chang et al., 2008), the experimenter aurally presented a three-syllable word, and the children were asked to delete one syllable and reply with the remaining part of the word. There were 29 items in this task, with 15 real words and 14 nonsense words. The score of the task was the number of correctly answered items.

In each item of the onset deletion task (Tong et al., 2017), the experimenter aurally presented a syllable or multi-syllable nonsense word, and the children were asked to reiterate each syllable without the initial sound. There were 22 items in this task, with 14 one-syllable items and 8 multi-syllable items. The score for the task was the number of correctly answered items.

In each item of the rime deletion task, the experimenter aurally presented a syllable, and the children were asked to reiterate each syllable without the end sound. There were 6 items in this task. The score for the task was the number of correctly answered items.

In each item of the tone detection task (Zhang et al., 2012), the experimenter aurally presented three syllables. Two of these syllables shared the same tone, while the other had a different tone. The children were asked to identify the different one for each

item. There were 12 items in this task. The score was the number of correctly answered items.

Vocabulary. In each item of this task (McBride-Chang, Tardif, et al., 2008), the experimenter aurally presented a word and asked the children to explain it. Their answers were marked based on comprehensiveness and clarity from 0 to 2: 2 points were allotted to answers that fully described the word, a score of 1 was given for answers that partly described the word, and a score of 0 was given for a wrong or no answer. This task had 30 items. The inter-rater reliability was .95 and .97 at the first and the second waves, respectively. Discrepancies between raters were resolved through discussion.

Working memory. Working memory was examined through the backward digit span test based on the Wechsler Intelligence Scale for Children (Wechsler, 1991). In each item of this test, the children were asked to repeat backwards a digit string that was presented aurally (roughly one digit per second) by the experimenter. The strings started at two digits and gradually increased to nine digits. This test consisted of 14 items and one point was given for each correct answer.

3.2.2. Psychological domain

Children's interest in reading. The children's interest in reading questionnaire (see Appendix A) was adapted from the parental questionnaire used in the Program for International Student Assessment (PISA) (OECD, 2019). One item about reading for information gathering was removed due to the reading level of the participants in this

study. We asked the parents to report on their children's interest using a 4-point scale (1 = strongly disagree to 4 = strongly agree).

Psychological problem. Children's psychological problems were measured by the Conners' Parent Rating Scale - Revised (Su et al., 2001). This scale consisted of 48 items (see Appendix B for the sample items), with subscales covering a variety of psychological problems, such as anxiety, inattention and psychosomatic problems. The Chinese version of the scale showed good reliability and sensitivity in differentiating children with emotional and attentional disabilities and typically developing children (Su et al., 2001). Parents were asked to indicate whether their children exhibited the behaviors through a 4-point scale (0 = Not at all, 1 = sometimes/mildly, 2 = frequently/severe, 3 = very frequently/very severe). The sum scores of the scale were calculated.

3.2.3. Ecological domain

Family SES. We asked the parents to report on their highest attained education and their occupations. Parental education was measured with an 8-point scale ranging from 1 = finished primary school to 8 = finished doctoral studies. Parental occupation was measured with a 5-point scale ranging from 1 = unemployed/unskilled work to 5 = senior managerial or senior professional work. The education scores and the occupation scores from the two parents were averaged into one family education score and one family occupation score, respectively.

At the second wave, we also asked the parents to report their income levels on a 7-point scale ranging from 1 = below 3000 RMB to 7 = above 18000 RMB, with 3000 RMB interval (e.g., 2 = 3001 RMB to 6000 RMB, 3 = 6001 RMB to 9000 RMB) between each option. Similarly, the income scores from both parents were averaged into one score of family income.

To construct the Time 1 SES index for each family, we first standardized the education score and the occupation score (because these two scores had different ranges) and then conducted a principal component analysis for the two standardized scores using a varimax rotation. The results showed that only one component had an eigenvalue exceeding 1, explaining 77.42% of the variance. This component was used as the Time 1 SES index in this study.

Similarly, to construct the Time 2 SES index for each family, we first standardized the education score, the occupation score, and the income score and then conducted a principal component analysis for the three standardized scores using a varimax rotation. The results showed that only one component had an eigenvalue exceeding 1, explaining 62.52% of the variance. This component was used as the SES index at Time 2 in this study.

Home literacy environment. Home literacy environment was examined by asking about literacy activities at home, the number of children's books at home, and the number of adults' books at home.

At Time 1, literacy activities at home before entering the primary school were examined through the home literacy activities questionnaire of the International

Association for the Evaluation of Education Achievement-Progress in International Reading Literacy Study (IEA-PIRLS) (Martin et al., 2007). The questionnaire consisted of 10 items (see Appendix C) related to literacy activities at home (e.g., shared reading), and parents were asked to indicate the frequency of these activities through a 3-point scale (1 = never or almost never, 2 = sometimes, 3 = frequently). At Time 2, the home activities questionnaire from the Progress in International Reading Literacy Study (PIRLS; Tse et al., 2010) was adapted to examine the present literacy activities at home, where items that related to literacy activities (e.g., discuss the materials that your child has read in class) were included. The questionnaire consisted of six items (see Appendix D), and parents were asked to indicate the frequency of these activities through a 4-point scale (1 = never or almost never, 2 = one or two times per month, 3 = one or two times per week; 4 = every day or almost every day).

At both time points, the number of children's books at home was measured using a 6-point scale (1 = 0-10 books, 2 = 11-25 books, 3 = 26-50 books, 4 = 51-100 books, 5 = 101-200 books, and 6 = over 200 books). The number of adults' books at home was also measured using a 6-point scale (1 = 0-10 books, 2 = 11-25 books, 3 = 26-100 books, 4 = 101-200 books, 5 = 201-500 books, and 6 = over 500 books).

3.2.4. Word reading ability

Chinese character reading. This task had 100 Chinese characters, which were arranged in order of ascending difficulty (Liu & Liu, 2020; McBride-Chang et al.,

2003). The children were asked to read the characters one by one and received one point for each correct answer. The test was terminated when a child received 0 points on 15 consecutive items. The score for the task was the number of correctly read characters.

Reading fluency. In this task, the children were asked to read as many words as they could in 45 seconds. This task had 21 single-character words, 76 two-character words, 5 three-character words and 2 four-character words (104 items in total). A list of eight words was presented to the children prior to the test for practice. The score of the task was the number of correctly read words within the time limit. This task has been used successfully in previous studies (e.g., Liu & Liu, 2020; Pasquarella et al., 2015).

3.2.5. Control variable

Nonverbal intelligence. Nonverbal intelligence was measured with Raven's Standard Progressive Matrices (Raven, Court, & Raven, 1996). Sets A and B of the test were administered, consisting of 24 items. One point was given for each correct answer.

3.3. Procedure

At Time 1, all children were tested individually by trained experimenters in a quiet classroom in their school. The test took place in the spring semester of grade one. At Time 2, the format of the measurement was revised to shorten the measurement period and to keep social distance for infection control due to the Coronavirus disease 2019 (COVID-19). Specifically, the two word reading tasks and all the measures in the cognitive domain (except the tone awareness task) were transformed into digital

versions on PC and the children were group-tested in the computer room at school. Instructions were prerecorded by one graduate student and the children's answers were recorded through microphones and later transcribed/scored by graduate students (except for the homophone awareness task, in which the answers were recorded directly by selection using a mouse). The children from the same class (about 40 children per class) were tested together. Five experimenters were presented in each session to provide guidance and instruction to children in need of it.

In addition, at Time 2, the nonverbal intelligence task and the tone awareness task were group-tested in the children's classroom in paper form. The children from the same class were tested together. The instructions were presented aurally by the experimenter. The children were asked to write down their answers on the answer sheets provided. The questionnaires were completed by the children's parents at home. The parents were assured of their anonymity and that there were no right or wrong answers. They were also encouraged to answer the questionnaire truthfully. Because the psychological problem scale did not correlate with most of the variables at Time 1, this scale was deleted from the questionnaire at Time 2 to reduce the parents' workloads and to expediate the data collection process.

It should be noted that safety procedures brought about by the COVID-19 pandemic were adhered to. During the data collection phrase at Time 2, there was no local case occurring in the city. Moreover, prior to the data collection, all the experimenters had tested negative for the virus. All the experimenters wore masks during the data collection at school.

Chapter 4: Data Analysis and Results

4.1. Descriptive Results

The descriptive statistics and Cronbach's α for all the measures used in this study are shown in Table 1. The measures in this study have shown good reliability and there was no large skewness for the distributions of the measurements. The syllable awareness task at both times and the rime deletion task, onset deletion task, and the working memory task at Time 1 showed Leptokurtic distributions (Kurtosis > 3), which indicated that the scores for these tasks were clustered around the mean. The scores for the other measures did not deviate largely from the normal distribution. The zero-order correlations between the variables at Time 1, Time 2, and across both times are shown in Table 2, Table 3, and Table 4, respectively.

Table 2 shows that, at Time 1, the two word reading tasks were significantly correlated with each other (r = .87, p < 0.01). The two word reading tasks were significantly correlated with all the variables in the cognitive domain (rs = .25 - .49, ps < 0.01). They were also significantly correlated with children's interest in reading, literacy activities at home, and the number of children's books at home (rs = .19 - .25, ps < 0.05). The four factors of the ecological domain (i.e., family SES, literacy activities at home, the number of children's and adult's books at home) were significantly correlated with each other (rs = .24 - .36, ps < 0.05). Family SES was also correlated with morphological awareness and nonverbal intelligence (rs = .16 - .29, ps < 0.05). The literacy activity at home was correlated with children's interest in reading and their nonverbal intelligence (rs = .20 - .45, ps < 0.05). The numbers of

children's and adult's books at home were correlated with children's homophone awareness, and interest in reading (*r*s = .15 - .27, *p*s < 0.05). Children's interest in reading wwas significantly correlated with nonverbal intelligence, tone awareness, and vocabulary (*r*s = .15 - .17, *p*s < 0.05). Finally, the factors in the cognitive domain were significantly correlated with each other (*r*s = .19 - .45, *p*s < 0.05), except the correlations between rime awareness and morphological structural awareness, vocabulary, work memory, and the correlation between tone awareness and vocabulary, which were all non-significant.

Table 3 showed that, at Time 2, the two outcome measures were significantly correlated with each other (*r* = .52, *p* < 0.01). Chinese character reading was significantly correlated with all other variables (*r*s = .18 - .35, *p*s < 0.05), except for homophone awareness, tone awareness, inattention, hyperactivity, and literacy activities at home. Word reading fluency was significantly correlated with all other variables (*r*s = .17 - .50, *p*s < 0.05) except for inattention, hyperactivity, and the number of children's books at home. The four factors in the ecological domain were significantly correlated with each other (*r*s = .19 - .52, *p*s < 0.05), except the correlation between the number of adults' books at home and literacy activities at home, which was non-significant. The number of children's books at home was significantly correlated with morphological awareness, vocabulary, working memory, and children's interest in reading (*r*s = .17 - .36, *p*s < 0.05). The number of adults' books at home were significantly correlated with vocabulary and children's interest in reading (*r*s = .16 - .23, *p*s < 0.05). Children's interest in reading was significantly

correlated with morphological structural awareness (r = .22, p < 0.05). Finally, factors in the cognitive domain were all significantly correlated with each other (rs = .17 - .59, ps < 0.05), except for the non-significant correlation between tone awareness and homophone awareness.

As shown in Table 4, the variables significantly correlated with themselves across both times (rs = .16 - .71, ps < 0.05). The cognitive factors were mostly significantly correlated with each other across the times (rs = .16 - .51, ps < 0.05), except that morphological structural awareness at Time 1 was only significantly correlated with morphological structural awareness at Time 2 and vocabulary at Time 2 (rs = .16 - .23, ps < 0.05). In addition, homophone awareness at Time 1 was not significantly correlated with tone awareness at Time 2, tone awareness at Time 1 was not significantly correlated with the two levels of morphological awareness at Time 2, and vocabulary at Time 1 was not significantly correlated with Time 2 syllable awareness, rime awareness, tone awareness, or working memory. Most cognitive factors at Time 1 were correlated with the two word reading variables at Time 2. The ecological factors were significantly correlated with each other across times (rs = .15 - .71, ps < 0.05), except that family SES and literacy activities at home were not significantly correlated across times, and the number of children's books at Time 1 was not significantly correlated with literacy activities at Time 2. The ecological factors at Time 1 (except the number of adults' books at home) were also significantly correlated with word reading fluency at Time 2. Children's reading interest at Time 1 significantly correlated with the two MA tasks and home literacy environment

variables at Time 2 (*r*s = .18 - .34, *p*s < 0.05), while psychological problems at Time 1 significantly correlated with homophone awareness, children's interest in reading, home literacy activities and the number of books for adults at Time 2 (*r*s = -.17 - -.27, *p*s < 0.05). The two word reading variables were significantly correlated across times (*r*s = .50 - .71, *p*s < 0.01). The two word reading variables at Time 1 were significantly correlated with most cognitive factors, children's interest in reading and family SES, as well as the numbers of children's and adults' books at home at Time 2. In addition, Time 1 children's interest in reading, family SES, and the number of children's books at home at Time 1 were significantly correlated with morphological structural awareness at Time 2 (*r*s = .18 - .24, *p*s < 0.05); Family SES at Time 1 was significantly correlated with vocabulary and working memory at Time 2 (*r*s = .21 - .24, *p*s < 0.05).

Table 1. *Descriptive Statistics for Measures in This Study*

Variable	Cronbach's α	Mean	SD	Range	Max	Skew	Kurtosis
Age_T1	/	85.97	4.91	69.1-109.7	–	.68	2.56
Age_T2	/	102.99	4.30	96-117	–	.53	.13
NI_T1	/†	16.44	3.80	6-23	24	-.47	-.36
NI_T2	/†	19.52	2.86	9-23	24	-1.44	2.58
MSA_T1	0.87	61.70	21.30	6-119	124	-.17	-.14
MSA_T2	0.84	67.24	18.79	3-101	124	-.88	1.06
HOMO_T1	0.82	22.54	3.90	9-31	33	-.36	.11
HOMO_T2	0.77	24.62	4.56	5-33	33	-1.07	1.63
SD_T1	0.88	24.92	5.12	2-29	29	-2.10	5.07
SD_T2	0.86	24.45	5.36	0-29	29	-2.75	8.86
OD_T1	0.92	15.70	4.77	0-22	22	-1.55	3.14
OD_T2	0.91	10.86	5.61	0-22	22	-.68	-.32
RD_T1	0.82	5.51	1.33	0-6	6	-3.25	10.08
RD_T2	0.85	3.69	3.64	0-6	6	-.54	-1.31
TD_T1	0.80	6.52	2.70	0-11	12	-.48	-.53
TD_T2	0.82	7.90	3.23	0-12	12	-.28	-1.07

Variable	Cronbach's α	Mean	SD	Range	Max	Skew	Kurtosis
VOC_T1	0.89	16.80	6.63	0-35	60	.39	-.01
VOC_T2	0.87	22.35	7.85	0-42	60	-.30	.28
WM_T1	0.71	4.42	1.91	0-14	14	1.26	3.30
WM_T2	0.69	4.28	2.04	0-10	14	.24	-.08
PP_T1	0.93	19.04	12.05	0-59	144	.85	
CRI_T1	0.75	25.63	3.81	16-36	40	.21	.10
CRI_T2	0.83	27.46	4.29	17-40	40	.31	.24
F_Edu_T1	/	3.48	1.55	1-7	8	.44	-1.01
F_Edu_T2	/	3.39	1.50	1-7	8	.36	-1.07
M_edu_T1	/	3.30	1.47	1-6	8	.31	-1.12
M_edu_T2	/	3.41	1.53	1-7	8	.23	-1.10
F_job_T1	/	2.84	1.08	1-5	5	.50	-.56
F_job_T2	/	2.90	1.04	1-5	5	.43	-.61
M_job_T1	/	2.33	1.11	1-5	5	.23	-1.19
M_job_T2	/	2.45	1.15	1-5	5	.21	-1.14
F_income_T2	/	3.61	1.67	1-7	7	.73	-.43
M_income_T2	/	2.51	1.45	1-7	7	1.21	1.42
HLA_T1	0.88	19.31	4.29	6-30	30	-.17	.24
HLA_T2	0.78	17.77	3.74	4-24	24	-1.05	1.29
CBOOK_T1	/	2.56	1.17	1-6	6	.50	-.12
CBOOK_T2	/	3.13	1.18	1-6	6	.30	.03
ABOOK_T1	/	1.88	0.91	1-6	6	1.17	2.23
ABOOK_T2	/	2.07	1.04	1-5	6	.59	-.33
CCR_T1	0.97	43.86	17.53	1-96	100	.59	.15
CCR_T2	0.96	64.10	18.59	3-95	100	-1.31	1.35
RF_T1	/*	32.58	14.43	2-73	588	.53	-.28
RF_T2	/*	61.16	20.58	2-102	588	-.53	.10

Note: T1 = Time 1; T2 = Time 2; NI = nonverbal intelligence; MSA = morphological structural awareness; HOMO = homophone awareness; SD = syllable deletion; OD = onset deletion; RD = rime deletion; TD = tone detection; VOC = vocabulary; WM = working memory; PP = psychological problem; CRI = Child reading interest; F_Edu = father's education level; M_Edu = mother's education level; F_job = father's occupation; M_job = mother's occupation; F_income = father's income level; M_income = mother's income level; HLA = home literacy activities; CBOOK = the number of children's books at home; ABOOK = the number of adults' books at home; CCR = Chinese character reading; RF = word reading fluency.

† The reliability of the nonverbal intelligence test was not calculated because this measure is from a standardized test.

* Because only the total number of the correctly read words was recorded, the reliability could not be calculated.

Table 2. *Zero-order Correlations between Variables at Time 1*

	NI_T1	MSA_T1	HOMO_T1	SA_T1	PA_T1	RA_T1	TA_T1	VOC_T1	WM_T1	PP_T1	CRI_T1	SES_T1	HLA_T1	CBOOK_T1	ABOOK_T1	CCR_T1	RF_T1
NI_T1	—																
MSA_T1	**.19***	—															
HOMO_T1	**.39****	**.32****	—														
SA_T1	**.50****	**.23****	**.34****	—													
PA_T1	**.38****	**.23****	**.37****	**.45****	—												
RA_T1	**.24****	.12	**.29****	**.42****	**.58****	—											
TA_T1	**.35****	**.21****	**.27****	**.33****	**.45****	**.34****	—										
VOC_T1	**.27****	**.38****	**.43****	**.24****	**.20****	.05	.13	—									
WM_T1	**.36****	**.22****	**.26****	**.37****	**.28****	.07	**.33****	**.19****	—								
PP_T1	.08	-.14	-.04	.02	.02	.01	-.06	-.07	-.06	—							
CRI_T1	**.17***	.07	.04	0.03	.00	-.01	**.16***	**.15***	.07	**-.19***	—						
SES_T1	**.22****	**.16***	**.29****	0.09	.14	.09	.06	.11	.06	-.04	.16	—					
HLA_T1	**.20****	.03	.11	0.11	.06	-.10	.00	.07	.11	**-.24****	**.45****	**.30****	—				
CBOOK_T1	.10	.06	**.18***	-0.01	.08	-.04	.04	**.15***	**.15***	-.13	**.27****	**.34****	**.24****	—			
ABOOK_T1	.00	.07	**.15***	.04	.03	-.03	-.01	.11	.06	**-.19***	**.22****	**.41****	**.36****	**.47****	—		
CCR_T1	**.47****	**.25****	**.42****	**.45****	**.37****	**.26****	**.26****	**.45****	**.31****	-.05	**.25****	.15	**.19****	**.22****	.05	—	
RF_T1	**.50****	**.26****	**.49****	**.46****	**.40****	**.26****	**.25****	**.45****	**.34****	-.02	**.19***	.15	**.21****	**.19***	.04	**.87****	—

Note: T1 = Time 1; NI = nonverbal intelligence; MSA = morphological structural awareness; HOMO = homophone awareness; SA = syllable awareness; PA = phoneme awareness; RA = rime awareness; TA = tone awareness; VOC = vocabulary; WM = working memory; PP = psychological problem; CRI = Child reading interest; SES = family socioeconomic status; HLA = home literacy activities; CBOOK = the number of children's books at home; ABOOK = the number of adults' books at home; CCR = Chinese character reading; RF = word reading fluency.

* $p < 0.05$; ** $p < 0.01$

Significant correlations are shown in bold font.

Table 3. *Zero-order Correlations between Variables at Time 2*

	NI_T2	MSA_T2	HOMO_T2	SA_T2	PA_T2	RA_T2	TA_T2	VOC_T2	WM_T2	CRI_T2	SES_T2	HLA_T2	CBOOK_T2	ABOOK_T2	CCR_T2	RF_T2
NI_T2	—															
MSA_T2	**.18***	—														
HOMO_T2	**.22****	**.40****	—													
SA_T2	.14	**.35****	**.29****	—												
PA_T2	**.29****	**.49****	**.37****	**.36****	—											
RA_T2	**.24****	**.38****	**.34****	**.34****	**.59****	—										
TA_T2	.15	**.20***	.13	**.17***	**.36****	**.26****	—									
VOC_T2	**.32****	**.54****	**.43****	**.32****	**.47****	**.35****	**.21****	—								
WM_T2	**.21****	**.30****	**.21****	**.20****	**.37****	**.24****	**.25****	**.27****	—							
CRI_T2	.05	**.22****	.05	.05	.03	-.03	.06	.12	.05	—						
SES_T2	.05	**.20***	**.32****	.15	.10	.10	-.03	**.23***	.15	.07	—					
HLA_T2	.02	.10	.11	.06	.11	.07	.01	.06	.13	**.28****	**.18***	—				
CBOOK_T2	-.09	**.18***	**.17***	.08	.14	.06	-.03	**.18***	**.17***	**.36****	**.19***	**.21****	—			
ABOOK_T2	.08	.09	.19*	.08	.03	-.04	-.09	**.16***	.07	**.23****	**.27****	.12	**.52****	—		
CCR_T2	**.18***	**.27****	.14	**.25****	**.31****	**.25****	.11	**.35****	**.29****	**.30****	.15	.13	**.31****	**.18***	—	
RF_T2	**.32****	**.46****	**.31****	**.32****	**.49****	**.32****	**.26****	**.50****	**.45****	**.22****	**.22***	**.17***	**.20***	.12	**.52****	—

Note: T2 = Time 2; NI = nonverbal intelligence; MSA = morphological structural awareness; HOMO = homophone awareness; SA = syllable awareness; PA = phoneme awareness; RA = rime awareness; TA = tone awareness; VOC = vocabulary; WM = working memory; CRI = Child reading interest; SES = family socioeconomic status; HLA = home literacy activities; CBOOK = the number of children's books at home; ABOOK = the number of adults' books at home; CCR = Chinese character reading; RF = word reading fluency.

* $p < 0.05$; ** $p < 0.01$

Significant correlations are shown in bold font.

Table 4. *Zero-order Correlations between Variables across the Two Times*

	NI_T2	MSA_T2	HOMO_T2	SA_T2	PA_T2	RA_T2	TA_T2	VOC_T2	WM_T2	CRI_T2	SES_T2	HLA_T2	CBOOK_T2	ABOOK_T2	CCR_T2	RF_T2
NI_T1	**.32****	**.35****	**.26****	**.28****	**.37****	**.25****	**.17***	**.40****	**.35****	.03	.15	.04	.13	.06	**.30****	**.51****
MSA_T1	.03	**.16***	.13	.08	.13	.03	.09	**.23****	-.01	-.10	-.03	-.07	-.03	.02	-.08	.12
HOMO_T1	**.31****	**.28****	**.33****	**.23****	**.36****	**.19***	.10	**.45****	**.26****	.04	**.25****	.09	**.22****	**.22****	**.21****	**.43****
SA_T1	**.39****	**.36****	**.31****	**.42****	**.51****	**.37****	**.23****	**.47****	**.37****	-.07	.15	.06	.06	.15	**.43****	**.52****
PA_T1	**.23****	**.19***	**.23****	**.33****	**.43****	**.36****	**.18***	**.32****	**.26****	-.04	.13	.08	**.17***	.08	**.19***	**.41****
RA_T1	**.17***	**.24****	**.19***	**.33****	**.45****	**.30****	**.21****	**.16***	**.17***	-.12	.17	.05	-.01	-.11	**.20***	**.33****
TA_T1	**.18***	.13	.14	**.20***	**.45****	**.29****	**.27****	**.19***	**.29****	-.02	.01	.03	.06	.01	.14	**.31****
VOC_T1	**.21****	**.29****	**.23****	.14	**.18***	.08	-.01	**.46****	.06	.07	.09	.00	.09	**.18***	.11	**.36****
WM_T1	**.22****	**.17***	**.21****	**.21****	**.25****	.12	**.16***	**.22****	**.33****	.06	.08	-.09	.06	.10	.15	**.30****
CRI_T1	-.04	**.18***	**.24****	.13	.09	-.06	.09	.09	.03	**.59****	.12	**.29****	**.34****	**.20***	.16	.16
PP_T1	-.05	-.11	**-.23****	.08	-.02	-.05	.004	-.06	-.10	**-.27****	-.01	**-.17***	-.16	**-.21***	-.01	-.07
SES_T1	.04	**.19***	.13	.13	.08	-.01	-.01	**.24****	**.21***	.15	**.71****	.11	**.25****	**.33****	.13	**.17***
HLA_T1	.13	.02	.08	.04	.11	-.02	.08	.13	.06	**.42****	.18	**.18***	**.15***	**.22****	.11	**.19***
CBOOK_T1	.00	**.24****	.06	.09	.03	.06	.05	.12	.11	**.29****	.13	.08	**.50****	**.31****	.15	**.17***
ABOOK_T1	-.03	.15	.06	.05	-.05	-.14	-.04	.08	-.02	**.17***	**.19***	**.17***	**.23****	**.53****	-.01	.04
CCR_T1	**.29****	**.38****	**.34****	**.29****	**.38****	**.23****	**.16***	**.51****	**.27****	**.26****	.18	.08	**.21****	**.22****	**.53****	**.66****
RF_T1	**.30****	**.31****	**.27****	**.28****	**.35****	.14	**.22****	**.46****	**.30****	**.19***	**.20***	.06	**.24****	**.23****	**.50****	**.71****

Note: T1= Time 1; T2 = Time 2; NI = nonverbal intelligence; MSA = morphological structural awareness; HOMO = homophone awareness; SA = syllable awareness; PA = phoneme awareness; RA = rime awareness; TA = tone awareness; VOC = vocabulary; WM = working memory; CRI = Child reading interest; PP = psychological problem; SES = family socioeconomic status; HLA = home literacy activities; CBOOK = the number of children's books at home; ABOOK = the number of adults' books at home; CCR = Chinese character reading; RF = word reading fluency.

* $p < 0.05$; ** $p < 0.01$

Significant correlations are shown in bold font.

4.2. Analytic Plan of Structural Modeling

4.2.1. Data preparation

To increase the probability of model convergence, all the scores of the measurements were standardized (i.e., z scores) before entering the models. In addition, the scores for phonological awareness and morphological awareness were composite scores of relevant measures (i.e., the score of morphological awareness was created by averaging the z scores of compounding production task and homophone identification task, and the score of phonological awareness was created by averaging the z scores of four phonological awareness tasks). These score compositions increased the likelihood of model convergence and were in accordance with the objective of this study (i.e., to examine the relationships among the larger components of reading and word reading). The measurement models and the structural models were specified using the lavaan package (Rosseel, 2012) in R (R Core Team, 2014). Missing data were handled with the full information maximum likelihood method. The maximum likelihood robust (MLR) estimator, which is robust to non-normality, was used to estimate the model parameters.

4.2.2. Concurrent models specification

Confirmatory factor analysis was first conducted to evaluate the measurement models at two time points. Because psychological problems at Time 1 was not significantly correlated with most of the variables in this study, including the word reading variables at the two time points, it was removed from the psychological component at Time 1 (and it was not examined at Time 2). Thus, the psychological component at both times was indicated by the children's interest in reading. The two measurement models for the two time points were composed of the same measures, with two exceptions. First, for the ecological component at Time 1, the frequency of

various literacy activities conducted before primary school was included. For the ecological component at Time 2, the frequency of various literacy activities conducted currently was included; second, in addition to the education levels and occupations that were measured at Time 1, parents' income was added as one of the indices for family SES at Time 2. Age and nonverbal intelligence were controlled in the models.

Moreover, to examine the direct and indirect relationships among the three components and word reading at each time point, structural models were specified and compared using the chi-square test of difference. A significant chi-square test of difference indicates that the model with less degrees of freedom should be retained. On the other hand, a nonsignificant chi-square test of difference indicates that the two models provide equal fit to the data, and the model with more degrees of freedom should be retained for parsimony.

4.2.3. Model specification across two waves

Since the final models at the two time points shared the same paths, a series of multi-group analysis was then conducted to examine whether the two models had significant differences. Specifically, in each model, one path was constrained across the two waves, and this model was compared with the fully unconstrained model (i.e., all paths were free to vary across the two waves). The nonsignificant difference in model fitness between the constrained model and the fully unconstrained model indicated that there was no significant difference in this path across the two times and thus should be constrained for parsimony. On the other hand, the significant better fit for the fully unconstrained model over the constrained one suggested that there were differences in this specific path across waves and thus should be retained to vary across the two times. The chi-square test of difference was used to compare the fitness of the models. The end

of this process was to land on the models that could account for the differences for the two time points while remaining as parsimonious as possible.

In addition, three types of longitudinal model were specified. First, to examine the early prediction of the three components on the growth of word-reading ability, the three components at Time 1 were structured to predict word reading at Time 2, with the control of the auto-regressor (word reading at Time 1). Second, to examine the longitudinal effect of the ecological component on word reading, the ecological component at Time 1 was set to predict the psychological and the cognitive components at Time 2, which in turn contribute to the word reading at Time 2, with the control of the auto-regressor (word reading at Time 1). Third, a cross-lagged model was constructed to examine the bidirectional relationships between the components and word reading, with the control of the auto-regressive effects. In this model, family SES at Time 2 was removed from the ecological component at Time 2 for two related reasons. First, as a distal and stable ecological variable, prior reading-related components and children's word reading were unlikely to influence later SES (e.g., children's interest in reading at Time 1 was unlikely to predict their parents' occupations at Time 2). Thus, it was not logical to put it at Time 2 for prediction. Second, the family SES scores at the two times were highly correlated ($r = .71$, $p < .001$, the highest cross-time correlations among all the variables, see Table 4), hence the inclusion of family SES at both times without the direct path between the two would decrease the model fit and interfere with the estimations of the parameters for other variables. Age and nonverbal intelligence were controlled in the models.

The model fit was assessed by a group of fit indices. Specifically, the nonsignificant chi-square test, comparative fit index (CFI) values close to 0.95 or higher, root means square error of approximation (RMSEA) values below 0.06, and standardized root mean square residual

(SRMR) values below 0.09 are indicative of good model fit (Hu & Bentler, 1999; Kline, 2015), although the chi-square test is very sensitive to the sample size and it should not be a cause for overly concern if it is significant (Hu & Bentler, 1999).

The indirect effects were estimated using the monteCarloMed function (with 10000 resamples) in the semTools package (Jorgensen et al., 2018) in R (R Core Team, 2014). This function returns a point estimate and a confidence interval for the indirect effect base on a Monte Carlo test of mediation (MacKinnon et al., 2004). The indirect effect would be significant if the confidence interval did not cover zero.

4.3. Results of Structural Modeling

4.3.1. Confirmation factor analysis

At Time 1, the four-factor model showed adequate fit, $\chi^2 = 75.21$, $df = 39$, $p < 0.001$, CFI = .94, SRMR = .05, RMSEA = .07. As illustrated in Figure 2, all measures loaded significantly on their respective latent variable. The cognitive component significantly covaried with the ecological component ($\beta = .28$, $SE = .04$, $p < 0.05$), the psychological component significantly covaried with the ecological component ($\beta = .43$, $SE = .06$, $p < 0.001$), and the three components significantly covaried with word reading (βs = .24 –.75, ps < .05).

For the Time 2 model, $\chi^2 = 73.05$, $df = 39$, $p = 0.001$, CFI = .90, SRMR = .06, RMSEA = .07. As illustrated in Figure 2, all measures loaded significantly on their respective latent variable. The psychological component significantly covaried with the ecological component ($\beta = .41$, $SE = .07$, $p < 0.05$), and the three components significantly covaried with word reading (βs = .30 –.79, ps < .05).

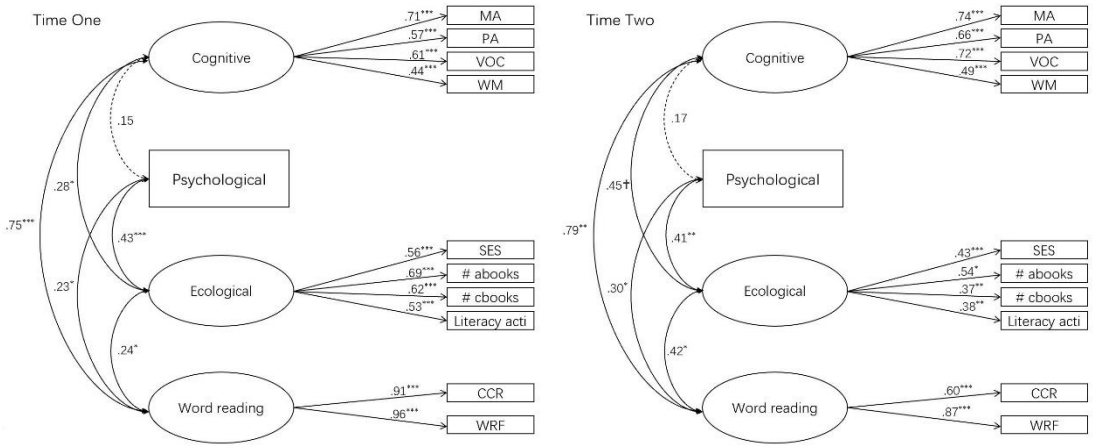

Figure 2. Confirmatory factor analysis models for the components of reading and word reading at two time points. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component. MA = morphological awareness; PA = phonological awareness; VOC = vocabulary; WM = verbal working memory; SES = socioeconomic status; # abooks = number of books for adults at home; #cbooks = number of books for children at home; Literacy acti = literacy activities at home; CCR = Chinese character reading; WRF = word reading fluency; Significant relations were shown in the solid lines, nonsignificant relations were shown in the dotted lines.
†p = 0.05; *p < 0.05; **p < 0.01; ***p < 0.001

4.3.2. Evaluation of the structural models at two time points

Three structural models (see Figure 3) were compared and evaluated at each time point: (a) no mediation model (i.e., each component contributed directly to word reading), (b) partial mediation model (i.e., the ecological component contributed directly to word reading and indirectly via the mediations of the psychological and cognitive components), and (c) complete mediation model (i.e., the contribution of the ecological component to word reading was fully mediated by the psychological and cognitive components).

The results of the chi-square test of difference are shown in Table 5. At both time points, there was no significant difference between the three models under comparison (ps > .54). Thus, the model with the effect of the ecological component fully mediated (i.e., model c) was retained at both time points for parsimony. The final structural models (see Figure 4) at both time points showed good fit: for the Time 1 model, χ^2 = 70.51, df = 44, p = 0.007, CFI = .96, SRMR = .05,

RMSEA = .06; for the Time 2 model, χ^2 = 81.28, *df* = 44, *p* = 0.001, CFI = .91, SRMR = .06, RMSEA = .07.

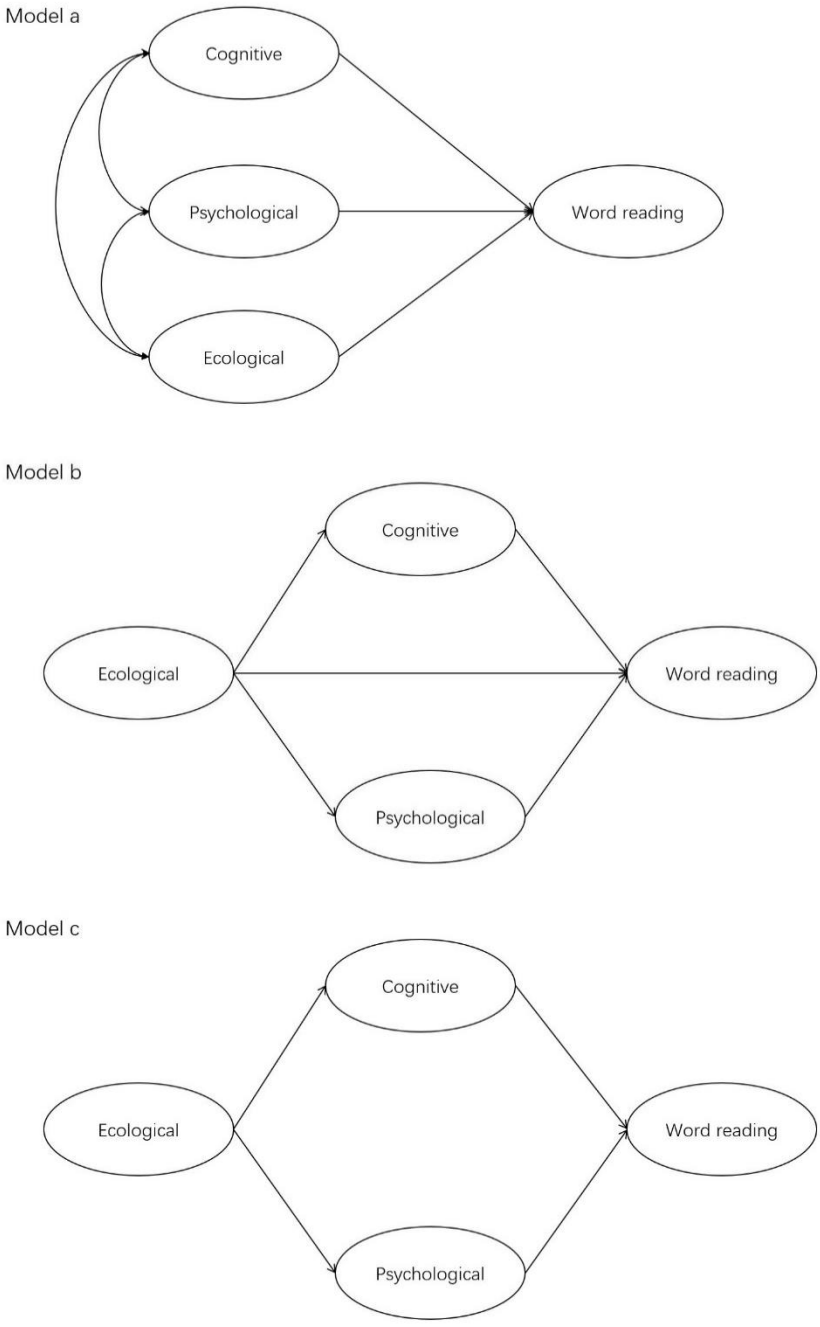

Figure 3. The structural models under comparison. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component.

Table 5. *Results of the chi-square test of difference between models*.

Models	*df*	AIC	BIC	χ^2	$\Delta\chi^2$	Δdf	*p*
No mediation_T1	42	6079.8	6284.9	70.07	\	\	\
Partial mediation_T1	43	6078.2	6280.0	70.51	.38	1	.54
Full mediation_T1	44	6076.2	6274.7	70.51	.008	1	.93
No mediation_T2	42	5739.4	5939.0	81.10	\	\	\
Partial mediation_T2	43	5737.4	5933.9	81.19	.13	1	.72
Full mediation_T2	44	5735.5	5928.8	81.28	.10	1	.75

Note. T1 = Time 1; T2 = Time 2; AIC = Akaike information criterion; BIC = Bayesian information criterion.

For the Time 1 model, the effect of the cognitive component on word reading was significant (β = .59, *SE* = .08, $p < 0.001$, 95% C.I. [.44, .74]) whereas the effect of the psychological component was not (β = .10, *SE* = .08, $p = 0.21$, 95% C.I. [-.06, .25]). The effect of the ecological component on the cognitive (β = .22, *SE* = .10, $p < 0.05$, 95% C.I. [.03,.41]) and the psychological (β = .40, *SE* = .08, $p < 0.001$, 95% C.I. [.25, .56]) components were both significant. In addition, the indirect effect of the ecological effect on word reading via the cognitive component was significant (95% C.I. [.02, .40]), whereas its indirect effect via the psychological component was nonsignificant (95% C.I. [-.03, .18]). In this model, the ecological component explained 1.97% of the variance of word reading, the psychological component explained 1.4% of the variance of word reading, while the cognitive component explained 35.6% of the variance of word reading. In other words, a total of 38.97% the variance of word reading was explained by the three components.

For the Time 2 model, both the cognitive component (β = .65, *SE* = .10, $p < 0.001$, 95% C.I. [.46, .85]) and the psychological component (β = .23, *SE* = .10, $p < 0.05$, 95% C.I. [.04, .41]) had significant contributions to word reading. The effects of the ecological component on the

cognitive components (β = .51, *SE* = .13, $p < 0.001$, 95% C.I. [.25, .77]) and the psychological (β = .39, *SE* = .10, $p < 0.001$, 95% C.I. [.19, .59]) were significant. In addition, the indirect effects of the ecological effect on word reading via the cognitive component (95% C.I. [.12, .66]) and via the psychological component (95% C.I. [.0001, .24]) were both significant. In this model, the ecological component explained 3.3% of the variance of word reading, the psychological component explained 9.1% of the variance of word reading, while the cognitive component explained 36.7% of the variance of word reading. In other words, a total of 49.1% the variance of word reading was explained by the three components.

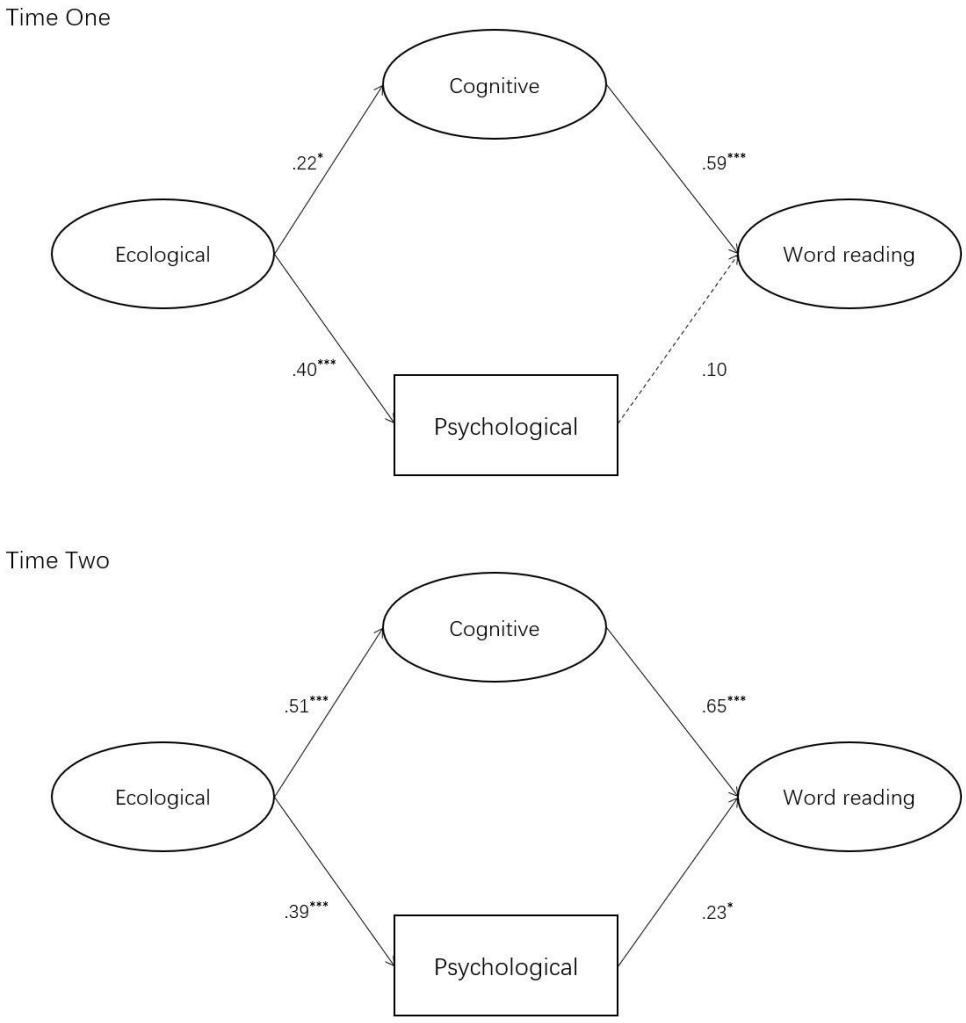

Figure 4. The final models at the two time points. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component. Significant relations are shown in the solid lines, nonsignificant relations are shown in the dotted lines.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

4.3.3. Evaluation of the structural models across two time points

Multi-group analysis. Because the two concurrent models were composed of the same paths, a series of multi-group analyses was conducted to examine whether there were significant differences for the constituted paths between the two waves. First, the fully unconstrained model across the two waves served as the baseline model. This model showed a good fit, $\chi^2 = 150.60$, $df = 88$, $p < 0.001$, CFI = .94, SRMR = .05, RMSEA = .06. Then, models with one path constrained

were compared with the baseline model. As shown in Table 6, there was only one model that differed significantly from the baseline model, which constrained the path from the ecological component to the cognitive component across the two waves, indicating that the path should be set to vary.

Table 6. Model comparison results for multiple-group analysis across two time points

Paths set to be constrained across waves	$\Delta\chi^2$ (Δdf)	p value
Ecological → psychological	0.009(1)	0.92
Ecological → cognitive	6.63(1)	0.01
Psychological → word reading	0.28(1)	0.59
Cognitive → word reading	0.74(1)	0.39

Next, the model with the path from the ecological to the cognitive components set free while the other paths were constrained was compared with the fully unconstrained model. The result showed that the difference for the two models was nonsignificant, $\Delta\chi^2 = 1.14$, $\Delta df = 3$, $p = .77$. Thus, this model was retained as the final model across the two waves. The model (Figure 5) showed a good fit, $\chi^2 = 151.93$, $df = 91$, $p < 0.001$, CFI = .95, SRMR = .05, RMSEA = .06. For the constrained paths across the two time points, the cognitive component significantly contributed to word reading ($B = .74$, $SE = .14$, $p < 0.001$), the psychological component significantly contributed to word reading ($B = .11$, $SE = .04$, $p < 0.01$), and the ecological component significantly contributed to the psychological component ($B = .77$, $SE = .18$, $p < 0.001$). For the unconstrained path across the two time points, the ecological component significantly contributed to the cognitive component at Time 1 ($B = .23$, $SE = .11$, $p < 0.05$). It also significantly contributed to the cognitive component at Time 2 ($B = .55$, $SE = .17$, $p < 0.01$), but at a different significance level.

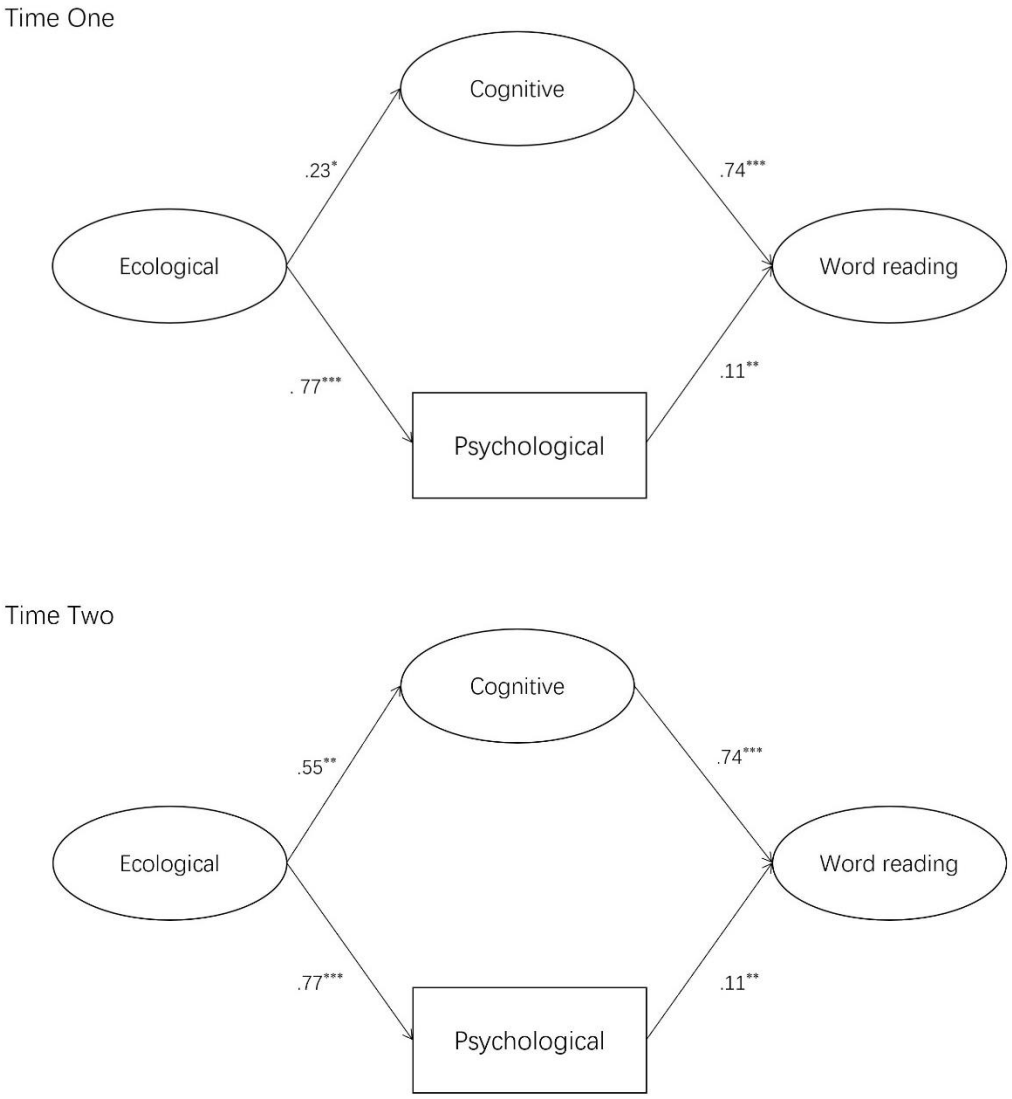

Figure 5. The final models across the two time points in multi-group analysis. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component.
*p < 0.05; **p < 0.01; ***p < 0.001

4.3.4. Components at Time 1 on the growth of character reading

This model shared a similar structure with the final models across the two time points, with the Time 1 components of reading as the predictors and Time 2 word reading as the outcome variable. In addition, Time 1 word reading was included as the auto-regressor, with the Time 1

ecological, psychological and cognitive components regressed on it. The model (Figure 6) showed a good fit, $\chi^2 = 100.40$, $df = 61$, $p = 0.001$, CFI = .96, SRMR = .05, RMSEA = .06. With the Time 1 word reading included as the auto-regressor (β = .93, *SE* = .14, $p < 0.001$, 95% C.I. [.66, 1.20]), the paths from the psychological and cognitive components at Time 1 to word reading at Time 2 were nonsignificant, (βs = -.17 - -.002, *SE*s = .09 - .18, *p*s > 0.34), the paths from the ecological component to the psychological component (β = .40, *SE* = .08, $p < 0.001$, 95% C.I. [.25, .56]) and to the cognitive component (β = .22, *SE* = .10, $p < 0.05$, 95% C.I. [.03, .41]) were both significant. The path from the cognitive component (β = .58, *SE* = .09, $p < 0.001$, 95% C.I. [.42, .75]) to Time 1 word reading was significant, whereas the paths from the psychological component (β = .10, *SE* = .08, $p = 0.26$, 95% C.I. [-.07, .26]) and the ecological component (β = -.005, *SE* = .10, $p = 0.96$, 95% C.I. [-.19, .19]) to Time 1 word reading were nonsignificant.

In addition, the indirect effect of the Time 1 ecological component on Time 2 word reading via the Time 1 cognitive component and Time 1 word reading was significant (95% C.I. [.01, .28]), as well as the indirect effect of the Time 1 cognitive component on Time 2 word reading via Time 1 word reading (95% C.I. [.25, .93]).

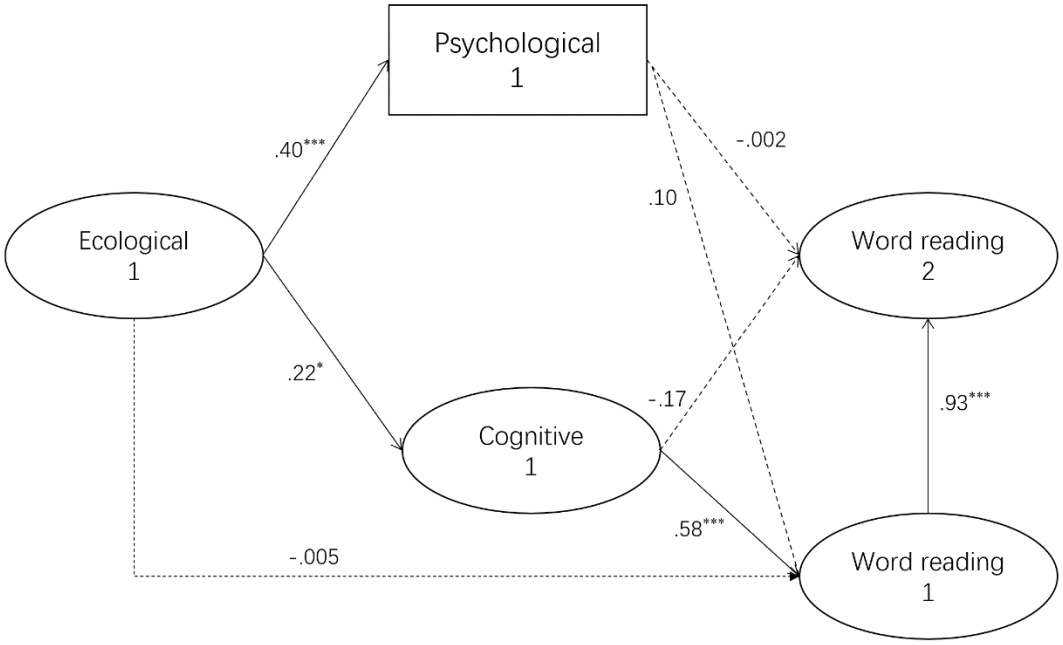

Figure 6. Components at Time 1 on the growth of character reading. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component. The numerals 1 and 2 after variables represent time points one and two, respectively. Significant relations are shown in the solid lines, nonsignificant relations are shown in the dotted lines.
*p < 0.05; ***p < 0.001

4.3.5. Longitudinal effect of the ecological component on word reading

This model shared a similar structure with the previous one, except that the cognitive and psychological components were from Time 2, and both were predicted by Time 1 word reading (i.e., auto-regressor). The model (Figure 7) showed a good fit, χ^2 = 99.75, df = 61, p = 0.001, CFI = .96, SRMR = .05, RMSEA = .06. Both Time 1 word reading (β = .62, SE = .10, p < 0.001, 95% C.I. [.43, .80]) and the Time 2 cognitive component (β = .38, SE = .11, p < 0.01, 95% C.I. [.17, .59]) significantly contributed to Time 2 word reading, whereas the contribution of the Time 2 psychological component was nonsignificant (β = .13, SE = .08, p = 0.09, 95% C.I. [-.03, .28]). Moreover, the Time 2 psychological component was significantly contributed to by

the Time 1 ecological component (β = .34, *SE* = .08, $p < 0.001$, 95% C.I. [.18, .50]) and Time 1 word reading (β = .20, *SE* = .09, $p < 0.05$, 95% C.I. [.03, .37]). The Time 2 cognitive component was significantly contributed to by Time 1 word reading (β = .45, *SE* = .11, $p < 0.001$, 95% C.I. [.24, .67]) but not the Time 1 ecological component (β = .08, *SE* = .13, $p = 0.59$, 95% C.I. [-.18, .33]). In addition, the longitudinal indirect effects of the ecological component were all nonsignificant, while the indirect effect of Time 1 word reading on Time 2 word reading via the Time 2 cognitive component was significant (95% C.I. [.03, .23]).

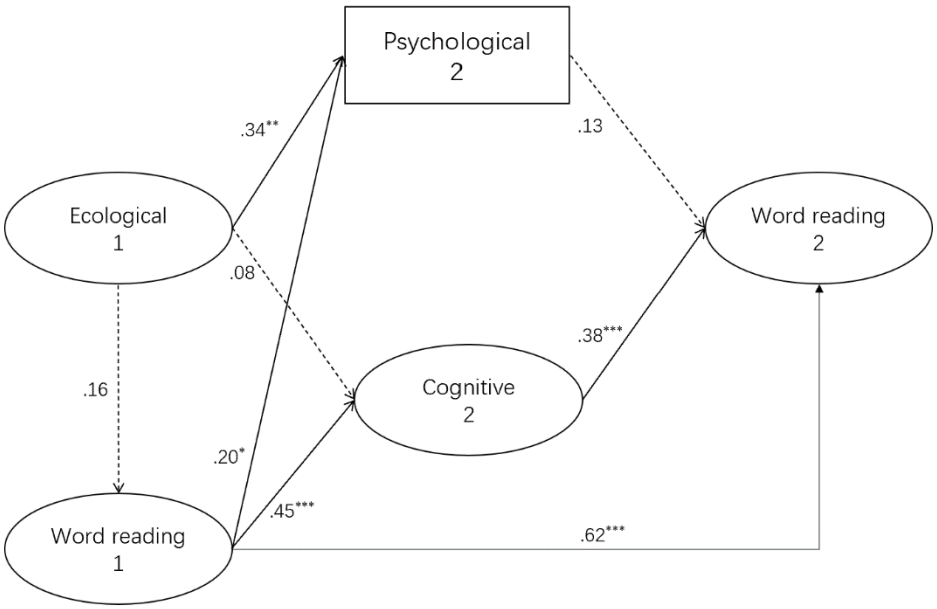

Figure 7. Longitudinal effect of the ecological component on word reading. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component. The numerals 1 and 2 after variables represent time points one and two, respectively. Significant relations are shown in the solid lines, nonsignificant relations are shown in the dotted lines.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

4.3.6. Bidirectional relationships between the components and word reading

A cross-lagged model with all three components and word reading at the two time points was constructed. Concurrent variables were set to correlate with each other. The model showed an

acceptable fit, $\chi^2 = 312.34$, $df = 169$, $p < 0.001$, CFI = .90, SRMR = .06, RMSEA = .07. In this model (Figure 8), all the auto-regressive paths were significant (βs = .50 - .90, *p*s < 0.01). Moreover, the Time 1 ecological component marginally predicted the Time 2 psychological component (β = .15, *SE* = .08, $p < 0.08$, 95% C.I. [-.03, .31]), and Time 1 word reading significantly predicted the Time 2 psychological component (β = .30, *SE* = .11, $p < 0.01$, 95% C.I. [.10, .51]).

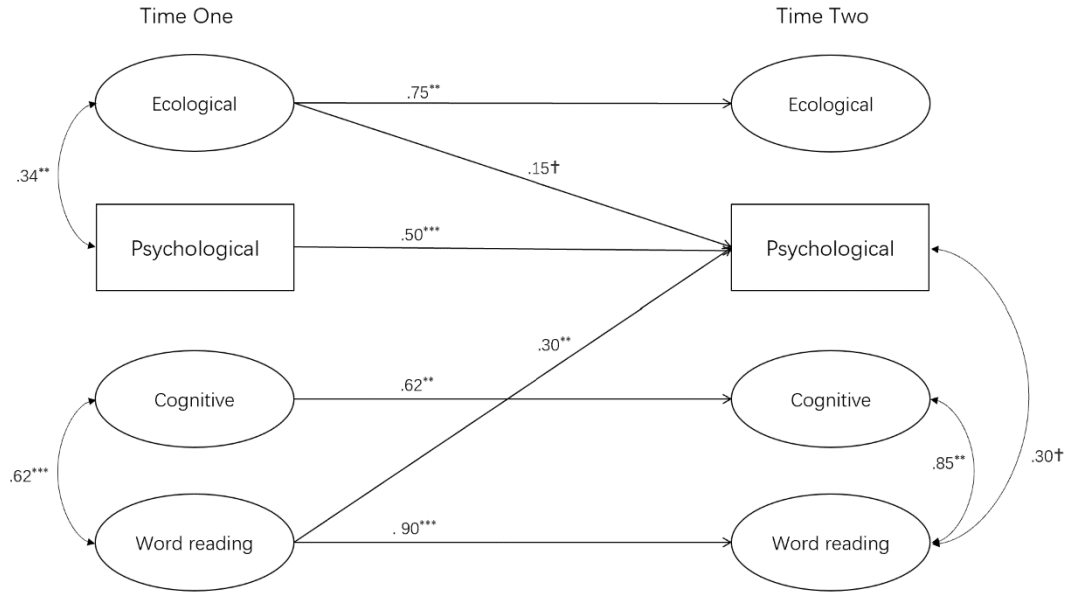

Figure 8. The cross-lagged model for the two time points. Ecological = ecological component; Cognitive = cognitive component; Psychological = psychological component. Nonsignificant paths were removed for simplicity.
†$p < 0.08$; **$p < 0.01$; ***$p < 0.001$

Chapter 5: Discussion

This longitudinal study examined the relationships between the factors from the cognitive, psychological, ecological domains, and word reading in Chinese primary school children from grades one to three. This study is among the first to incorporate the factors from multiple domains and examine the relationships between the components and word reading in Chinese children using the theoretical framework of the Componential Model of Reading (CMR). The main findings of this study are: 1) at both time points, the factors for each component (i.e., cognitive, psychological, ecological) significantly loaded onto the respective component, and each component was significantly correlated with word reading (except the ecological component and word reading at Time 2; 2) at both time points, the cognitive and the psychological components directly contributed to word reading, while the ecological component only contributed indirectly to word reading via the mediations of the other two components; 3) when comparing the models at the two time points, only the path from the ecological component to the cognitive component showed a significant difference. Specifically, the strength of the path was significantly higher at the second time; 4) the cognitive component at Time 1 contributed to word reading at Time 2 via the mediation of word reading at Time 1; 5) the longitudinal indirect effects of the ecological component were nonsignificant; 6) the Time 1 ecological component and word reading were found to predict the Time 2 psychological component in the cross-lagged model. These findings are discussed in detail in the following sections.

5.1. The validation of CMR in Chinese lower-grade students

CMR provided a theoretical framework for this study to examine the relationships between factors from multiple domains and reading ability comprehensively. Unlike other reading models

(e.g., the Simple View of Reading; Gough & Tunmer, 1986), CMR has incorporated factors from more domains (ecological, psychological), which increases the probability of locating the cause of reading difficulties in children (Aaron et al., 2008), and allowed the examinations of the interactions between factors from multiple domains and reading ability that were conducted in this study. In previous studies, CMR was mainly adopted for research on children learning to read alphabetic languages (e.g., Aaron et al., 2008; Kieffer & Vukovic, 2012; Ortiz et al., 2012). Only one previous study (Joshi et al., 2012) included children from China, in which character decoding and listening comprehension combined were found to account for 25% and 42% of the variance in reading comprehension for grade two and grade four Chinese primary students, respectively. However, only the cognitive component (i.e., decoding and listening comprehension) was included in that study (Joshi et al., 2012), so the complete CMR framework had not been examined in the Chinese context prior to the current study.

Because the Chinese writing system is a lot different (e.g., visually complex characters, opaque orthography) from alphabetic languages such as English and Spanish (McBride, 2016a), the examination of CMR in Chinese society provides a stringent test for the universality of the theory. Moreover, insights about reading development in different languages can be gained by comparing the results found in the Chinese society with the results found in other societies. For example, by comparing the results for children who are learning to read different languages (English, Spanish, Chinese), Joshi et al. (2012) suggested that the level of transparency of the language may influence the contribution of decoding and listening comprehension on reading comprehension. Similar implications about reading development may also be drawn from the cross-language/society results in the ecological and psychological domains. Thus, one of the

aims for this study was to validate the complete CMR framework in Chinese society. This validation is discussed in the following section.

5.1.1. The adaptation of CMR in Chinese children: word reading as the outcome

The original CMR model (Aaron et al., 2008) specified two factors for the cognitive domain: word recognition and comprehension, which were derived from the Simple View of Reading (SVR) (Gough & Tunmer, 1986). In the two original models (CMR and SVR), reading comprehension was the reading outcome. Because both models were initially developed for children learning to read English (Aaron et al., 2008; Gough & Tunmer, 1986), the reading outcome and corresponding cognitive factors may not have been applicable to the participants in this study, that is, early readers in Chinese.

In this study, word reading was selected as the reading outcome based on the reading ability of the participants (i.e., lower grade students). The significant factor loadings of word reading accuracy and word reading fluency on the latent variable of word reading in the measurement models of this study showed that word reading was measured aptly by these two indicators. When comparing the two time points, the latent variable of word reading was similarly and accurately measured by word reading accuracy and word reading fluency at Time 1 (βs = .91 to .96), whereas at Time 2, the word-reading fluency (β = .88) appeared to be the more sensitive measure of word reading compared to word-reading accuracy (β = .59). This is aligned with the findings of a longitudinal study by Yeung et al. (2016), where the Chinese children were also measured in grades one and three. Their results showed that in grade one, both word reading and reading fluency contributed to reading comprehension, whereas in grade three, only reading fluency contributed to it. These researchers suggested that, as the children in grade three had generally acquired a high level of reading accuracy, their reading fluency became more

important in reading comprehension (Yeung et al., 2016). Thus, it may be that as the grade increases, word reading fluency becomes the more sensitive indicator of word reading in Chinese children.

In addition, in this study, all components were significantly covaried with word reading in the measurement models, with the highest covariance found with the cognitive component (βs = .75 to .79), and lower covariance with the psychological and ecological components (βs = .24 to .42). This distribution of correlations is similar to the results found in bilingual children learning to read English, which used reading comprehension as the outcome (Li et al., 2020). This result suggested that the three components have similar influences on word reading and reading comprehension.

5.1.2. The adaptation of CMR in Chinese children: cognitive factors

In the original CMR model (Aaron et al., 2008), word decoding and listening comprehension were included as the cognitive factors. However, because the reading outcome was changed to word reading in this study, the cognitive factors were also revised accordingly. In this study, morphological awareness (MA), phonological awareness (PA), vocabulary, and working memory were included in the cognitive component.

The results of confirmation factor analysis at the two time points showed that the three language-related skills and knowledge (MA, PA, vocabulary) were representative of the cognitive component (βs = .57 to .74). Specifically, MA had the highest factor loadings (βs = .71 to .74) at both time points, indicating that this was the central cognitive factor in this group of Chinese lower grade students. This result is consistent with previous studies (e.g., Dulay et al., 2021; McBride-Chang et al., 2003; Tong et al., 2017). As an opaque writing system with inconsistent

phonological rules, the ability to recognize, differentiate and manipulate morphemes helps children to learn new words (e.g., Dulay et al., 2021; Liu et al., 2013).

In comparison, the factor loading of working memory on the cognitive component was lower (βs = .44 to .48) in this study. This result suggests that working memory may be a distal factor (compared to language-related skills and knowledge) in the cognitive domain, and its effect on word reading was mediated by the more proximal factors (e.g., PA). In supporting this view, Das et al. (2008) found that the proximal factors (PA, rapid naming), but not the distal cognitive skills (planning, attention, successive and simultaneous processing), uniquely predicted word reading in grade three and four students from Canada. However, one distal cognitive skill (i.e., planning) in their study was found to have an indirect effect on word reading through the mediation of PA and rapid naming (Das et al., 2008). Similarly, Yang et al. (2019) did not find a unique contribution of basic cognitive variables on character reading in Chinese first graders, although they did find an indirect effect on character reading via language processing skills (PA, MA, orthographic awareness, rapid naming).

5.1.3. The adaptation of CMR in Chinese children: ecological factors

Four important factors at the family level were chosen to be included in the ecological component in this study, that is, the number of books for children at home, the number of books for adults at home, the literacy activities at home, and family SES.

The numbers of the books and literacy activities at home belong to the larger construct of home literacy environment, and family SES was viewed as the distal ecological factor that have impacts on a variety of children's outcomes (e.g., physical, social, academic), all of which were found to be related to children's reading development in previous studies (e.g., Bradley & Corwyn, 2002; Burgess et al., 2002; Liu et al., 2018; Puglisi et al., 2017). The result of the

confirmatory factor analysis in this study showed that all four factors significantly regressed on the latent variable of the ecological component. Moreover, the factor loadings of the four factors at the two time points provided three clues about the compositions of the ecological component at the family level.

First, at both time points of this study, the factor loading of the number of books for adults at home was the largest of the four factors. Its prominence in children's reading development was also discovered in previous studies. For example, the number of books at home was found to be a universal predictor of the schooling years eventually spent by the children, as those growing up in homes with many books were found to have three more schooling years than those from homes with few books (Evans et al., 2010). The Evans et al. study found this home library effect in 27 countries, with the strongest being in China (Evans et al., 2010). Similarly, van Bergen et al. (2017) found in the Netherlands that, after controlling the parents' own reading abilities, the number of books at home was the only predictor of children's reading ability, with literacy activities at home not emerging as a predictor. Nevertheless, the number of books at home was not only related to the frequency of literacy activities at home, but also represented how much the families valued the reading activities, both of which could have contributed to the children's reading development (van Bergen et al., 2017). Thus, the results from this study confirm the suggestion of earlier research that having books at home is conducive to children's reading development.

Second, literacy activities at home had a smaller factor loading on the ecological component in this study, suggesting that these activities were not central to the ecological component. This result also corresponds with previous studies. For example, the correlations between literacy activities and the children's reading ability were found to be mostly nonsignificant in two

previous studies that examined Chinese children (Deng et al., 2015; Liu et al., 2018). This small factor loading of literacy activities may be explained by two reasons. First, when children enter primary school, the relationship between parents' literacy activities and the children's reading abilities may become more complex. On the one hand, literacy activities at home can facilitate children's reading ability. On the other hand, the parents whose children are lagging in reading attainment at school may provide extra literacy activities at home, so that the relationship becomes negative. This negative relationship was indeed found in the study by Deng et al. (2015), in which reading ability in grade one negatively predicted informal literacy activities (e.g., shared reading) at home one year later. The mix of the facilitative effect of literacy activities and the responsive literacy activities when children are performing poorly at school may reduce the overall strength of the relationship between literacy activities and reading ability in primary school children. Second, the questions about the frequency of literacy activities at home may have induced a sense of social desirability, so that the answers to these questions reflected the parents' intentions (to conduct frequent activities) rather than their actual behaviors, which in turn could have reduced its predictive ability on the children's reading outcomes. In comparison, the question about the number of books at home may be less corroded by the social desirability effect since the answer to this question is more tangible.

Third, in this study, the number of books for children had the second largest loading ($\beta = .62$) on the ecological component at Time 1, but its loading ($\beta = .37$) on the component was greatly reduced at Time 2. The decrease in the factor loading suggests that the importance of children' books to their reading development is decreased as they move further into formal schooling. In a previous study, the number books the children had at home when they were in kindergarten was found to predict their emergent literacy skills (e.g., vocabulary, PA), which in turn contributed to

their word reading in grade one, presumably because having more books invites more literacy interactions between parents and children, and the interactions improve children's literacy skills (Zhang et al., 2019). However, as children enter primary school, most of the literacy instruction is transferred from home to school, and from informal to formal, so that the factors (e.g., teachers, textbooks, homework) in the school environment may become more important to their reading development, and the number of children's books as the proxy of informal literacy instruction at home thus becomes less important.

To summarize, the results of this study suggest that as a proxy of the family's valuing of reading activities, the number of books for adults at home are central to the latent variable of the ecological component in Chinese lower grade students, while the literacy activities at home are less important to the ecological component, which may be due to the combinations of the social desirability effect, the increased impact of formal schooling, as well as the different patterns of the relationship between literacy activities and the children's reading ability (facilitative, responsive). More studies are needed to determine the importance of the ecological factors to reading development in lower grade students from China.

5.1.4. The adaptation of CMR in Chinese children: psychological factors

In this study, general psychological problems and reading interest were selected as the two factors for the psychological component. This choice was informed by literature suggesting that general psychological problems (e.g., anxiety, defiance) may affect lower graders' adaptation to the school environment, such as the interactions with teachers and classmates, which in turn could affect their academic achievement (e.g., Kwok et al., 2007; Spira et al., 2005; Zhang et al., 2018). Interest in reading was found to predict parents' literacy activities in early readers

(Boerma et al., 2018; Pezoa et al., 2019), which in turn may also facilitate their reading development.

The result of this study showed that the measure of the general psychological problems was not significantly correlated with most of the other measures (including the reading outcomes). There are two possible reasons for this result. First, most of the items in the psychological problems scale referred to the children's psychological problems in general situations (e.g., he/she does not like to follow the rules, he/she is rude to adults), rather than in the learning context, which may limit its influence on academic achievement (Zhang et al., 2018). A similar result was found in the study by Zhang et al. (2018), in which the children's problem behaviors (e.g., bullying) did not predict the initial level or the growth rate of reading ability in Chinese early readers. Second, the psychological problems measure (i.e., Conners' Parent Rating Scale-Revised) was originally used to identify children with psychological problems (Gianarris et al., 2001), so it is sensitive in differentiating those with general psychological problems from typically developing children, but may be less adequate when accounting for psychological problems in typically developing children such as the participants in this study.

Because the general psychological problems scores were not significantly correlated with most of the variables at Time 1, and the data collection process at Time 2 was shortened due to the COVID-19 pandemic, the scale was not used at Time 2. As a result, the psychological component in this study consisted only of reading interest. The confirmation factor analysis in this study showed that, at both times, the psychological component was significantly covaried with word reading, which was in accordance with the findings of previous studies (e.g., Baroody & Diamond, 2012; Bracken & Fischel, 2008; Guthrie et al., 1999).

In the CMR model it is envisaged that all three components are important to literacy development, and "a child can fail to acquire satisfactory levels of literacy skills because of deficits in any component in any one of these three domains" (Aaron et al., 2008, p. 69). This was supported by the significant covariances between the three components and word reading in this study. Specifically, all the components were significantly covaried with word reading at both times. In other words, the result of confirmation factor analysis showed that CMR is valid in Chinese lower grade students with the adaption of using word reading as the reading outcome.

5.2. The concurrent effects of components on word reading

The two concurrent models (Figure 4) in this study showed that: 1) of the three components, the cognitive one had the largest contribution to word reading; 2) the contribution of the psychological component to word reading changed from nonsignificant to significant from Time 1 to Time 2; and 3) the cognitive and psychological components has direct contributions to word reading, whereas the contribution of the ecological component was indirect (through the mediations of the other two components).

First, at both times, the cognitive component had the largest contributions (βs = .59 - .65, *p*s < .001) to word reading. It explained 35.6% and 36.7% of the variance for word reading at Time 1 and Time 2, respectively. For reference, the three components in total explained 38.97% and 49.1% of the variance for word reading at Time 1 and Time 2, respectively. This large contribution of the cognitive component was in accordance with previous studies that included factors from all three domains (Li et al., 2020; Ortiz et al., 2012; but see Chiu et al., 2012 for a different result). For studies that only incorporated cognitive factors, the large contribution of the cognitive component was also evident (e.g., Høien-Tengesdal & Høien, 2012; Joshi et al., 2012; Kim, 2017). One extreme example was a study by Kim (2017), which found that the latent

variables of word reading and listening comprehension explained all the variance in reading comprehension in grade two students from the United States.

The large contribution of the cognitive component may be explained by its proximal role in reading development. Compared to the psychological and ecological components, the cognitive component is linked more directly to children's reading behavior (Tunmer & Chapman, 2012). Moreover, other components may exert influence on reading indirectly through the cognitive component, which increases the relationship between the cognitive component and reading. For example, the ecological component was found to contribute to reading outcome through the mediation of the cognitive component (Li et al., 2020). This result was also observed in this study, as will be discussed in the paragraph after the next one.

Second, the contribution of the psychological component to word reading changed from nonsignificant to significant from Time 1 to Time 2. Its explained variance for word reading was increased from 1.4% at Time 1 to 9.1% at Time 2. This may have been caused by the strengthened relationships between the psychological factor and reading-related behaviors as the children received more formal schooling. The characters that the children had learned in the first two grades (about 1800 characters) could have substantiated the relationship between reading interest and reading behaviors, which in turn improved their reading ability. For example, Becker et al. (2010) found that the relationship between intrinsic reading motivation (with items similar to the reading-interest measure in this study) and reading ability was mediated by the reading amount in higher grade students from Germany. Because the children in this study had only begun to read in grade one, the mediator (i.e., reading amount) may not have been strong enough to support the relationship. The children's reading behavior was not examined in this study, but

future studies could investigate its potential mediation role in the relationship between reading interest and reading ability in Chinese lower graders.

Third, this study found that the ecological component only contributed indirectly to word reading through the mediation of the other two components (i.e., cognitive and psychological). The indirect effect of the ecological component was in line with the findings of a study by Li et al. (2020), the indirect effect of the ecological component via the cognitive and psychological components in higher grade students (Chinese-English bilingual) from Canada. The mediations of the cognitive factors on the effect of ecological factors have also been observed in earlier studies of Chinese children. For example, morphological awareness and vocabulary were found to mediate the effect of family SES on reading comprehension in Chinese grade one students (Cheng & Wu, 2017). Similarly, emergent literacy skills (e.g., syllable awareness, rapid naming) were found to mediate the effects of family SES and home literacy environment variables (e.g., literacy instructions at home) on word reading in grade one students from China (Zhang et al., 2019).

On the other hand, the mediation of the psychological component on the effect of the ecological component has been examined less in Chinese children. However, this indirect path has both theoretical and empirical foundations. According to Bronfenbrenner's (1986) Ecological Systems Theory, the family as a proximal environmental factor can have an all-round influence on children's development, including their cognitive and psychological factors. For example, as was found in this study, parents who provide richer literacy environments may foster not only children's cognitive abilities but also their interest in reading. This was also found in Canadian children, specifically, that children who have more storybook exposure in kindergarten are more

likely to read for pleasure when they are in grade four (Sénéchal, 2006). A similar result was found in early readers from Finland (Silinskas et al., 2020).

The variance of word reading explained by the three components in total was 38.97% at Time 1 and 49.1% at Time 2. The two percentages were comparable to a previous study on Chinese primary school children. Joshi et al. (2012) found that character recognition and listening comprehension explained 25% and 42% of the variance in reading comprehension for Chinese grade 2 and grade 4 students respectively. In contrast, the study found that decoding and listening comprehension explained about 60% and 50% of the variance in reading comprehension for Spanish and English participants respectively (Joshi et al., 2012). More factors may be considered in explaining the reading ability of Chinese children.

5.3. The relationship between three components and word reading across times

The longitudinal design of this study allowed a comparison of models and an investigation of longitudinal relationships between the two time points. In the sections below, the model comparison between the two time points, the prediction of the early components of word-reading growth, and the bidirectional relationships between the components and word reading at the two time points are discussed.

5.3.1. The comparison of the models between the two time points

Because the structure of the models at the two time points was the same, an examination was conducted in this study of whether the paths in the two models differed significantly. The results showed that none of the paths at the two time points had significant differences, except the path from the ecological component to the cognitive component. Specifically, although this path was

significant at both times, its strength was significantly larger at Time 2 (β = .23, *SE* = .11, $p <$ 0.05 at Time 1, β = .55, *SE* = .17, $p < 0.01$ at Time 2).

The increased strength of the relationship of the ecological factors and the cognitive skills with development was also found in previous studies. For example, no relationships were found in early readers (3 to 5 years old, from the Philippines) between HLE and literacy skills , except for the relationship between literacy resources and vocabulary (Dulay et al., 2018). However, when the same cohort was 5 to 8 years old, significant relationships between literacy activities and children's emergent literacy skills (PA, vocabulary) were found (Dulay et al., 2019). This increased path from the ecological to the cognitive factors may be attributed to two reasons. First, the cognitive abilities at Time 1 (i.e., grade one) may be underdeveloped, which could reduce the effect of the ecological component. This is evident from the lower means and standard deviations of the scores in the cognitive measures at the first time point than at the second one. Second, as the experiences of home literacy activities accumulate with development, the parents' activities may become more effective in improving the children's literacy skills. In other words, the parents may be better able to conduct effective literacy activities at home, and the children may also be more receptive to the instructions, which could facilitate the relationships between the literacy activities and the children's literacy skills (e.g., vocabulary). Moreover, as the children move further into the formal schooling, the literacy activities and resources at home may become more structured and goal-oriented, which could also strengthen the relationship between HLE and literacy skills. For example, as the grade increases, the role of the literacy activities at home may transform from leading the children's literacy development to supporting formal literacy education (e.g., supervising reading homework), which may be more effective in improving children's literacy skills. Also, Deng et al., 2015 reported that as school providing

constant feedback on children's reading abilities (e.g., the scores for homework, parent-teacher meetings), parents can offer targeted literacy activities for the improvement of children's reading-related abilities. For instance, after children fail on the Pinyin knowledge in an exam, their parents may teach the related knowledge more often at home.

Generally speaking, though, the final models at the two times were shown to be consistent in this study. In both models, the ecological component contributed to the cognitive and psychological components, and the cognitive and psychological components contributed to word reading. These results suggest that the relationships between the three components and word reading are stable in lower grades.

According to the stages of reading development described by Chall (1983), children in the lower grades are at the "learning to read" stage, with the major task of learning to read common words. Similarly, the lower grades are also categorized as one learning stage of the Chinese course curriculum in China, with the main task of learning to read common characters and words (Ministry of Education of the People's Republic of China, 2011). In other words, the lower grades are considered as being one particular stage by both the reading development theory and the course curriculum in China, and this may be the reason for the stable relationships between the components and word reading.

5.3.2. The predictions of early components on the growth of word reading

To examine whether the early components predicted the growth of word reading, two models (Figures 6 and 7) were constructed and analyzed in this study. First, the three components at Time 1 were set to predict the word reading at Time 2, with Time 1 word reading included as the auto-regressor. When the auto-regressor was included, the early components did not contribute to the word reading at Time 2. However, the longitudinal indirect path from the Time 1 ecological

component to Time 2 word reading via the Time 1 cognitive component and Time 1 word reading was found to be significant.

Second, to examine the longitudinal indirect effect of the ecological component on the growth of word reading, the Time 1 ecological component was set to predict the Time 2 cognitive and psychological components, which in turn contributed to word reading at Time 2, with Time 1 word reading included as the auto-regressor. The longitudinal indirect effect of the ecological component on word reading was found to be nonsignificant, however, the longitudinal indirect effect of Time 1 word reading on Time 2 word reading via the Time 2 cognitive component was significant.

The results for the two models indicated that the effects of the components may be time limited. Similar findings were found in previous studies. For example, a longitudinal study by Wagner et al. (1997) tracked English-speaking children from kindergarten to grade four and found that their word-reading ability continued to be more stable with progressive grade levels. Specifically, the effects of early phonological and vocabulary variables on later word reading diminished into non-significance while the effect of early word reading (i.e., auto-regressor) became the major predictor (Wagner et al., 1997). The stable word reading ability has also been evident in the high auto-correlations (i.e., the correlations between the same variable across times) of Chinese children's word reading-ability in Chinese children. For instance, a longitudinal study by Pan et al. (2011) showed that the auto-correlations of word-reading ability were from .76 to .88. in the lower grade period (from grade one to three). In this study, the auto-correlations for word reading between the two time points were .53 to .71. These relatively lower correlations may have been caused by the extended holiday and the online schooling before the data collection at

Time 2 due to the COVID-19 pandemic, which may have enlarged the variances of the reading scores.

Wagner et al. (1997) suggested that the time-limit effects (i.e., early factors did not exert influence on later reading when the auto-regressor was included) can be viewed the effects of the factors (e.g., vocabulary) being encapsulated in the individual level of concurrent word reading ability. This view was in accordance with the two significant longitudinal indirect effects found in this study. The first longitudinal indirect path (from Time 1 ecological component to Time 2 word reading via Time 1 cognitive component and Time 1 word reading) indicated that the effects of early components (ecological and cognitive components at Time 1) were first channeled through the concurrent word reading, which in turn contributed to later word reading. The second indirect path (from Time 1 word reading to Time 2 word reading via the Time 2 cognitive component) indicated that the early word reading contributed to the later cognitive component, which in turn contributed to concurrent word reading.

To summarize, the longitudinal models in this study showed that early ecological and cognitive components contributed to concurrent word reading, which in turn contributed to later word reading both directly and indirectly via the cognitive component.

5.3.3. Bidirectional relationships between the components and word reading

To examine the bidirectional relationships between the components and word reading, a cross-lagged model was constructed for the two time points in this study. The results (Figure 8) showed that, in addition to the auto-regressive paths, which were all significant, two cross-lagged paths were found to be significant. The first one was from the Time 1 ecological component to the Time 2 psychological component, and the second one was from the Time 1 word reading to the Time 2 psychological component.

The prediction of the early ecological component on the later psychological factor (i.e., reading interest) was consistent with previous studies. For example, Senechal (2006) found that the literacy activities (e.g., shared reading of the storybooks) in kindergarten predicted the frequency of reading for pleasure in French-speaking children from Canada when they were in grade four. A similar result was also found in English-speaking children from the United States (Weigel et al., 2006). This result suggested that the literacy activities and resources provided by the parents fostered the children's interest in reading.

Previous studies have also found that early reading interest predicted later literacy activities (e.g., Pezoa et al., 2019), however, this path was not found in this study. The nonsignificant path from reading interest to the ecological component in this study may be explained by two causes. First, as children begin formal schooling, the literacy activities provided by Chinese parents may be less related to the children's reading interests, but more related to their reading performances at school. As mentioned above, Deng et al. (2015) found that the word reading ability in grade one negatively predicted the literacy activities offered by the parents in grade two. These researchers suggested that Chinese parents conducted more literacy activities at home when they perceived their children to be lagging in reading at school (Deng et al., 2015). In comparison, a study of kindergarten children from Chile found a path from early reading interest to later literacy activities (Pezoa et al., 2019), so the parents did not need at this stage to respond to their children's reading performances but only their reading interests, which may have been conducive to the emergence of the path.

Second, at the second time point, the children in this study were in grade three. According to the Chinese course curriculum in China, children in grade three should be able to read about two-thousand characters (Ministry of Education of the People's Republic of China, 2011), which

allows them to read most children's books n independently (for unfamiliar words, they can use a dictionary, which is also introduced in lower grades). Thus, there may be less need for literacy activities to be provided by parents (e.g., shared reading) (Boerma et al., 2018; Hill & Taylor, 2004).

In addition, a cross-lagged path from early word reading to later reading interest was found in this study. Similar results have been found in previous studies. For example, using the cross-lagged panel modeling design, McElvany et al. (2008) found that reading comprehension in grade three predicted intrinsic motivation in grade four in children from Germany. Therefore, it seems that the more proficient children are in reading, the more they are interested in the activity. In contrast, the cross-lagged path from early reading interest to later word reading was not significant in this study. As the early time point was grade one in this study, the children's interest in reading at grade one may not have transferred into word reading later due to their limited reading ability at that time. McElvany et al. (2008)found with German children that the effect of intrinsic reading motivation in grade three on reading comprehension in grade six was mediated by the amount of reading they had done. Future studies may add the measure of reading amount and examine the relationship in higher grade students in China.

In contrast to the hypothesized bidirectional relationships between word reading and the three components, no significant bidirectional relationship was found in this study. The three components at Time 1 did not contribute to word reading at Time 2. As discussed in the above section, this result may be due to the time-limit effect of the components. Specifically, the effects of the early components were encapsulated in the concurrent word reading ability, which in turn contributed to later word reading ability (Wagner et al., 1997).

In a previous study, word reading in grade one was found to negatively predict Chinese children's literacy activities in grade two (Deng et al., 2015). In this study, however, early word reading did not contribute to later ecological or cognitive components. It should be noted that the previous study only found the negative path from early word reading to later informal literacy activities (e.g., shared reading) but not to later formal literacy activities (e.g., teaching children to read characters) (Deng et al., 2015). Thus, it is possible that, by combining both formal and informal literacy activities and literacy resources at home, the path from early word reading to later HLE became nonsignificant in this study. Moreover, the strong auto-regressive effects of ecological and cognitive components (βs = .62 - .75, $p < 0.01$) may also have limited the cross-lagged effects from word reading to the two components.

5.4. Theoretical and Educational Implications

By incorporating factors from multiple domains and examining both the concurrent and longitudinal relationships between the components and word reading under the framework of CMR in a group of Chinese lower grade students, this study has provided several theoretical and educational implications, as discussed in the following sections.

5.4.1. Theoretical implications of this study

There are several theoretical implications of the present study. First, the study extended the CMR model on multiple fronts. To our knowledge, this study is the first one to examine all three components of CMR in Chinese children. One previous study (Joshi et al., 2012) applied CMR with Chinese children, but only examined the cognitive component and its effect on their reading. The full application of CMR with Chinese children in this study has extended the validity of the model. Moreover, whereas previous studies utilizing the model have only

examined the effects of the components on reading ability (e.g., Joshi et al., 2012; Kieffer & Vukovic, 2012; Li et al., 2020), this study investigated the bidirectional relationships between the components and word reading, using a longitudinal design. For example, in this study, word reading and the ecological component in grade one were found to contribute to the psychological component in grade three. This investigation introduced a new dimension to the model, and ultimately brought a more dynamic understanding of literacy development in relation to learning to read Chinese. In addition, word reading, rather than reading comprehension, was selected as the reading outcome in this study after considering the ages of the participants and the language characteristics. The results of this study showed that word reading and the corresponding cognitive factors (e.g., vocabulary, PA, MA) can be incorporated into the CMR model, and thus that the use of the model can be extended to early readers who are not yet capable of reading at the passage level.

As a broadly defined theoretical framework, CMR may be refined in structure and composition. Structurally, in addition to the relationship between components and reading abilities, future studies may attend to the inner structures of each component. For example, within the cognitive domain, domain-general abilities (e.g., working memory) may exert influence on domain-specific abilities (e.g., MA). Similar relationships exist in the ecological component (e.g., family SES influence home literacy environment), the psychological component (e.g., general psychological state influence reading attitude), and reading abilities (e.g., word reading contributes to reading comprehension). In other words, future studies could build models that include structures both within and between components and reading outcomes. In this study, however, the inner structure was not considered due to the small sample size relative to the number of the factors included.

The composition of each component in CMR may be considered in two aspects in future studies. First, the factors included in each component may be different across languages and countries. For example, phonological awareness maybe more important in alphabetic languages due to the richness and the regularity of the phonological cues (e.g., recurring spelling cues), while morphological awareness is more important in learning to read Chinese (McBride, 2016a). For the ecological factors, the neighborhood security may be important for countries that have prevalent criminal problems (Little et al., 2019), while family SES may be less important for egalitarian societies and countries with heavily state-funded and/or state-regulated school systems.

Second, the method of composing a group of factors into the respective component may also be explored in future studies. In this study, I used the more recognized (by the researchers in the psychology field) reflective model to group the factors. In the reflective model, the casual path flows from the latent variable (i.e., components) to the indicators (i.e., factors), so that the manipulation of the latent variable would cause a change in the indicators but not vice versa. In addition, the reflective measurement approach focuses on maximizing the overlap between indicators that are interchangeable.

In contrast, the formative structure posits a composite variable (i.e., components) that encapsulates the common variation in a group of indicators (i.e., factors). The causal path in the reflective model flows from the indicators to the composite variable. Unlike the reflective measurement, the formative measurement approach focused on minimizes the overlap between indicators that are complementary. With the development of statistical method and software, future studies may utilize the formative model when composing the factors into components.

Furthermore, the findings of this study suggest a new way of examining the relationships between the influencing factors and reading outcomes. By aggregating the factors within one domain into a large component, a higher-level investigation of the relationships between the large components and reading can be conducted. Specifically, the results of the confirmatory factor analysis suggest a higher-level construct (i.e., component) for the factors in each domain. For example, MA, PA, vocabulary, and working memory can be aggregated into the cognitive component, and family SES and factors of HLE can be aggregated into the ecological component. The relationships between the two components and word reading can then be examined in the structural equation model. This investigation has provided a broad developmental picture of reading development, which allows researchers to compare the importance of the components and the sources of reading difficulties.

Moreover, the examination of the relationships between the components and the reading outcomes (i.e., the macro relationships) has provided a new theoretical perspective. Previous studies focused mainly on uncovering the detailed mechanisms between the factors and word reading within one domain (e.g., the mechanism of the relationship between MA and word reading), which I have tentatively named the examinations of the micro relationships. However, reading development may include not only the mechanisms at the micro level but also those at the macro level. For example, both family SES and HLE have been found to exert wide influences on children's cognitive and language-related abilities (e.g., Bradley & Corwyn, 2002; O'Brien et al., 2020). The two ecological factors were also found to be linked in previous studies, with HLE serving as a conduit for family SES to influence reading development (e.g., Liu et al., 2018), or as two correlated ecological factors that both contribute to the reading outcome (e.g., O'Brien et al., 2020). Thus, in addition to the specific relationships between the

individual factors and reading ability, the factors from the same domain may exert global effects on the factors from another domain and the reading outcomes. Indeed, these macro relationships between the components and the reading outcome were found in this study; future studies may attend to both the micro and the macro relationships between the factors and the reading outcomes.

The strong time-limit effects in this study (i.e., the early components did not predict later word reading when the auto-regressor was included) indicate that the predictive effects of the factors on the growth of word reading were limited in the early grades of Chinese primary school children. Researchers may need to search for predictive factors in earlier developmental phases (e.g., kindergarten). Moreover, by constructing multiple concurrent and longitudinal models, this study has attended to the expressive duration of developmental pathways. For example, both the concurrent and the longitudinal paths from the ecological component to the cognitive component were constructed. One motive for the examination was to see whether the effects of the components were concurrent or longitudinal, and if the effect was longitudinal, whether it could be expressed in a fixed period (i.e., from Time 1 to Time 2). Although this study did not find any significant longitudinal effects of the components due to the highly stable nature of word reading in the early grades, it is recommended to consider the expressive duration of a certain effect. Future studies could examine and compare different time lags (e.g., concurrent, six-month, one-year) of the direct and indirect effects of the components on reading. Moreover, statistical modeling (e.g., latent growth model) focused on the growth curve of the variables could also be utilized.

Finally, the interactions of the three components (cognitive, ecological, psychological) in contributing to the reading outcome show that the influencing factors of reading development are

not only limited to the cognitive domains. Factors from the ecological and psychological domains, and their direct, indirect and bidirectional relationships should all be considered for a more comprehensive understanding of reading development in Chinese children. Although studies have begun to investigate the relationships between the factors from different domains and reading outcomes, most of them have viewed ecological factors as the distal factors that exerted influence on the cognitive factors or the reading results (e.g., Dulay et al., 2018; Puglisi et al., 2017). However, the ecological factors (e.g., literacy activities at home) could also be the result of children's reading abilities, as suggested in the study by Deng et al. (2015), where they found that reading ability in grade one negatively predicted the frequency of home literacy activities in grade two in Chinese children. In addition, the relationship between the psychological factors (e.g., reading interest) and reading ability may be bidirectional as well, as shown by the prediction of early word reading on later reading interest in this study. Similar dynamic and bidirectional relationships could exist between the ecological factors and the psychological factors (e.g., Pezoa et al., 2019; Wang & Liu, 2021). Thus, there is a need to take measurements of the influencing factors and the reading results at multiple time points and to examine their bidirectional relationships with development.

5.4.2. Educational implications of this study

In addition to the theoretical implications, the results of this study also have implications for educators and policy makers. First, when looking for the sources of reading difficulties in Chinese early readers, educators (teachers, parents) may search for factors beyond the cognitive domain, such as the children's home literacy environments and their psychological states. Schools and communities could provide shared literacy resources (e.g., books, tablets with installed literacy games), which may be beneficial to children's literacy development with less

literacy resources at home. Parents should realize that their behaviors and conditions also influence their children's reading development, such as the levels of their own language skills (e.g., Puglisi et al., 2017) and the frequency of literacy activities, so that they could reach for other resources and activities (e.g., tutorial classes) when they are not capable or available to provide literacy activities at home. Teachers should realize that children receive different levels of literacy education before primary school so that special attention should be paid to those who come from disadvantageous backgrounds (e.g., low SES families).

Second, the connection between school and parents could be strengthened so that parents can conduct timely and targeted literacy activities at home (e.g., instruction of the Pinyin knowledge when a child cannot answer the related questions in the mid-term exam), which could improve their cognitive abilities and, in turn, their reading abilities. Relatedly, family intervention aimed at improving parents' instructional and interactional skills when providing literacy activities could be developed, since literacy activities have been shown to be effective and important for Chinese children (Wang & Liu, 2021).

Third, the longitudinal path from early word reading to later reading interest was found in the cross-lagged model in this study. Moreover, the path from reading interest to word reading emerged for the concurrent model at Time 2, but not the concurrent model at Time 1. These results agree with those of a longitudinal study by Torppa et al. (2020), which found that poorer comprehension and reading fluency ability predicted less leisure reading from grade one to three in Finnish children. However, in later grades, more book reading for leisure predicted better reading comprehension. Thus, at the early developmental stage, educators may focus on improving children's reading abilities rather than evoking reading interest in early readers.

However, when children have the ability to read books independently, suitable literacy materials can be provided to substantiate the path from reading interest to reading ability.

Fourth, as reading ability is highly stable when children enter primary school, reading intervention or formal literacy instruction may be commenced early in primary school. In mainland China, formal literacy instruction is not allowed in kindergarten (Li & Rao, 2005), although parents and teachers usually teach some literacy knowledge to kindergarten children (McBride, 2016b). However, since there are no stipulations for the content, quantity and quality of literacy education in kindergarten, children's reading abilities may be quite different when they enter primary school depending on the prior literacy instruction that they have received. This is confirmed by studies that examined the character reading ability in kindergarten children from mainland China, where large standard deviations were found for the reading tasks (e.g., Liu et al., 2020; Pan et al., 2011). Compared to their peers, the children who receive little literacy education before primary school can be disadvantaged in their literacy development during the whole primary school period, which could affect their development in other subjects (e.g., mathematics).

The difference in reading ability, with and without the formal literacy education before primary school, has been evident in the studies that examined children from Hong Kong and mainland China. Whereas children from mainland China do not received formal literacy instruction before primary school, those in Hong Kong do so when they enter kindergarten. As a result, the children from Hong Kong were found to outperform their counterparts from mainland China consistently in the reading tasks from kindergarten to the middle grades of primary school (e.g., Li et al., 2008; Li & Rao, 2000, 2005), despite the children from Hong Kong encountering more challenges during the literacy development (e.g., more opaque mapping from the oral language

onto the written one). Thus, it seems that the early formal literacy instruction could have long-lasting benefits for reading ability. Policy makers from mainland China may need to rethink about this ban on formal literacy instruction in preschool and kindergarten.

5.5. Limitations and Future Directions

This study has three main limitations. First, data were only collected from two time points, which prevented the more detailed examination of the relationships between the components and word reading in the early reading developmental phase. Future studies could collect data at more time points, which is beneficial in searching for the predictive effects of the components and the dynamic relationships between the components and word reading. For example, as the level of word reading is highly stable once children entered formal education, the data collection could extend earlier to the third year in kindergarten in searching for the predictive factors of reading ability. Moreover, a cross-lagged model with more than two time points could be constructed to see the developmental changes in the relationships between the components and word reading. Second, by aggregating the factors from the same domain into a larger component, this study did not investigate the specific mechanisms underlying the relationships between factors and word reading. Future studies could sort factors into subdivided groups and investigate the relationships between the factors from different groups and word reading. For example, the factors could be categorized into domain-general factors (that exerted influence not only in learning to read but also in learning other knowledge such as mathematics) and domain-specific factors (that mainly exert influence in learning to read), which then allow researchers to examine the potential mediation of the domain-specific factors on the relationship between the domain-general factors and word reading.

Relatedly, the factors included in the three components were not fully representative of each domain. The cognitive component mainly covered the language-related variables (MA, PA, vocabulary, and working memory) but did not include factors such as orthographic awareness, executive function (only working memory was included), and visual attention, which were also found to be important in learning to read Chinese (e.g., Chung & McBride-Chang, 2011; Liu & Liu, 2020; Siok & Fletcher, 2001). The psychological component only included children's interest in reading in the structural equation modeling, and the ecological component only included factors at the family level but not the school and the neighborhood levels. Future studies could incorporate more factors from different levels and examine their interactive effects on the reading development.

Third, although this is a longitudinal study, the correlational nature of the study prevented casual conclusions to be drawn from the results. Future studies could use interventional and experimental methods to investigate the causal relationships between the components and word reading in Chinese children. Moreover, because this study did not examine the parents' reading ability or incorporate genetic data, it was not possible to dissect the genetic influences on the components and word reading from the environmental ones. Future studies could examine the parents' reading abilities as the genetic proxy or use twin-study data to examine the genetic influences (Hart et al., 2021).

One additional limitation of this study is the group-based test format at Time 2 due to the epidemic prevention measures of COVID-19, which inevitably affect the data quality. For example, the children may skip items because they accidently click the mouse (in the PC tests), or they do not want to answer the items. However, I have worked with my colleagues to make sure the PC tests are easy to use for the children. The PC tests have undergone multiple iterations

before the data collection. During the test, five experimenters (myself included) were monitoring the test process and intervened whenever the child has a problem or did not attend to the test. In the paper-form tests administered in the classroom, headmaster of the class is presented to make sure the measuring process is smooth.

5.6. Conclusion

In summary, by tracking a group of Chinese primary school children from grade one to grade three, the study found that the ecological and cognitive factors that were important to reading development can be loaded onto the respective components. Moreover, the cognitive and psychological components contributed directly to word reading, while the ecological component contributed indirectly to word reading via the mediations of the other two components. Developmentally, the effect of the ecological component on the cognitive component increased as the children moved to higher grade levels. In addition, the cognitive component in grade one contributed to word reading in grade three via the mediation of word reading in grade one, and the ecological component and word reading in grade one were found to predict the psychological component in grade three. These findings underline the importance of incorporating factors from multiple domains (ecological, psychological, cognitive) and time points for a complete picture of reading development in Chinese children. The results of this study also extended the Componential Model of Reading (CMR) in Chinese lower grade students.

Reference

Aaron, P. G., Joshi, R. M., Gooden, R., & Bentum, K. E. (2008). Diagnosis and Treatment of Reading Disabilities Based on the Component Model of Reading. *Journal of Learning Disabilities*, *41*(1), 67–84. https://doi.org/10.1177/0022219407310838

Adlof, S. M., Catts, H. W., & Little, T. D. (2006). Should the simple view of reading include a fluency component? *Reading and Writing*, *19*(9), 933–958.

Aikens, N. L., & Barbarin, O. (2008). Socioeconomic Differences in Reading Trajectories: The Contribution of Family, Neighborhood, and School Contexts. *Journal of Educational Psychology*, *100*(2), 235–251. https://doi.org/10.1037/0022-0663.100.2.235

Alexander, J. E., & Filler, R. C. (1976). *Attitudes and reading*. Newark, Del.: International Reading Association.

Anders, Y., Rossbach, H.-G., Weinert, S., Ebert, S., Kuger, S., Lehrl, S., & von Maurice, J. (2012). Home and preschool learning environments and their relations to the development of early numeracy skills. *Early Childhood Research Quarterly*, *27*(2), 231–244.

Anderson, P. (2002). Assessment and Development of Executive Function (EF) During Childhood. *Child Neuropsychology*, *8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724

Anmarkrud, Ø., & Bråten, I. (2009). Motivation for reading comprehension. *Learning and Individual Differences*, *19*(2), 252–256.

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience*, *4*(10), 829.

Baker, L., Scher, D., & Mackler, K. (1997). Home and family influences on motivations for reading. *Educational Psychologist*, *32*(2), 69–82.

Baker, L., & Wigfield, A. (1999). Dimensions of children's motivation for reading and their relations to reading activity and reading achievement. *Reading Research Quarterly*, *34*(4), 452–477.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Macmillan.

Baroody, A. E., & Diamond, K. E. (2012). Links Among Home Literacy Environment, Literacy Interest, and Emergent Literacy Skills in Preschoolers At Risk for Reading Difficulties. *Topics in Early Childhood Special Education*, *32*(2), 78–87. https://doi.org/10.1177/0271121410392803

Becker, M., McElvany, N., & Kortenbruck, M. (2010). Intrinsic and Extrinsic Reading Motivation as Predictors of Reading Literacy: A Longitudinal Study. *Journal of Educational Psychology*, *102*(4), 773–785. https://doi.org/10.1037/a0020084

Beech, J. R. (1990). Parents' attitudes and the reading performance of their children. *Perceptual and Motor Skills*, *70*(3_suppl), 1387–1392.

Boerma, I. E., Mol, S. E., & Jolles, J. (2018). Parents Adjust the Quality of Their Home Literacy Environment to the Reading Interest of Their Third to Sixth Graders. *Parenting*, *18*(4), 240–258. https://doi.org/10.1080/15295192.2018.1524243

Boland, T. (1993). The importance of being literate: Reading development in primary school and its consequences for the school career in secondary education. *European Journal of Psychology of Education*, *8*(3), 289.

Bracken, S. S., & Fischel, J. E. (2008). Family reading behavior and early literacy skills in preschool children from low-income backgrounds. *Early Education and Development*, *19*(1), 45–67. https://doi.org/10.1080/10409280701838835

Bradley, R. H., & Corwyn, R. F. (2002a). Socioeconomic status and child development. *Annual Review of Psychology*, *53*(1), 371–399.

Bradley, R. H., & Corwyn, R. F. (2002b). Socioeconomic Status and Child Development. *Annual Review of Psychology*, *53*(1), 371–399. https://doi.org/10.1146/annurev.psych.53.100901.135233

Bradley, R. H., Corwyn, R. F., Burchinal, M., McAdoo, H. P., & García Coll, C. (2001). The home environments of children in the United States Part II: Relations with behavioral development through age thirteen. *Child Development*, *72*(6), 1868–1886. https://doi.org/10.1111/1467-8624.t01-1-00383

Brody, G. H., Flor, D. L., & Gibson, N. M. (1999). Linking maternal efficacy beliefs, developmental goals, parenting practices, and child competence in rural single-parent African American families. *Child Development*, *70*(5), 1197–1208.

Bronfenbrenner. (1986). Ecology of the family as a contexto for human development. *Developmental Psychology*, *22*(6), 723–742. https://doi.org/10.1037/0012-1649.22.6.723

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology*, *33*(3), 205–228.

Burgess, S. (1997). The role of shared reading in the development of phonological awareness: A longitudinal study of middle to upper class children. *Early Child Development and Care*, *127*(1), 191–199. https://doi.org/10.1080/0300443971270116

Burgess, S. R., Hecht, S. A., & Lonigan, C. J. (2002). Relations of the home literacy environment (HLE) to the development of reading-related abilities: A one-year longitudinal study. *Reading Research Quarterly*, *37*(4), 408–426. https://doi.org/10.1598/rrq.37.4.4

Cain, K., & Barnes, M. A. (2017). Reading comprehension. *Theories of Reading Development*, 257–282.

Cain, K., & Oakhill, J. (2014). Reading comprehension and vocabulary: Is vocabulary more important for some aspects of comprehension? *LAnnee Psychologique*, *114*(4), 647–662.

Carlisle, J. F. (2000). Awareness of the structure and meaning of morphologically complex words: Impact on reading. *Reading and Writing An Interdisciplinary Journal*, *12*, 169–190. https://doi.org/10.1023/A:1008131926604

Carretti, B., Cornoldi, C., De Beni, R., & Romanò, M. (2005). Updating in working memory: A comparison of good and poor comprehenders. *Journal of Experimental Child Psychology*, *91*(1), 45–66.

Cartwright, K. B. (2012). Insights From Cognitive Neuroscience: The Importance of Executive Function for Early Reading Development and Education. *Early Education and Development*, *23*(1), 24–36. https://doi.org/10.1080/10409289.2011.615025

Castles, A., & Nation, K. (2006). How does orthographic learning happen? *From Inkmarks to Ideas: Current Issues in Lexical Processing*, *February*, 151–179. https://doi.org/10.4324/9780203841211

Chall, J. S. (1983). *Stages of reading development*. McGraw-Hill.

Chapman, J. W., & Tunmer, W. E. (1995). Development of young children's reading self-concepts: An examination of emerging subcomponents and their relationship with reading achievement. *Journal of Educational Psychology*, *87*(1), 154.

Chen, X., Hao, M., Geva, E., Zhu, J., & Shu, H. (2009). The role of compound awareness in Chinese children's vocabulary acquisition and character reading. *Reading and Writing*, *22*(5), 615–631. https://doi.org/10.1007/s11145-008-9127-9

Cheng, Y., & Wu, X. (2017). The relationship between SES and reading comprehension in Chinese: A mediation model. *Frontiers in Psychology*, *8*(APR), 1–7. https://doi.org/10.3389/fpsyg.2017.00672

Cheng, Y., Zhang, J., Li, H., Wu, X., Liu, H., Dong, Q., Li, L., Nguyen, T. P., Zheng, M., Zhao, Y., & Sun, P. (2017). Growth of Compounding Awareness Predicts Reading Comprehension in Young Chinese Students: A Longitudinal Study From Grade 1 to Grade 2. *Reading Research Quarterly*, *52*(1), 91–104. https://doi.org/10.1002/rrq.155

Cheng, Y., Zhang, J., Wu, X., Liu, H., & Li, H. (2016). Cross-lagged relationships between morphological awareness and reading comprehension among Chinese children. *Frontiers in Psychology*, *7*(SEP), 1–12. https://doi.org/10.3389/fpsyg.2016.01379

Chiu, M. M., McBride-Chang, C., & Lin, D. (2012). Ecological, Psychological, and Cognitive Components of Reading Difficulties: Testing the Component Model of Reading in Fourth Graders Across 38 Countries. *Journal of Learning Disabilities*, *45*(5), 391–405. https://doi.org/10.1177/0022219411431241

Chu, F. W., Van Marle, K., & Geary, D. C. (2016). Predicting children's reading and mathematics achievement from early quantitative knowledge and domain-general cognitive abilities. *Frontiers in Psychology*, *7*(MAY), 1–14. https://doi.org/10.3389/fpsyg.2016.00775

Chung, K. K. H., & McBride-Chang, C. (2011). Executive functioning skills uniquely predict Chinese word reading. *Journal of Educational Psychology*, *103*(4), 909.

Crampton, A., & Hall, J. (2017). Unpacking socio-economic risks for reading and academic self-concept in primary school: Differential effects and the role of the preschool home learning environment. *British Journal of Educational Psychology*, *87*(3), 365–382. https://doi.org/10.1111/bjep.12154

Cunningham, A. E., & Stanovich, K. E. (1998). What reading does for the mind. *American Educator*, *22*, 8–17.

Das, J. P., Georgiou, G., & Janzen, T. (2008). Influence of distal and proximal cognitive processes on word reading. *Reading Psychology*, *29*(4), 366–393. https://doi.org/10.1080/02702710802153412

De Jong, P. F., & Leseman, P. P. M. (2001). Lasting effects of home literacy on reading achievement in school. *Journal of School Psychology*, *39*(5), 389–414. https://doi.org/10.1016/S0022-4405(01)00080-2

Deacon, S. H., Holliman, A. J., Dobson, G. J., & Harrison, E. C. J. (2018). Assessing Direct Contributions of Morphological Awareness and Prosodic Sensitivity to Children's Word Reading and Reading Comprehension. *Scientific Studies of Reading*, *22*(6), 527–534. https://doi.org/10.1080/10888438.2018.1483376

Deng, C.P., Silinskas, G., Wei, W., & Georgiou, G. K. (2015). Cross-lagged relationships between home learning environment and academic achievement in Chinese. *Early Childhood Research Quarterly*, *33*, 12–20. https://doi.org/10.1016/j.ecresq.2015.05.001

Dulay, Katrina M., Cheung, S. K., & McBride, C. (2019). Intergenerational transmission of literacy skills among Filipino families. *Developmental Science*, *22*(5), 1–14. https://doi.org/10.1111/desc.12859

Dulay, Katrina May, Cheung, S. K., & McBride, C. (2018). Environmental correlates of early language and literacy in low- to middle-income Filipino families. *Contemporary Educational Psychology*, *53*(February), 45–56. https://doi.org/10.1016/j.cedpsych.2018.02.002

Dulay, Katrina May, Law, S. Y., McBride, C., & Ho, C. S. H. (2021). Reciprocal effects of morphological awareness, vocabulary knowledge, and word reading: A cross-lagged panel analysis in Chinese. *Journal of Experimental Child Psychology*, *206*, 105100. https://doi.org/10.1016/j.jecp.2021.105100

Evans, M. D. R., Kelley, J., Sikora, J., & Treiman, D. J. (2010). Family scholarly culture and educational success: Books and schooling in 27 nations. *Research in Social Stratification and Mobility*, *28*(2), 171–197. https://doi.org/10.1016/j.rssm.2010.01.002

Franceschini, S., Gori, S., Ruffino, M., Pedrolli, K., & Facoetti, A. (2012). A causal link between visual spatial attention and reading acquisition. *Current Biology*, *22*(9), 814–819.

Fuchs, L. S., Fuchs, D., Hosp, M. K., & Jenkins, J. R. (2001). Oral reading fluency as an indicator of reading competence: A theoretical, empirical, and historical analysis. *Scientific Studies of Reading*, *5*(3), 239–256.

Geary, D. C. (1993). Mathematical disabilities: cognitive, neuropsychological, and genetic components. *Psychological Bulletin*, *114*(2), 345.

Georgiou, G. K., Inoue, T., & Parrila, R. (2021). Developmental Relations Between Home Literacy Environment, Reading Interest, and Reading Skills: Evidence From a 3-Year Longitudinal Study. *Child Development*, *92*(5), 2053–2068. https://doi.org/10.1111/cdev.13589

Georgiou, G. K., Parrila, R., Cui, Y., & Papadopoulos, T. C. (2013). Why is rapid automatized naming related to reading? *Journal of Experimental Child Psychology*, *115*(1), 218–225. https://doi.org/10.1016/j.jecp.2012.10.015

Georgiou, G. K., Parrila, R., & Liao, C. H. (2008). Rapid naming speed and reading across languages that vary in orthographic consistency. *Reading and Writing*, *21*(9), 885–903. https://doi.org/10.1007/s11145-007-9096-4

Gianarris, W. J., Golden, C. J., & Greene, L. (2001). The conners' parent rating scales: A critical review of the literature. In *Clinical Psychology Review* (Vol. 21, Issue 7). https://doi.org/10.1016/S0272-7358(00)00085-4

Gori, S., & Facoetti, A. (2015). How the visual aspects can be crucial in reading acquisition: The intriguing case of crowding and developmental dyslexia. *Journal of Vision*, *15*(1), 1–20. https://doi.org/10.1167/15.1.8

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education*, *7*(1), 6–10. https://doi.org/10.1177/074193258600700104

Guthrie, J. T., Wigfield, A., Metsala, J. L., & Cox, K. E. (1999). Motivational and cognitive predictors of text comprehension and reading amount. *Scientific Studies of Reading*, *3*(3), 231–256.

Hart, S. A., Little, C., & van Bergen, E. (2021). Nurture might be nature: cautionary tales and proposed solutions. *Npj Science of Learning*, *6*(1), 1–12. https://doi.org/10.1038/s41539-020-00079-z

Hart, S. A., Soden, B., Johnson, W., Schatschneider, C., & Taylor, J. (2013). Expanding the environment: gene× school-level SES interaction on reading comprehension. *Journal of Child Psychology and Psychiatry*, *54*(10), 1047–1055.

Haughbrook, R., Hart, S. A., Schatschneider, C., & Taylor, J. (2017). Genetic and environmental influences on early literacy skills across school grade contexts. *Developmental Science*, *20*(5). https://doi.org/10.1111/desc.12434

Helmke, A. (1999). From optimism to realism? Development of children's academic self-concept from kindergarten to grade 6. In *Individual development from 3 to 12: Findings from the Munich Longitudinal Study* (pp. 198–221). Cambridge University Press.

Hill, C. J., Bloom, H. S., Black, A. R., & Lipsey, M. W. (2008). Empirical benchmarks for interpreting effect sizes in research. *Child Development Perspectives*, *2*(3), 172–177.

Hill, N. E., & Taylor, L. C. (2004). Parental school involvement and children's academic achievement: Pragmatics and issues. *Current Directions in Psychological Science*, *13*(4), 161–164.

Hill, T. D., Trinh, H. N., Wen, M., & Hale, L. (2016). Perceived neighborhood safety and sleep quality: a global analysis of six countries. *Sleep Medicine*, *18*, 56–60.

Ho, C. S.-H., Ng, T.-T., & Ng, W.-K. (2003). A "radical" approach to reading development in Chinese: The role of semantic radicals and phonetic radicals. *Journal of Literacy Research*, *35*(3), 849–878.

Ho, C. S. H., Chan, D. W., Chung, K. K. H., Lee, S. H., & Tsang, S. M. (2007). In search of subtypes of Chinese developmental dyslexia. *Journal of Experimental Child Psychology*, *97*(1), 61–83. https://doi.org/10.1016/j.jecp.2007.01.002

Høien-Tengesdal, I., & Høien, T. (2012). The Reading Efficiency Model: An Extension of the Componential Model of Reading. *Journal of Learning Disabilities*, *45*(5), 467–479. https://doi.org/10.1177/0022219411432688

Hood, M., Conlon, E., & Andrews, G. (2008). Preschool Home Literacy Practices and Children's Literacy Development: A Longitudinal Analysis. *Journal of Educational Psychology*, *100*(2), 252–271. https://doi.org/10.1037/0022-0663.100.2.252

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing*, *2*(2), 127–160.

Howard, E. R., Páez, M. M., August, D. L., Barr, C. D., Kenyon, D., & Malabonga, V. (2014). The importance of SES, home and school language and literacy practices, and oral vocabulary in bilingual children's English reading development. *Bilingual Research Journal*, *37*(2), 120–141.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55.

Hua, S., Wenling, L., Anderson, R., Yu-Min, K., & Xuan, Y. (2002). The role of home-literacy environment in learning to read Chinese. In *Chinese children's reading acquisition* (pp. 207–223). Springer.

Im-Bolter, N., Johnson, J., & Pascual-Leone, J. (2006). Processing limitations in children with specific language impairment: The role of executive function. *Child Development*, *77*(6), 1822–1841. https://doi.org/10.1111/j.1467-8624.2006.00976.x

Joshi, R. M., Tao, S., Aaron, P. G., & Quiroz, B. (2012). Cognitive Component of Componential Model of Reading Applied to Different Orthographies. *Journal of Learning Disabilities*, *45*(5), 480–486. https://doi.org/10.1177/0022219411432690

Katzir, T., Lesaux, N. K., & Kim, Y. S. (2009). The role of reading self-concept and home literacy practices in fourth grade reading comprehension. *Reading and Writing*, *22*(3), 261–276. https://doi.org/10.1007/s11145-007-9112-8

Kieffer, M. J., & Vukovic, R. K. (2012). Components and Context: Exploring Sources of Reading Difficulties for Language Minority Learners and Native English Speakers in Urban

Schools. *Journal of Learning Disabilities*, *45*(5), 433–452. https://doi.org/10.1177/0022219411432683

Kim, Y. S. G. (2017). Why the Simple View of Reading Is Not Simplistic: Unpacking Component Skills of Reading Using a Direct and Indirect Effect Model of Reading (DIER). *Scientific Studies of Reading*, *21*(4), 310–333. https://doi.org/10.1080/10888438.2017.1291643

Kim, Y. S. G., Guo, Q., Liu, Y., Peng, Y., & Yang, L. (2020). Multiple Pathways by Which Compounding Morphological Awareness Is Related to Reading Comprehension: Evidence From Chinese Second Graders. *Reading Research Quarterly*, *55*(2), 193–212. https://doi.org/10.1002/rrq.262

Kim, Y. S., Park, C. H., & Wagner, R. K. (2014). Is oral/text reading fluency a "bridge" to reading comprehension? *Reading and Writing*, *27*(1), 79–99. https://doi.org/10.1007/s11145-013-9434-7

Kirby, J. R., Ball, A., Geier, B. K., Parrila, R., & Wade-Woolley, L. (2011). The development of reading interest and its relation to reading ability. *Journal of Research in Reading*, *34*(3), 263–280. https://doi.org/10.1111/j.1467-9817.2010.01439.x

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. Guilford publications.

Kuo, L., & Anderson, R. C. (2006). Morphological Awareness and Learning to Read : A Cross-Language Perspective Morphological Awareness and Learning to Read : A Cross-Language Perspective. *Educational Psychologist*, *41*(3), 161–180. https://doi.org/10.1207/s15326985ep4103

Kwok, O. man, Hughes, J. N., & Luo, W. (2007). Role of resilient personality on lower achieving first grade students' current and future achievement. *Journal of School Psychology*, *45*(1), 61–82. https://doi.org/10.1016/j.jsp.2006.07.002

Law, Y.-K. (2013). The Relationship between Extrinsic Motivation, Home Literacy, Classroom Instructional Practices, and Reading Proficiency in Second-Grade Chinese Children. *Research in Education*, *80*(1), 37–51. https://doi.org/10.7227/rie.80.4

Lei, L., Pan, J., Liu, H., McBride-Chang, C., Li, H., Zhang, Y., Chen, L., Tardif, T., Liang, W., Zhang, Z., & Shu, H. (2011). Developmental trajectories of reading development and impairment from ages 3 to 8 years in Chinese children. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *52*(2), 212–220. https://doi.org/10.1111/j.1469-7610.2010.02311.x

Leong, C. K., Tse, S. K., Loh, K. Y., & Hau, K. T. (2008). Text comprehension in Chinese children: Relative contribution of verbal working memory, pseudoword reading, rapid automatized naming, and onset-rime phonological segmentation. *Journal of Educational Psychology*, *100*(1), 135.

Leseman, P. P. M., & Jong, P. F. (1998). Home Literacy: Opportunity, Instruction, Cooperation and Social-Emotional Quality Predicting Early Reading Achievement. *Reading Research Quarterly*, *33*(3), 294–318. https://doi.org/10.1598/rrq.33.3.3

Levesque, K. C., Kieffer, M. J., & Deacon, S. H. (2017). Morphological awareness and reading comprehension: Examining mediating factors. *Journal of Experimental Child Psychology*, *160*, 1–20. https://doi.org/10.1016/j.jecp.2017.02.015

Levesque, K. C., Kieffer, M. J., & Deacon, S. H. (2018). Inferring Meaning From Meaningful Parts: The Contributions of Morphological Skills to the Development of Children's Reading Comprehension. *Reading Research Quarterly*, 1–18. https://doi.org/10.1002/rrq.219

Li, Hong, Shu, H., McBride-Chang, C., Liu, H., & Peng, H. (2012). Chinese children's character recognition: Visuo-orthographic, phonological processing and morphological skills. *Journal of Research in Reading*, *35*(3), 287–307. https://doi.org/10.1111/j.1467-9817.2010.01460.x

Li, Hui, Corrie, L. F., & Wong, B. K. M. (2008). Early teaching of Chinese literacy skills and later literacy outcomes. *Early Child Development and Care*, *178*(5), 441–459. https://doi.org/10.1080/03004430600789365

Li, Hui, & Rao, N. (2000). Parental influences on Chinese literacy development: A comparison of preschoolers in Beijing, Hong Kong, and Singapore. *International Journal of Behavioral Development*, *24*(1), 82–90. https://doi.org/10.1080/016502500383502

Li, Hui, & Rao, N. (2005). Curricular and instructional influences on early literacy attainment: Evidence from Beijing, Hong Kong and Singapore. *International Journal of Early Years Education*, *13*(3), 235–253. https://doi.org/10.1080/09669760500295870

Li, M., & Kirby, J. R. (2015). The Effects of Vocabulary Breadth and Depth on English Reading. *Applied Linguistics*, *36*(5), 611–634. https://doi.org/10.1093/applin/amu007

Li, M., Koh, P. W., Geva, E., Joshi, R. M., & Chen, X. (2020). The componential model of reading in bilingual learners. *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000459

Lin, D., McBride-Chang, C., Shu, H., Zhang, Y., Li, H., Zhang, J., Aram, D., & Levin, I. (2010). Small wins big: Analytic Pinyin skills promote Chinese word reading. *Psychological Science*, *21*(8), 1117–1122.

Little, C. W., Hart, S. A., Phillips, B. M., Schatschneider, C., & Taylor, J. E. (2019). Exploring neighborhood environmental influences on reading comprehension. *Journal of Applied Developmental Psychology*, *62*(February), 173–184. https://doi.org/10.1016/j.appdev.2019.02.009

Liu, Catrina, & Chung, K. K. H. (2021). Bidirectional Relations among Paired Associate Learning, Language-Specific Skills and Chinese Word Reading in Kindergarten Children. *Early Education and Development*, *00*(00), 1–16. https://doi.org/10.1080/10409289.2021.1912549

Liu, Catrina, Chung, K. K. H., Wang, L. C., & Liu, D. (2020). The relationship between paired associate learning and Chinese word reading in kindergarten children. *Journal of Research in Reading*, *00*(00), 1–20. https://doi.org/10.1111/1467-9817.12333

Liu, Cuina, Georgiou, G. K., & Manolitsis, G. (2018). Modeling the relationships of parents' expectations, family's SES, and home literacy environment with emergent literacy skills and word reading in Chinese. *Early Childhood Research Quarterly*, *43*, 1–10. https://doi.org/10.1016/j.ecresq.2017.11.001

Liu, D., Chen, X., & Wang, Y. (2016). The impact of visual-spatial attention on reading and spelling in Chinese children. *Reading and Writing*, *29*(7), 1435–1447. https://doi.org/10.1007/s11145-016-9644-x

Liu, D., Li, H., & Wong, K. S. R. (2017). The Anatomy of the Role of Morphological Awareness in Chinese Character Learning: The Mediation of Vocabulary and Semantic Radical Knowledge and the Moderation of Morpheme Family Size. *Scientific Studies of Reading*, *21*(3), 210–224. https://doi.org/10.1080/10888438.2017.1278764

Liu, J., Peng, P., & Luo, L. (2020). The Relation Between Family Socioeconomic Status and Academic Achievement in China: A Meta-analysis. *Educational Psychology Review*, *32*(1), 49–76. https://doi.org/10.1007/s10648-019-09494-0

Liu, P. D., & McBride-Chang, C. (2010). What Is Morphological Awareness? Tapping Lexical Compounding Awareness in Chinese Third Graders. *Journal of Educational Psychology*, *102*(1), 62–73. https://doi.org/10.1037/a0016933

Liu, P. D., McBride-Chang, C., Wong, T. T. Y., Shu, H., & Wong, A. M. Y. (2013). Morphological awareness in Chinese: Unique associations of homophone awareness and lexical compounding to word reading and vocabulary knowledge in Chinese children. *Applied Psycholinguistics*, *34*(4), 755–775. https://doi.org/10.1017/S014271641200001X

Liu, S., & Liu, D. (2020). Visual-spatial Attention and Reading Achievement in Hong Kong Chinese Children: Evidence from a One-year Longitudinal Study. *Scientific Studies of Reading*, *24*(3), 214–228. https://doi.org/10.1080/10888438.2019.1648475

Liu, Y., Georgiou, G. K., Zhang, Y., Li, H., Liu, H., Song, S., Kang, C., Shi, B., Liang, W., Pan, J., & Shu, H. (2017). Contribution of cognitive and linguistic skills to word-reading accuracy and fluency in Chinese. *International Journal of Educational Research*, *82*, 75–90. https://doi.org/10.1016/j.ijer.2016.12.005

MacKinnon, D. P., Lockwood, C. M., & Williams, J. (2004). Confidence limits for the indirect effect: Distribution of the product and resampling methods. *Multivariate Behavioral Research*, *39*(1), 99–128.

Manis, F. R., Seidenberg, M. S., & Doi, L. M. (1999). See Dick RAN: Rapid naming and the longitudinal prediction of reading subskills in first and second graders. *Scientific Studies of Reading*, *3*(2), 129–157.

Martin, M. O., Mullis, I. V. S., & Kennedy, A. M. (2007). Progress in International Reading Literacy Study (PIRLS): PIRLS 2006 Technical Report. *International Association for the Evaluation of Educational Achievement*.

McBride-Chang, C., Cho, J. R., Liu, H., Wagner, R. K., Shu, H., Zhou, A., Cheuk, C. S. M., & Muse, A. (2005). Changing models across cultures: Associations of phonological awareness and morphological structure awareness with vocabulary and word recognition in second graders from Beijing, Hong Kong, Korea, and the United States. *Journal of Experimental Child Psychology*, *92*(2), 140–160. https://doi.org/10.1016/j.jecp.2005.03.009

McBride-Chang, C., & Suk-Han Ho, C. (2005). Predictors of beginning reading in Chinese and English: A 2-year longitudinal study of Chinese kindergartners. *Scientific Studies of Reading*, *9*(2), 117–144.

McBride-Chang, C., Tong, X., Shu, H., Wong, A. M. Y., Leung, K. W., & Tardif, T. (2008). Syllable, phoneme, and tone: Psycholinguistic units in early Chinese and english word recognition. *Scientific Studies of Reading*, *12*(2), 171–194. https://doi.org/10.1080/10888430801917290

McBride-Chang, C., Wat, C. P., Shu, H., Zhou, A., & Wagner, R. K. (2003). Morphological Awareness Uniquely Predicts Young Children's Chinese Character Recognition. *Journal of Educational Psychology*, *95*(4), 743–751. https://doi.org/10.1037/0022-0663.95.4.743

McBride, C. (2016a). Is Chinese Special? Four Aspects of Chinese Literacy Acquisition that Might Distinguish Learning Chinese from Learning Alphabetic Orthographies. *Educational Psychology Review*, *28*(3), 523–549. https://doi.org/10.1007/s10648-015-9318-2

McBride, C. (2016b). *Children's literacy development: A cross-cultural perspective on learning to read and write*.

McCoy, M. G., Frick, P. J., Loney, B. R., & Ellis, M. L. (1999). The potential mediating role of parenting practices in the development of conduct problems in a clinic-referred sample. *Journal of Child and Family Studies*, *8*(4), 477–494.

McElvany, N., Kortenbruck, M., & Becker, M. (2008). Lesekompetenz und Lesemotivation: Entwicklung und Mediation des Zusammenhangs durch Leseverhalten. *Zeitschrift Für Pädagogische Psychologie*, *22*(34), 207–219.

McKenna, M. C., & Kear, D. J. (1990). Measuring attitude toward reading: A new tool for teachers. *The Reading Teacher*, *43*(9), 626–639.

McKenna, M. C., Kear, D. J., & Ellsworth, R. A. (1995). Children's attitudes toward reading: A national survey. *Reading Research Quarterly*, 934–956.

McKinnon, R. D., & Blair, C. (2019). Bidirectional relations among executive function, teacher–child relationships, and early reading and math achievement: A cross-lagged panel analysis. *Early Childhood Research Quarterly*, *46*, 152–165. https://doi.org/10.1016/j.ecresq.2018.03.011

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100.

Molfese, V. J., Modglin, A., & Molfese, D. L. (2003). The Role of Environment in the Development of Reading Skills. *Journal of Learning Disabilities*, *36*(1), 59–67. https://doi.org/10.1177/00222194030360010701

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: Evidence from a

longitudinal study. *Developmental Psychology*, *40*(5), 665–681. https://doi.org/10.1037/0012-1649.40.5.665

Newman, J., Noel, A., Chen, R., & Matsopoulos, A. S. (1998). Temperament, Selected Moderating Variables and Early Reading Achievement. *Journal of School Psychology*, *36*(2), 215–232. https://doi.org/10.1016/S0022-4405(98)00006-5

Norton, E. S., & Wolf, M. (2012). Rapid automatized naming (RAN) and reading fluency: Implications for understanding and treatment of reading disabilities. *Annual Review of Psychology*, *63*, 427–452.

O'Brien, B. A., Ng, S. C., & Arshad, N. A. (2020). The structure of home literacy environment and its relation to emergent English literacy skills in the multilingual context of Singapore. *Early Childhood Research Quarterly*, *53*, 441–452. https://doi.org/10.1016/j.ecresq.2020.05.014

Oakhill, J., & Kyle, F. (2000). The relation between phonological awareness and working memory. *Journal of Experimental Child Psychology*, *75*(2), 152–164.

OECD. (2019). *PISA 2018 Assessment and Analytical Framework*. OECD Publishing.

Ortiz, M., Folsom, J. S., Al Otaiba, S., Greulich, L., Thomas-Tate, S., & Connor, C. M. (2012). The componential model of reading: Predicting first grade reading performance of culturally diverse students from ecological, psychological, and cognitive factors assessed at kindergarten entry. *Journal of Learning Disabilities*, *45*(5), 406–417.

Ouellette, G., & Beers, A. (2010). A not-so-simple view of reading: How oral vocabulary and visual-word recognition complicate the story. *Reading and Writing*, *23*(2), 189–208. https://doi.org/10.1007/s11145-008-9159-1

Ouellette, G. P. (2006). What's meaning got to do with it: The role of vocabulary in word reading and reading comprehension. *Journal of Educational Psychology, 98*(3), 554–566. https://doi.org/10.1037/0022-0663.98.3.554

Pan, J., McBride-Chang, C., Shu, H., Liu, H., Zhang, Y., & Li, H. (2011). What Is in the Naming? A 5-Year Longitudinal Study of Early Rapid Naming and Phonological Sensitivity in Relation to Subsequent Reading Skills in Both Native Chinese and English as a Second Language. *Journal of Educational Psychology, 103*(4), 897–908. https://doi.org/10.1037/a0024344

Pan, J., Song, S., Su, M., McBride, C., Liu, H., Zhang, Y., Li, H., & Shu, H. (2016). On the relationship between phonological awareness, morphological awareness and Chinese literacy skills: evidence from an 8-year longitudinal study. *Developmental Science, 19*(6), 982–991. https://doi.org/10.1111/desc.12356

Pasquarella, A., Chen, X., Gottardo, A., & Geva, E. (2015). Cross-language transfer of word reading accuracy and word reading fluency in Spanish-English and Chinese-English bilinguals: Script-universal and script-specific processes. *Journal of Educational Psychology*, *107*(1), 96.

Peng, P., Sha, T., & Li, B. (2013). The deficit profile of working memory, inhibition, and updating in Chinese children with reading difficulties. *Learning and Individual Differences, 25*, 111–117. https://doi.org/10.1016/j.lindif.2013.01.012

Peng, P., Wang, T., Wang, C. C., & Lin, X. (2019). A meta-analysis on the relation between fluid intelligence and reading/ mathematics: Effects of tasks, age, and social economics status. *Psychological Bulletin, 145*(2), 189–236. https://doi.org/10.1037/bul0000182

Perfetti, C. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading*, *11*(4), 357–383. https://doi.org/10.1080/10888430701530730

Perfetti, C. (2017). Lexical quality revisited. In *Developmental perspectives in written language and literacy* (pp. 51–67). https://www.google.com/books?hl=zh-TW&lr=&id=wCtBDwAAQBAJ&oi=fnd&pg=PA51&dq=lexical+quality+revisited&ots=R335y23xC4&sig=cMZTYBiyzrfzz501CP0DU648zfw

Petscher, Y. (2010). A meta-analysis of the relationship between student attitudes towards reading and achievement in reading. *Journal of Research in Reading*, *33*(4), 335–355. https://doi.org/10.1111/j.1467-9817.2009.01418.x

Pezoa, J. P., Mendive, S., & Strasser, K. (2019). Reading interest and family literacy practices from prekindergarten to kindergarten: Contributions from a cross-lagged analysis. *Early Childhood Research Quarterly*, *47*, 284–295. https://doi.org/10.1016/j.ecresq.2018.12.014

Phillips, B. M., & Lonigan, C. J. (2009). Variations in the home literacy environment of preschool children: A cluster analytic approach. *Scientific Studies of Reading*, *13*(2), 146–174. https://doi.org/10.1080/10888430902769533

Plaza, M., & Cohen, H. (2007). The contribution of phonological awareness and visual attention in early reading and spelling. *Dyslexia*, *13*(1), 67–76.

Proctor, C. P., Silverman, R. D., Harring, J. R., & Montecillo, C. (2012). The role of vocabulary depth in predicting reading comprehension among English monolingual and Spanish-English bilingual children in elementary school. *Reading and Writing*, *25*(7), 1635–1664. https://doi.org/10.1007/s11145-011-9336-5

Puglisi, M. L., Hulme, C., Hamilton, L. G., & Snowling, M. J. (2017). The Home Literacy Environment Is a Correlate, but Perhaps Not a Cause, of Variations in Children's Language

and Literacy Development. *Scientific Studies of Reading*, *21*(6), 498–514. https://doi.org/10.1080/10888438.2017.1346660

R Core Team. (2013). *R: A language and environment for statistical computing*.

Ruan, Y., Georgiou, G. K., Song, S., Li, Y., & Shu, H. (2018). Does writing system influence the associations between phonological awareness, morphological awareness, and reading? A meta-analysis. *Journal of Educational Psychology*, *110*(2), 180–202. https://doi.org/10.1037/edu0000216

Scarborough, H. S., & Dobrich, W. (1994). On the efficacy of reading to preschoolers. *Developmental Review*, *14*(3), 245–302.

Schiefele, U., Schaffner, E., Möller, J., Wigfield, A., Nolen, S., & Baker, L. (2012). Dimensions of reading motivation and their relation to reading behavior and competence. *Reading Research Quarterly*, *47*(4), 427–463. https://doi.org/10.1002/RRQ.030

Schunk, D. H. (2003). Self-efficacy for reading and writing: Influence of modeling, goal setting, and self-evaluation. *Reading &Writing Quarterly*, *19*(2), 159–172.

Senechal, M. (2006). Testing the Home Literacy Model: Parent Involvement in Kindergarten Is Differentially Related to Grade 4 Reading Comprehension, Fluency, Spelling, and Reading for Pleasure. *Scientific Studies of Reading*, *10*(1), 59–87. https://doi.org/10.1207/s1532799xssr1001

Sénéchal, M. (2006). Testing the home literacy model: Parent involvement in kindergarten is differentially related to grade 4 reading comprehension, fluency, spelling, and reading for pleasure. *Scientific Studies of Reading*, *10*(1), 59–87.

Sénéchal, M., & LeFevre, J. (2002). Parental involvement in the development of children's reading skill: A five-year longitudinal study. *Child Development*, *73*(2), 445–460.

Sesma, H. W., Mahone, E. M., Levine, T., Eason, S. H., & Cutting, L. E. (2009). The contribution of executive skills to reading comprehension. *Child Neuropsychology*, *15*(3), 232–246.

Shu, H., Chen, X., Anderson, R. C., Wu, N., & Xuan, Y. (2003). Properties of School Chinese: Implications for Learning to Read. *Child Development*, *74*(1), 27–47. https://doi.org/10.1111/1467-8624.00519

Shu, H., Peng, H., & McBride-Chang, C. (2008). Phonological awareness in young Chinese children. *Developmental Science*, *11*(1), 171–181. https://doi.org/10.1111/j.1467-7687.2007.00654.x

Sikiö, R., Siekkinen, M., Holopainen, L., Silinskas, G., Lerkkanen, M. K., & Nurmi, J. E. (2018). Maternal parenting styles, homework help, and children's literacy development in language minority and Finnish-speaking families. *European Journal of Psychology of Education*, *33*(2), 235–250. https://doi.org/10.1007/s10212-017-0330-4

Silinskas, G., Sénéchal, M., Torppa, M., & Lerkkanen, M. (2020). *Home Literacy Activities and Children ' s Reading Skills , Independent Reading , and Interest in Literacy Activities From Kindergarten to Grade 2*. *11*(July), 1–15. https://doi.org/10.3389/fpsyg.2020.01508

Siok, W. T., & Fletcher, P. (2001). The role of phonological awareness and visual-orthographic skills in Chinese reading acquisition. *Developmental Psychology*, *37*(6), 886–899. https://doi.org/10.1037/0012-1649.37.6.886

Skwarchuk, S. L., Sowinski, C., & LeFevre, J. A. (2014). Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model. *Journal of Experimental Child Psychology*, *121*(1), 63–84. https://doi.org/10.1016/j.jecp.2013.11.006

Snowling, M. J., & Hulme, C. (2020). Annual Research Review: Reading disorders revisited – the critical importance of oral language. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *5*, 635–653. https://doi.org/10.1111/jcpp.13324

Son, S.-H., & Morrison, F. J. (2010). The nature and impact of changes in home learning environment on development of language and academic skills in preschool children. *Developmental Psychology*, *46*(5), 1103.

Song, S., Georgiou, G. K., Su, M., & Hua, S. (2016). How Well Do Phonological Awareness and Rapid Automatized Naming Correlate With Chinese Reading Accuracy and Fluency? A Meta-Analysis. *Scientific Studies of Reading*, *20*(2), 99–123. https://doi.org/10.1080/10888438.2015.1088543

Sonnenschein, S., & Munsterman, K. (2002). The influence of home-based reading interactions on 5-year-olds' reading motivations and early literacy development. *Early Childhood Research Quarterly*, *17*(3), 318–337.

Spencer, M., Muse, A., Wagner, R. K., Foorman, B., Petscher, Y., Schatschneider, C., Tighe, E. L., & Bishop, M. D. (2015). Examining the underlying dimensions of morphological awareness and vocabulary knowledge. *Reading and Writing*, *28*(7), 959–988. https://doi.org/10.1007/s11145-015-9557-0

Spencer, M., Quinn, J. M., & Wagner, R. K. (2017). *Vocabulary, morphology, and reading comprehension*. *2017*, 239–256. https://doi.org/10.1075/swll.15.14spe

Spira, E. G., Bracken, S. S., & Fischel, J. E. (2005). Predicting Improvement after first-grade reading difficulties: The effects of oral language, emergent literacy, and behavior skills. *Developmental Psychology*, *41*(1), 225–234. https://doi.org/10.1037/0012-1649.41.1.225

Tabachnick, B. G., & Fidell, L. (1989). *Using multivariate statistics (pp. 123-191).* New York: Harper & Row.

Taggart, B., Melhuish, E. C., Phan, M. B., Sammons, P., Sylva, K., & Siraj-Blatchford, I. (2008). Effects of the Home Learning Environment and Preschool Center Experience upon Literacy and Numeracy Development in Early Primary School. *Journal of Social Issues*, *64*(1), 95–114. https://doi.org/10.1111/j.1540-4560.2008.00550.x

Taylor, J., Ennis, C. R., Hart, S. A., Mikolajewski, A. J., & Schatschneider, C. (2017). Home environmental and behavioral risk indices for reading achievement. *Learning and Individual Differences*, *57*(August 2016), 9–21. https://doi.org/10.1016/j.lindif.2017.05.010

Taylor, J., Erbeli, F., Hart, S. A., & Johnson, W. (2020). Early classroom reading gains moderate shared environmental influences on reading comprehension in adolescence. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *61*(6), 689–698. https://doi.org/10.1111/jcpp.13134

Tercanlioglu, L. (2001). The nature of Turkish students' motivation for reading and its relation to their reading frequency. *The Reading Matrix*, *1*(2).

Thames, D. G., & Reeves, C. K. (1994). Poor readers' attitudes: Effects of using interests and trade books in an integrated language arts approach. *Literacy Research and Instruction*, *33*(4), 293–307.

Tong, Xiuhong, Tong, X., & McBride, C. (2017). Unpacking the relation between morphological awareness and Chinese word reading: Levels of morphological awareness and vocabulary. *Contemporary Educational Psychology*, *48*, 167–178. https://doi.org/10.1016/j.cedpsych.2016.07.003

Tong, Xiuli, Mcbride-Chang, C., Shu, H., & Wong, A. M. Y. (2009). Morphological awareness, orthographic knowledge, and spelling errors: Keys to understanding early chinese literacy acquisition. *Scientific Studies of Reading*, *13*(5), 426–452. https://doi.org/10.1080/10888430903162910

Torppa, M., Niemi, P., Vasalampi, K., Lerkkanen, M., Tolvanen, A., & Poikkeus, A. (2020). Leisure reading (but not any kind) and reading comprehension support each other—A longitudinal study across grades 1 and 9. *Child Development*, *91*(3), 876–900.

Tunmer, W. E., & Chapman, J. W. (2012). The Simple View of Reading Redux: Vocabulary Knowledge and the Independent Components Hypothesis. *Journal of Learning Disabilities*, *45*(5), 453–466. https://doi.org/10.1177/0022219411432685

van Bergen, E., van Zuijen, T., Bishop, D., & de Jong, P. F. (2017). Why Are Home Literacy Environment and Children's Reading Skills Associated? What Parental Skills Reveal. *Reading Research Quarterly*, *52*(2), 147–160. https://doi.org/10.1002/rrq.160

Van Steensel, R. (2006). Relations between socio-cultural factors, the home literacy environment and children's literacy development in the first years of primary education. *Journal of Research in Reading*, *29*(4), 367–382. https://doi.org/10.1111/j.1467-9817.2006.00301.x

Vasilyeva, M., Dearing, E., Ivanova, A., Shen, C., & Kardanova, E. (2018). Testing the family investment model in Russia: Estimating indirect effects of SES and parental beliefs on the literacy skills of first-graders. *Early Childhood Research Quarterly*, *42*(July 2017), 11–20. https://doi.org/10.1016/j.ecresq.2017.08.003

Vecera, S. P., & Rizzo, M. (2003). Spatial attention: normal processes and their breakdown. *Neurologic Clinics*, *21*(3), 575–607.

Verhoeven, L., & Van Leeuwe, J. (2008). Prediction of the development of reading comprehension: A longitudinal study. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *22*(3), 407–423.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., Donahue, J., & Garon, T. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: a 5-year longitudinal study. *Developmental Psychology*, *33*(3), 468.

Wang, L., & Liu, D. (2021). Unpacking the relations between home literacy environment and word reading in Chinese children : The influence of parental responsive behaviors and parents ' difficulties with literacy activities. *Early Childhood Research Quarterly*, *56*, 190–200. https://doi.org/10.1016/j.ecresq.2021.04.002

Wei, W., Georgiou, G. K., & Deng, C. (2015). Examining the Cross-Lagged Relationships Between RAN and Word Reading in Chinese. *Scientific Studies of Reading*, *19*(6), 446–455. https://doi.org/10.1080/10888438.2015.1077447

Weigel, D. J., Martin, S. S., & Bennett, K. K. (2006). Contributions of the home literacy environment to preschool-aged children's emerging literacy and language skills. *Early Child Development and Care*, *176*(3–4), 357–378. https://doi.org/10.1080/03004430500063747

Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of Educational Psychology*, *102*(1), 43.

Wigfield, A., & Guthrie, J. T. (1997a). Relations of Children's Motivation for Reading to the Amount and Breadth of Their Reading. *Journal of Educational Psychology*, *89*(3), 420–432. https://doi.org/10.1037/0022-0663.89.3.420

Wigfield, A., & Guthrie, J. T. (1997b). Relations of children's motivation for reading to the amount and breadth or their reading. *Journal of Educational Psychology*, *89*(3), 420.

Wu, X., Anderson, R. C., Li, W., Wu, X., Li, H., Zhang, J., Zheng, Q., Zhu, J., Shu, H., Jiang, W., Chen, X., Wang, Q., Yin, L., He, Y., Packard, J., & Gaffney, J. S. (2009). Morphological awareness and Chinese children's literacy development: An intervention study. *Scientific Studies of Reading*, *13*(1), 26–52. https://doi.org/10.1080/10888430802631734

Xue, J., Shu, H., Li, H., Li, W., & Tian, X. (2013). The Stability of Literacy-Related Cognitive Contributions to Chinese Character Naming and Reading Fluency. *Journal of Psycholinguistic Research*, *42*(5), 433–450. https://doi.org/10.1007/s10936-012-9228-0

Yang, X., Peng, P., & Meng, X. (2019a). Contributions of basic cognitive processing to Chinese Reading: The mediation effect of basic language processing. *Frontiers in Psychology*, *9*(JAN). https://doi.org/10.3389/fpsyg.2018.02670

Yang, X., Peng, P., & Meng, X. (2019b). How do metalinguistic awareness, working memory, reasoning, and inhibition contribute to Chinese character reading of kindergarten children? *Infant and Child Development*, *28*(3), 1–17. https://doi.org/10.1002/icd.2122

Yeniad, N., Malda, M., Mesman, J., Van Ijzendoorn, M. H., & Pieper, S. (2013). Shifting ability predicts math and reading performance in children: A meta-analytical study. *Learning and Individual Differences*, *23*(1), 1–9. https://doi.org/10.1016/j.lindif.2012.10.004

Yeo, L. S., Ong, W. W., & Ng, C. M. (2014). The Home Literacy Environment and Preschool Children's Reading Skills and Interest. *Early Education and Development*, *25*(6), 791–814. https://doi.org/10.1080/10409289.2014.862147

Yeung, P.-S., Ho, C. S.-H., Wong, Y.-K., Chan, D. W.-O., Chung, K. K., & Lo, L.-Y. (2013). Longitudinal predictors of Chinese word reading and spelling among elementary grade students. *Applied Psycholinguistics*, *34*(6), 1245–1277.

Yeung, P. S., Ho, C. S. H., Chan, D. W. O., & Chung, K. K. H. (2016). A componential model of reading in Chinese. *Learning and Individual Differences*, *45*, 11–24. https://doi.org/10.1016/j.lindif.2015.11.007

Yeung, P. S., Ho, C. S. J, Chan, D. W. O, Chung, K. K. H., & Wong, Y. K. (2013). A model of reading comprehension in Chinese elementary school children. *Learning and Individual Differences*, *25*, 55–66. https://doi.org/10.1016/j.lindif.2013.03.004

Yuet-Han Lau, J., & McBride-Chang, C. (2005). Home literacy and Chinese reading in Hong Kong children. *Early Education and Development*, *16*(1), 5–22.

Zhang, S. Z., Inoue, T., Shu, H., & Georgiou, G. K. (2019). How does home literacy environment influence reading comprehension in Chinese? Evidence from a 3-year longitudinal study. *Reading and Writing*, *October*. https://doi.org/10.1007/s11145-019-09991-2

Zhang, X., Hu, B. Y., Ren, L., & Fan, X. (2018). Sources of individual differences in young Chinese children's reading and mathematics skill: A longitudinal study. *Journal of School Psychology*, *71*(November), 122–137. https://doi.org/10.1016/j.jsp.2018.10.008

Zhang, X., & Sun, J. (2011). The reciprocal relations between teachers' perceptions of children's behavior problems and teacher–child relationships in the first preschool year. *The Journal of Genetic Psychology*, *172*(2), 176–198.

Zhang, Y., Tardif, T., Shu, H., Li, H., Liu, H., McBride-Chang, C., Liang, W., & Zhang, Z. (2013). Phonological skills and vocabulary knowledge mediate socioeconomic status effects in predicting reading outcomes for Chinese children. *Developmental Psychology*, *49*(4), 665–671. https://doi.org/10.1037/a0028612

Zhao, Y., Wu, X., Sun, P., Xie, R., Feng, J., & Chen, H. (2019). The relationship between morphological awareness and reading comprehension among Chinese children: evidence from multiple mediation models. *Learning and Individual Differences*, *72*(June 2018), 59–68. https://doi.org/10.1016/j.lindif.2019.04.005

Zhou, L., Duff, F. J., & Hulme, C. (2015). Phonological and Semantic Knowledge Are Causal Influences on Learning to Read Words in Chinese. *Scientific Studies of Reading*, *19*(6), 409–418. https://doi.org/10.1080/10888438.2015.1068317

Appendices

Appendix A: Items for the Questionnaire of Children's Interest in Reading

1. He/she only reads if he/she has to. (*reverse coded*)

2. Reading is his/her hobby.

3. He/she likes talking about books with other people.

4. Finishing a book from front to end is very difficult for him/her. (*reverse coded*)

5. He/she is always happy when receiving a book as a gift.

6. Reading is a waste of time in his/her eyes. (*reverse coded*)

7. He/she likes to go to bookstores or libraries.

8. He/she cannot sit still to read for more than a few minutes. (*reverse coded*)

9. He/she likes to express opinions about books he/she reads.

10. He/she likes to exchange books with friends.

Appendix B: Sample Items for the Conners' Parent Rating Scale-Revised

1. Behave rudely to adults

2. Always in fights with others

3. Always crying and screaming

4. Likes to brag

5. Easily distracted

Appendix C: Items for the Questionnaire of Home Literacy Environment at Time 1

Prior to entering primary school, how frequently did you or your family members conduct the activities listed below with your child?

1. Book reading
2. Telling stories
3. Singing
4. Playing with letters or characters, such as character learning cards
5. Discussing about the things you have done
6. Discussing about the books you have read
7. Playing word games, such as riddles about words
8. Writing characters
9. Reading signs or labels
10. Going to the library.

Appendix D: Items for the Questionnaire of Home Literacy Environment at Time 2

How frequently did you or your family members conduct the activities listed below with your child?

1. Listening to the child reading the text
2. Discussing about the things you and your child have done together
3. Discussing about the materials that your child have read on his/her own
4. Discussing about the materials that your child have read in class
5. Going to the library or the bookstore with your child
6. Aiding your child when he/she is doing reading-related homework