A Cross-sectional and Longitudinal Study of Cognitive Abilities Underlying Acquisition of Reading and Writing in Mandarin Chinese: An Actual Condition Survey Aimed to the Exploitation of Screening Tests

（中国語（北京語）の読み書き習得に関与する認知能力に関する横断的及び縦断的研究
—スクリーニング検査の開発のための実態調査— ）

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Chapter1 Introduction

1. The Definition and Assessment of Developmental Dyslexia

On the basis of the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10, 2016), learning disabilities are characterized by a significant discrepancy between an individual's general intellectual function and their ability to acquire new language and other cognitive skills. Developmental dyslexia, is considered a relatively common and nuclear subtype of specific learning disabilities in alphabetic languages. According to the International Dyslexia Association (Lyon, Shaywitz, & Shaywitz, 2003), developmental dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties in recognizing words accurately and/or fluently, and poor spelling and decoding abilities. The Diagnostic and Statistical Manual of the American Psychiatric Association (DSM-5, 2013) uses the term 'Specific Learning Disorder with impairment in reading' to describe dyslexia. The DSM-5 definition refers to a pattern of learning difficulties characterized by difficulties in accurate or fluent word reading, and poor spelling that have persisted for at least 6 months, in spite intervention which targeted those difficulties were provided (American Psychiatric Association, 2013). These difficulties result from specific cognitive deficits in the phonological component of language and are unexpected in the context of individual's other cognitive abilities (Lyon et al., 2003). The diagnostic criteria for Specific Learning Disabilities (SLD) in DSM-5 essentially require the difficulties experienced by the individual will be assessed using standardized achievement tests and found to be at a level significantly lower than most individuals of the same age (American

Psychiatric Association, 2013). Following the DSM-5 diagnostic criteria for SLD, some reading and writing tests need to be conducted when diagnosing a child as having developmental dyslexia. In addition, standardized achievement tests were developed in order to identify children with dyslexia not only in alphabetic languages (e.g. English) but also in logographic languages (e.g. Japanese).

Developmental dyslexia is also a common subtype of learning disability in China (Shu & Meng, 2000). There are also standardized reading and/or writing tests for Chinese speaking Children in Hong Kong (Ho, Chan, Tsang & Lee, 2000) and Taiwan (Huang, 2001). To our knowledge, there is no standardized assessment of developmental dyslexia in mainland China. There are several differences between children from mainland China and those from Taiwan and Hong Kong in terms of their literacy instruction methods, spoken languages, and script (Cheung & Ng, 2003). Mainland Chinese children are taught Pinyin, a phonetic alphabet system used to spell Chinese syllables, during their first 10 weeks of enrolment in first grade (Yeung, Ho, Wong, Chan, Chung & Lo, 2013). By contrast, Taiwanese children learn a system known as Zhu-Yin-Fu-Hao, in which phonemes are represented by various visual symbols (Huang & Hanley, 1997). Children from Hong Kong, meanwhile, are taught without the assistance of any phonetic coding system. Moreover, simplified characters are used in mainland China, whereas traditional characters are used in Taiwan and Hong Kong. The average number of strokes required for commonly used characters is 9.0 regarding the simplified characters used in mainland China, but 11.2 for the traditional characters used in Taiwan and Hong Kong (Chan, 1982). Because of the differences in characteristics of Chinese scripts and languages, those commonly used assessment tools for reading disability in Hong Kong or Taiwan could not be used with Mainland Chinese children directly.

Instead, checklists were often used as screening instruments for learning disabilities in Mainland China in the past decades. One of these checklists is the Pupil Rating Scale-Revised: Screening for learning disabilities (PRS) (Myklebust, 1981), which is characterized by its ease of use and interpretation. It consists of five subscales, which included Auditory Comprehension, Spoken Language, Orientation, Motor Coordination, and Personal-Social Behavior. Scores on the first two subscales are combined to produce a Verbal Score; scores on the remaining three subscales are combined to produce a Nonverbal Score. The Verbal and Nonverbal Scores are added together to produce a Total Score. In order to examine the criterion-related validity of PRS, Jing et al. (1998) and Wei (2004) tested correlations of the nonverbal scores, verbal scores and total scores of PRS with the scores of Combined Raven's Test (CRT) which is a revised version of Raven's Test in Chinese for nonverbal reasoning ability. These studies found moderate positive correlations between the scores of CRT with the nonverbal scores, verbal scores and total scores of PRS and thus they suggested that PRS was valid in estimating children's literacy abilities. However, researchers suggested that intelligence is irrelevant to reading abilities since poor readers are found at different IQ levels (e.g., Siegel, 1989; Naglieri & Reardon, 1993; Das, Naglieri, & Kirby, 1994). Thus, the correlation of PRS scores and intelligence test scores are not effective enough to prove the validity of PRS for the detection of reading and writing difficulties. It is hard to make a conclusion that the PRS is useful for identifying children with developmental dyslexia from these results.

Moreover, the validity of PRS was also investigated by calculating the correlation coefficient between PRS's verbal scores, nonverbal scores as well as total scores with children's scores on final exams (Jing, Morinaga, & Chen, 1998; Wei, 2004). These studies found that the verbal scores, nonverbal scores and total scores of PRS were significantly correlated with the scores of final exams. These studies concluded that PRS had good validity and was suitable for group screening of learning disabilities (Jing et al., 1998; Wang, Jing, Ai, Yu, Hu, Lv & Chen, 2010; Wei, 2004). However, since the content and difficulties of the final exam differ between schools, the results of one final exam can hardly reflect children's academic achievements objectively. In addition, it is not clear whether PRS can detect each specific subtype of learning disability in Chinese children, because rare previous study has investigated the relationship between PRS and data on basic academic skills (e.g. reading skills, writing skills, and calculation skills). Since developmental dyslexia is a nucleus subtype of specific learning disability, the effectiveness of a modified PRS should be tested in terms of the detection of developmental dyslexia to demonstrate the ongoing validity of PRS as a screening checklist.

2. Cognitive-linguistic abilities related to Chinese Reading and Writing Acquisition

Researches related to reading development and impairment from alphabetic languages have contributed to develop evidence-based reading and writing trainings for children with developmental dyslexia (e.g., Report of the National Reading Panel, 2000). Gabrieli (2009) suggested that the early identification for children who are at risk of dyslexia are important, because remediation usually maximize its effects in young children. In order to identify children who are at risk of developmental dyslexia, as well as provide them with effective intervention, influential cognitive factors for literacy acquisition need to be investigated at first. There are a considerable body of researches examining the association of dyslexia and cognitive abilities in alphabetic languages from early on (e.g.

Orton, 1937; Shankweiler, Liberman, Mark, Fowler & Fischer, 1979; Miles & Miles, 1999). In the past decades, studies of children with developmental dyslexia, have generated lots of evidence which indicated that learning to read and spell involves cognitive skills in visual, orthographic, phonological and semantic processing in alphabetic languages (Snowling & Hulme, 1989; Snowling, 2000).

Differed from the alphabetic orthography in which letters represent phonemes, each Chinese character represents a syllable and meantime a unit of meaning or morpheme. Chinese characters consist of many strokes, which makes them visually complex. Although the manifestation of difficulties in Chinese children with developmental dyslexia appears to be similar to which found in children learning alphabetic languages (Shu, McBride-Chang, Wu & Liu, 2006), McBride (2016) argued that reading development and its deficits in Chinese differ from those in alphabetical languages. Therefore, researches on Chinese literacy performance and cognitive abilities among Chinese children would help us understanding Chinese developmental dyslexia and shed light on which cognitive abilities should be tested for detecting cognitive origin of reading deficits in individual children.

Many studies focusing on the explorations of reading disabilities in relation to diverse cognitive constructs have been conducted on Hong Kong and Taiwan recently (Ho, Chan, Tsang & Lee, 2002; McBride-Chang & Kail, 2002; Siok & Fletcher, 2001; McBride-Chang, Lam, Lam, Doo, Wong & Chow, 2008). Prior researches on developmental dyslexia in Chinese (e.g. Ho, Chan, Lee, Tsang & Luan, 2004; Chung, Ho, Chan, Tsang & Lee, 2009; McBride-Change, Chung & Tong, 2011) suggest the involvement of visual skills, phonological awareness, naming speed and morphological awareness with the reading development and its deficits, as follows.

Visual skills are defined as the abilities which are applied to cognitive processes of organizing, interpreting, and storing representations of visual sensory stimuli, as well as their locations (Yang, Guo, Richman, Schmidt, Gerken, & Ding, 2013). Visual skills have been reported to be involved in detecting and memorising stroke patterns, which are essential for deriving meaning and sound when reading Chinese characters (Ho & Bryant, 1997a). A number of findings obtained by previous studies supported this notion (e.g., Ho & Bryant, 1999; Huang & Hanley, 1995; Siok & Fletcher, 2001; Tan, Spinks, Eden, Perfetti, & Siok, 2005; Lin & Uno, 2015). In some previous studies, pure copying skills, which were conceptualised as involving attention to visual detail and the ability to use visual-motor skills to represent such detail in print (Kalindi, McBride-Chang, Tong, Wong, Chung, & Lee, 2015), were found to be essential for reading and writing acquisition in Chinese (Siok & Fletcher, 2001; McBride-Chang, Chung, & Tong, 2011; Tan et al., 2005). However, there are few studies had examined the relationships between visual memory and Chinese literacy skills.

Phonological processing skills refer to the use of sound structure in a language. Phonological awareness, phonological recoding in lexical access, and verbal short-term memory have been identified as three primary phonological processing skills (Wagner & Torgesen, 1987) that are strongly correlated to reading ability in alphabetic languages. However, there is an ongoing debate regarding the association between phonological skills and the development of reading skills in Chinese. Ho, Law and Ng (2000) and Ho and Lai (1999) have reported that Hong Kong Chinese children with dyslexia are deficient in phonological awareness and phonological memory. A similar relationship between phonological skills and reading achievement in Chinese has also been reported by researchers across different areas of China such as Mainland China, Hong-Kong and Taiwan (Ho & Bryant, 1997b; Hu & Catts, 1998; Siok & Fletcher, 2001). While recognising the general importance of phonological skills for reading development in Chinese and English, some researchers suggested that phonological awareness skills did not always contribute to reading acquisition in Chinese significantly (Ho, Chan, Tsang & Lee, 2002; McBride-Chang, Cho, Liu, Wanger, Shu, Zhou, Cheuk & Muse, 2005). Furthermore, phonological memory deficits seem to cause developmental dyslexia in Chinese children (e.g., Ho, Law & Ng, 2000). Zhang and Zhang (1997) found that Chinese children with developmental dyslexia in Mainland China performed significantly worse in digit and text memory than normal children of the same age. Given these contradictory conclusions, it is necessary to further examine the influence of phonological skills on reading development in the Chinese context.

Phonological recoding in lexical access, another phonological processing skill defined by Wagner and Torgesen (1987), is usually measured by rapid automatized naming tasks that track the speed and automaticity of symbol recognition (Wolf, Bally & Morris, 1986). Given that many studies have demonstrated that this ability is linked with reading difficulties in both alphabetic languages (Wimmer, Mayringer, & Landerl, 2000) and Chinese (Liao, Georgiou & Parrila, 2008; McBride-Chang, Liu, Wong, Wong & Shu, 2012; Tan et al., 2005), naming speed is of significant interest in the field. Naming speed influences reading acquisition, but it is not clear whether the relationship between naming speed and Chinese literacy achievements change across different grades when other cognitive skills include into the consideration.

Furthermore, vocabulary has been shown to be an influential predictor of the acquisition of reading skills in Chinese. Shu et al. (2006) found that Chinese readers with developmental dyslexia differed from an age-matched control group in terms of their vocabulary skills. Early vocabulary knowledge has also sometimes emerged as an important factor in correlating Chinese reading performance in previous studies (e.g. Liu, McBride-Chang, Wong, Tardif, Stokes, Fletcher & Shu, 2010; Pan, McBride-Chang, Shu, Liu, Zhang, & Li, 2011). Most of the abovementioned studies used a vocabulary test measuring only expressive vocabulary skill. In other words, they did not use a receptive vocabulary test. In Uno and colleagues' study (2009), they found receptive vocabulary knowledge contributed to Japanese Kanji reading of school children. Therefore, receptive vocabulary knowledge might affect Chinese reading skills, since Japanese Kanji characters originated from Chinese characters. It is needed to investigate the relationships between vocabulary knowledge and reading abilities in Chinese using both expressive and receptive vocabulary tests.

Additionally, a growing amount of study has shown converging evidence on the importance of morphological awareness when reading Chinese, which is defined as awareness of, and access to, morphemes in words (Shu et al., 2006). In previous studies, morphological awareness was found to contribute uniquely to Chinese character recognition, character writing, reading fluency, as well as reading comprehension (McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Shu et al., 2006; Tong, McBride-Chang, Wong, Shu, Reitsma, & Rispens, 2011). These findings suggested that morphological awareness is crucial for Chinese reading and writing development.

In summary, previous researches have demonstrated that phonological skills, visual skills, naming speed, vocabulary knowledge and morphological awareness are important cognitive-linguistic skills for learning to read and write Chinese (e.g. Chan, Ho, Tsang, Lee, & Chung, 2006; Ho, Ng, & Ng, 2003; Liu & McBride-Chang, 2010; McBride-Chang et al., 2003; McBride-Chang & Ho, 2005; Shu et al., 2006; Tong et al., 2011). However, as above-mentioned, most previous cohort studies on the relationships between literacy development and cognitive constructs have been conducted mainly to children from Hong Kong and Taiwan (Huang & Hanley, 1997; Hu & Catts, 1998; McBride-Chang & Kail, 2002; Ho et al., 2004; McBride-Chang et al., 2008), whereas researches on reading and writing development in Mainland Chinese children are relatively fewer. The differences in scripts and literacy instruction methods implies the possibility of different optimal learning strategies (McBride, 2016). These differences may occur the discrepancy of cognitive abilities related to literacy development across Chinese different writing systems. Thus, the researches focusing on Mainland Chinese children's literacy development are very important. Furthermore, most of the previous studies recruited children in the particular grade as participants and they did not evaluate all potentially important skills (i.e., phonological skills, visual skills, naming speed, vocabulary knowledge and morphological awareness) comprehensively. These issues make it difficult to draw conclusions in the predictive power of each cognitive-linguistic skill in Chinese word reading as well as writing across various grades and over time.

3. Aims of the Present Studies

Based on the above review of the previous studies, there are the following limitations: 1) The validity and reliability of PRS as a screening checklist for learning disabilities have not been tested adequately. 2) There were still relatively few studies that have administered comprehensive cognitive tests to investigate the important predictors of both Chinese word reading and word writing in Mainland China. 3) Also, few studies have tested the longitudinal predictors of Chinese word reading and word writing across different grades in primary school. The present study addressed these issues. The primary aims of this study were 1) to examine the applicability of the PRS for Chinese children suspected of developmental dyslexia, and 2) to investigate relationships between cognitive-linguistic skills and reading/writing development in Chinese primary school children in Mainland China.

This study consisted of three parts. Study 1 aimed to clarify the validity of the PRS for detecting developmental dyslexia, i.e., how effectively the PRS can detect children who show low performance on objective reading and writing tests (Study 1-1). Moreover, we conducted a comprehensive set of cognitive ability tests to determine the reading and writing-related skills of Mandarin-speaking intermediate grade children, as a pilot study (Study 1-2). Since children in grade 3 have learned to read and write through formal school instructions for two years, they need to learn more and more Chinese characters and words without the assistance of Pinyin. As they enter into a relatively stable stage in the development of reading and writing skills, they are suitable to participant in this pilot study. The obtained results were compared with findings of previous studies that have conducted similar tests among children from Taiwan and Hong Kong, so that we can determined which tasks can be used to examined the association of Chinese literacy acquisition and cognitive abilities of Mandarin-speaking children at different ages in Study 2. Study 2 aimed to clarify whether the predictors for reading and writing skills differ across different ages. For this aim, we conducted a cross-sectional study in which Mandarin-speaking children from grade 1 to grade 6 participated, using a number of the cognitive ability tests that were selected and developed based on the findings of Study 1 and other previous research on Chinese literacy development. Study 3 investigated whether the relationship between literacy performance and cognitive-linguistic abilities changes with ages through a 2-years longitudinal study to track the development of word reading and writing in a group of children from grade 1 to grade 6.

In this way, the present study developed and administered vocabulary and cognitive tests to Mainland Chinese children, according to the characteristics of Chinese script and languages used in Mainland China, in order to examine the relationships between literacy development and cognitive abilities. The present study also aimed to obtain basic data for the exploitation of screening tests to detect children with reading and/or writing difficulties. Findings from this study might bring implications for how detect children suspected of developmental dyslexia as well as which literacy-related skills should be measured to offer an effective intervention to improve reading and writing abilities.

Table. 1 Cognitive abilities examined in the previous studies

		Variables						
	Literature	PA	PM	VS	RAN	MA	OA	Vocabulary
HK	Ho & Bryant,1997b	◎		○				
	Huang & Hanley, 1995	○		◎				○
	McBride-Chang & Kail, 2002	◎		○	○			○
	Ho et al., 2002	○	○		◎		○	
	Chan et al., 2006	○	◎		◎		◎	
	McBride-Chang, Lam, & Wong, 2011			◎	○	○	○	
	Pan et al., 2011	◎			◎			◎
	Tong, Tong & McBride, 2017	○				◎	○	○
TW	Huang & Hanley, 1995	○		◎				○
	Huang & Hanley, 1997	◎		○				○
	Hu & Catts,1998	◎	◎	○				
	Lin & Uno, 2015	○	○	◎	◎			○
	Liao, Kuo, & Mok, 2020	◎		◎	◎	◎	◎	
MC	Siok & Fletcher, 2001	◎		◎			○	
	Shu et al., 2006	○	○	○	◎	◎		◎
	Tan et al.,2005	○			◎			

Note: PA = Phonological awareness; PM = Phonological Memory; VS = Visual Skills; RAN = Rapid Automatized Naming; MA = Morphological Awareness; OA = Orthographic awareness
HK = Hong Kong; TW = Taiwan; MC = Mainland China

○＝Cognitive abilities tests have been conducted;

◎＝Significant predictors for Chinese reading

Chapter2

Study1: A Preliminary Research on Relationship between Reading /Writing Acquisition and Cognitive Abilities Among Mainland Chinese Children

Study1-1: Study on Assessment of Developmental Dyslexia in Mainland China: The Applicability of the PRS with Reading and Writing Test

Ⅰ.Purpose

The aim of this study was to assess the validity of Pupil Rating Scale-Revised (PRS) as a screening checklist for developmental dyslexia. In this study, we investigated how effectively the PRS can detect children who show low performance on objective reading and writing tests.

Ⅱ.Methods

1.Participants

The participants in study 1-1 were 140 third grade pupils (75 boys and 65 girls) from an elementary school in Ningbo Zhejiang, China. They were all native Chinese speakers. The following individual tests were administered to them when they enrolled in the third (June, 2017) and the group tests were conducted when they were fourth graders (October, 2017). Teachers in charge of these pupils were asked to rate their students when the participants enrolled in the fourth grade.

2. Measures

(1) Word-reading task

To evaluate the reading accuracy of Chinese words, we conducted a word-reading task. The stimuli consisted of 20 one-character words and 20 two-character compound words (see Appendix A). Equal numbers of stimuli in each character-length condition were classified into typical words or atypical words, in terms of the consistency of orthography-to-phonology mappings defined by Fang, Horng and Tzeng (1986). A character was classified as typical if the pronunciation of it was the most common pronunciation used in characters containing the same phonetic radical. A character was classified as atypical, if the pronunciation of the character was not the most common in characters containing the same phonetic radical. All words were selected from textbooks that had already been studied by the participants.

(2) Rapid word-reading task

To evaluate word-reading fluency, a rapid word-reading task was conducted. The stimuli consisted of 10 one-character words and 8 two-characters words that participants had already learned (see Appendix C). They were asked to read words as quickly and accurately as they could. Time was measured using stopwatches beginning when the children began to read, until they finished reading all the stimuli.

(3) Rapid passage-reading task

To evaluate reading fluency, a rapid passage-reading task was conducted. This task consisted of one paragraph with 336 words, and this original story was created by ourselves (see Appendix E). Participants were asked to read the passage as quickly and accurately as they could. Time was measured with stopwatches, beginning when children began to read, until they finished reading the passage.

(4) Word-writing task

To evaluate word-writing accuracy, a word-writing task was conducted (see Appendix F). 12 two-character compound words were selected as the stimuli and these were derived from textbooks widely used in Chinese primary schools. These words were printed out in Pinyin, and the children were then required to write down the corresponding Chinese words. The score of each participant was determined by totalling the number of correctly spelled words. A point was only awarded when both of the characters in a stimulus were spelled correctly.

(5) Raven's Coloured Progressive Matrices (RCPM)

Raven Coloured Progressive Matrices (Raven, Court, & Raven, 1995) were administered as a nonverbal intelligence test. The test consisted of 36 items and was divided into three sets. The items were ordered in terms of increasing difficulty. For each item, a coloured pattern with a missing part was presented to the children, and they were required to select the correct missing part from six choices. Each participant's score in this test was the number of correct answers for the three sets. RCPM was administered as an easy way to assess participants' intellectual maturity, and to exclude the effects of intellectual factors on reading/writing performance.

(6) The Pupil Rating Scale Revised

A Chinese version of the revised PRS modified by Jing et al. (1998) was used. It consisted of five subscales, including Auditory Comprehension, Spoken Language, Orientation, Motor Coordination, as well as Personal-Social Behaviour. The teachers in charge of the participants rated each child in terms of the five subscales.

3.Procedures

At the time of the first data collection, a word-reading task, a rapid word-reading task, and a rapid passage-reading task were administered to participants. For the word-reading task, rapid word-reading task, and rapid passage-reading task, each child was tested individually, and the examiners recorded errors. Each child’s responses were also audiotaped for later verification. The word-writing task and the RCPM were administered in the classrooms. In the second data collection, the word-writing task and the RCPM were administered to all the participants in this study who were also evaluated by their classroom teachers using the PRS Revised. Teachers in charge of the classes were asked to review the PRS evaluation methods before they rated their respective pupils. All of the checklists were collected on the same day. The present study was approved by the Ethics Committee of the University of Tsukuba (Graduate School of Comprehensive Human Sciences).

Ⅲ.Results

The children whose RCPM scores were below -1.5 SD were excluded (n = 7) from further study, to ensure the group were in the normal range for non-verbal IQ. The cut-off criterion in our studies was set to at least 1.5 SD below average. Given there was no formal and clear cut-off in diagnosing dyslexia, the operational criterion in our studies referred to the cut-off definition used for classifying individuals with dyslexia in previous researches (e.g., Chung et al., 2009; Siegel & Ryan, 1988).The children whose reading or writing test scores (tests 1 to 4) were below -1.5 SD (in more than one test) were classified as part of a RWD group (having a reading/writing disability), that is, they were thought to have ‘Reading deficits’ or ‘Writing deficits’. The main findings can be summarized as follows: 12% of the children (n = 16) were assessed as having a problem in reading Chinese Words accurately, 9% of the children (n = 12) were assessed as having a problem in reading fluency, and 8% of the children (n = 11) were assessed as having a problem in writing Chinese Words accurately. Among the RWD group, 54% of the children (n = 13) showed a single deficit in reading accuracy, reading fluency or writing accuracy. 29% of the RWD group children (n=7) showed double deficits in these reading/writing abilities, and about 17% of the children (n=4) showed triple deficits. Table 2 presents the deficit patterns of the RWD group.

Table 2. The deficit’s patterns of the RWD group

		Reading accuracy	Reading fluency	Writing accuracy
Single deficit	25% (n=6)	✕	○	○
(Total 54%, n=13)	16.6% (n=4)	○	✕	○
	12.5% (n=3)	○	○	✕
Double deficits	12.5% (n=3)	✕	✕	○
(Total 29%, n=7)	12.5% (n=3)	✕	○	✕
	4% (n=1)	○	✕	✕
Triple deficits	17% (n=4)	✕	✕	✕

Note: ○=Normal ✕=Deficit

According to the diagnostic criteria of the PRS, when total scores are below 65, and verbal scores are below 20, the child will be considered as having Verbal Learning Disabilities (Jing et al., 1998). On the other hand, when total scores are below 65, and nonverbal scores are below 40, the child will be considered as having Nonverbal Learning Disabilities. There was no participant who met these criteria. Thus, using PRS, no participants in this study were assessed as having Learning Disabilities. Table 3 presents the grade's mean score and standard deviation of the PRS.

Table 3. The Grade's PRS scores

PRS Score	Max	Min	Mdn	M	SD
Verbal	45	23	41	39.06	6.34
Nonverbal	75	42	66	65.23	9.95
Total	120	68	105	104.29	16.04

Note: N= 133

Pearson product-moment correlation coefficients between the total PRS scores and performance on literacy tests were calculated (Table 4). There was a significant correlation between the total PRS scores of whole grade and the performance on all literacy tests, with the exception of the rapid word-reading task.

Table 4. Correlation Coefficients between Total PRS Scores and the Grade's Scores on Reading and Writing Tests

	Total PRS Score	
Word-reading task	0.284	**
Rapid-word-reading task	-0.156	
Rapid-passage-reading task	-0.334	**
Word-writing task	0.476	**

Note: N= 133, *: $p < 0.05$ **: $p < 0.01$

Correlation coefficients between PRS subscales' scores and the scores of Reading and Writing Tests were also calculated per group (Table 5 and 6). In the Normal group, the scores of Auditory Comprehension and Spoken Language are significantly correlated to the scores of rapid passage-reading and word-writing tasks. Moreover, there was a significant correlation between the scores of Orientation and performance on all literacy tests.

Table 5. Correlation Coefficients between PRS Scores and the Scores on Reading and Writing Tests for Normal group

	Auditory Comprehension	Spoken Language	Orientation	Motor Coordination	Personal-Social Behavior
Word-reading task	0.199*	0.167	0.215*	0.095	0.162
Rapid-word-reading task	-0.103	-0.118	-0.218*	-0.110	-0.024
Rapid-passage-reading task	-0.319**	-0.274**	-0.305**	-0.303**	-0.212*
Word-writing task	0.392**	0.355**	0.300**	0.285**	0.317**

Note: N= 99, *: $p < 0.05$ **: $p < 0.01$

In the RWD group, on the other hand, only the score of word-writing task show the significant correlation with the scores of Auditory Comprehension and Orientation.

Table 6. Correlation Coefficients between PRS Scores and the Scores on Reading and Writing Tests for RWD group

	Auditory Comprehension	Spoken Language	Orientation	Motor Coordination	Personal-Social Behavior
Word-reading task	-0.019	-0.044	0.059	0.068	0.060
Rapid-word-reading task	0.155	0.274	0.214	0.133	0.190
Rapid-passage-reading task	-0.084	-0.020	-0.116	0.035	-0.148
Word-writing task	0.425*	0.363	0.470*	0.339	0.412*

Note: N= 24, *: $p < 0.05$ **: $p < 0.01$

A Mann-Whitney U test was conducted to compare the PRS Scores for the RWD group and the Normal group (Table 7). All PRS subscales' scores and the total score for the RWD group were significantly lower than those for the Normal group ($p < 0.05$).

Table 7. PRS Scores for the RWD and Normal Groups

	RWD (n=24)	Normal (n=99)		
PRS Score	M (SD)	M (SD)	U	p
Auditory Comprehension	15.58(2.73)	17.88(2.67)	652	0.000
Spoken Language	19.58(3.73)	22.16(3.52)	737	0.002
Orientation	15.63(2.60)	17.90(2.67)	650	0.000
Motor Coordination	12.33(2.10)	13.37(2.05)	825	0.014
Personal-Social Behavior	31.79(5.51)	35.23(5.47)	753.5	0.004
Verbal	34.96 (6.24)	40.04 (6.03)	660.5	0.000
Nonverbal	59.54 (9.47)	66.49 (9.65)	735	0.003
Total	94.5 (15.42)	106.54 (15.39)	712.5	0.002

Ⅳ. Discussion

No participants were identified as having learning disabilities by teachers' ratings in this study, even though 18% (n = 24) of the students showed low performance on objective reading and/or writing tests. In our study, 12% of the children (n = 16) were assessed as having problem in reading accuracy only. The estimate of number in the present study was relatively high comparing to 9.7% prevalence rate of developmental dyslexia in Hong Kong (Chan, Ho, Tsang, Lee & Chung, 2007). Indeed, depending on the different definition and criteria that researchers adopted, the prevalence rate of developmental dyslexia are about 5% to 10% in Chinese children (Chan et al., 2007). However, further analyses are needed to make it clear how many children who had low scores on literacy tests also performed poorly on cognitive abilities tests.

Regarding PRS scores, although the RWD group's PRS scores were significantly lower than those of the Normal group, none of the children in the RWD group met the PRS diagnostic criteria. It appears to be difficult to detect individual differences in terms of literacy achievement based on the results of PRS. It is hard to say that the PRS is useful for identifying children with developmental dyslexia.

Although the PRS's subscales do not include any questions related to reading or writing abilities, some reading and writing tests in this study were significantly correlated with the total PRS scores. This suggests that the PRS might be showing the relationship between reading and writing abilities in Chinese. Previous research found some relationships between subscales and reading ability. For example, Colligan (1979) found that Auditory Comprehension correlates highly with reading capability in English. The reason that there is a relationship between Auditory Comprehension and reading seems to be that this subscale includes measures such as following instructions and retaining information, both associated with working memory which has been implicated as a contributory factor in dyslexia. The subscale of Spoken language is also directly linked to reading, and has also been found to be associated with performance of reading in English-speaking children (Colligan, 1979). The present study also showed that some scores on the reading and/or writing tests were significantly correlated with the scores of Auditory Comprehension but these correlations were found in the Normal group only. However, no such relationship pertained for the RWD group, who showed only a correlation between word writing and Auditory Comprehension. In addition, the Normal group's reading and writing test performances were significantly correlated with the scores of Spoken Language, while the RWD's reading and writing test performances were not. Furthermore, the Orientation scores of the Normal group significantly correlated with their performance on reading and writing tests. Being oriented means that one has an accurate awareness of time, place, direction, and relationships. The PRS includes these four aspects of orientation, some of which have been associated with dyslexia (Myklebust, 1981), aspects which tend to be overlooked in more recent tests. Thus, these results suggest that performance on reading and/or writing tests in Chinese were correlated with the abilities of Auditory Comprehension, Spoken Language, and Orientation overall, which is consistent with the results of previous research in English. Moreover, the comparison between the Normal and RWD groups shows that the RWD group's scores on all of the subscales were significantly lower than those of the Normal group.

In contrast, Jing et al. (1998), who translated and revised the PRS into Chinese, examined pupils from primary schools in Guangzhou, and found that the prevalence of pupils with learning disabilities in Guangzhou was 8.3%. In addition, Wang et al. (2010) conducted investigations in four primary urban schools in Zhanjiang, and found that 10.3% of the participants were identified as having learning disabilities. It seems that these previous studies did screen out children with learning disabilities in Chinese. The difference between these studies and the current study was that in this study objective measures of literacy were administered, so that we were able to compare the ratings on the PRS with actual reading and writing achievement. By contrast, the previous studies relied on the findings of the PRS to identify children with difficulties, and the question of whether children suspected of learning disabilities have really reading and/or writing deficits is unclear. In the aspect of the detection of problems in reading and writing development, this study suggests that the findings of previous studies (Jing et al., 1998; Wang et al., 2010) might need further investigation on children's reading and writing achievement.

Sun and colleagues (2013) conducted studies on over 6000 students from primary schools to investigate the prevalence of developmental dyslexia and its potential risk factors. In the study by Sun et al. (2013), children with dyslexia were identified not only based on the scores of PRS, but also with reference to the scores of the Dyslexia Checklist for Chinese Children (DCCC), a Chinese language test and the Combined Raven's Test. This suggested that when using the PRS as a screening test for developmental dyslexia, some other supplementary tests are necessary. According to the study of Sun et al. (2013), gender, mother's education level, and learning habits were associated with dyslexia. Since PRS was used to evaluate children's behavioral characteristics at school by their teacher, a further study might be needed to investigate the family environment and children's behavior at home when screening for learning difficulties. Moreover, the study of Sun and colleagues (2013) investigated students only from grade 3 to grade 6. Children from grade 1 to grade 2 should also be included in the investigation in order to clarify the prevalence rate of dyslexia in young children and start to intervene as early as possible.

In addition, the PRS has also been used for screening bilingual or multilingual students with study problems, as well as in learning English. For example, Johnson (1997) conducted investigations in an international school in Belgium to compare the learning achievements of pupils with the teachers' evaluations of these children using the PRS. The results of Johnson's study suggest that the PRS may indeed aid in the early identification of youngsters in the process of acquiring English who may also have learning problems.

Previous studies have considered the PRS as an effective tool for identifying learning disabilities. However, we are concerned that pupils who use a different language in school and in daily life might have problems listening or speaking. Many children with learning disabilities have difficulty processing auditory information (Johnson, 1997). It is thought that teachers have tended to give lower scores for bilingual pupils with some learning problems, since the PRS subscales emphasize the pupils' abilities on auditory comprehension and spoken language.

On the other hand, there are many kinds of dialects in most regions of China, whereas usually Mandarin is used in schools. Children who speak dialects at home use Mandarin at school. The PRS has been conducted in many regions of China, including Zhejiang, Jiangsu, and Guangzhou. In previous studies (Jing et al., 1998; Wang et al., 2010), teachers were asked to follow the manual of the PRS and rate the children objectively. As a result, the verbal and total scores of pupils in Guangzhou where children may speak Cantonese at home, were relatively lower than those in other regions (Wei, 2004). The influence of Cantonese, which retains many characteristics of ancient Chinese, has been found to lead to lower evaluations of pupils in Guangzhou. Children who speak a dialect seem to show low auditory comprehension and low spoken-language skills relative to children who speak Mandarin. Consequently, teachers are more likely to identify them as having learning disabilities.

According to the international definition of learning disabilities (e.g., National Joint Committee on Learning Disabilities, 2016), not only Speaking and Listening difficulties, but also Reading, Spelling, and Calculating are included. A learning disability is represented as a category of disabilities in several domains (Fletcher, Lyon, Barnes, Stuebing, Francis, Olson, Shaywitz & Shaywitz, 2002). In contrast, the subscales of PRS are focused on Auditory Comprehension and Spoken Language. Although the secondary consequences of developmental dyslexia may include problems in reading comprehension, and reduced reading experience can impede growth of vocabulary as well as background knowledge (Lyon et al., 2003), Auditory comprehension in children with developmental dyslexia is not necessarily poor. Thus, it can be considered that children who have reading or writing problems may be overlooked when we base our assessments solely on PRS scores. Actually, the results of present study indicate that none of the children at risk on reading or writing would be correctly identified using the PRS. Although the teachers were required to evaluate their students following the evaluation methods of PRS, we could not expect all of them were objective raters. Moreover, it is not clear that the PRS was designed to consider differences in IQ level between those children who might be diagnosed as developmental dyslexia, and those who have a more generalized learning difficulty based on low IQ. Furthermore, many studies simply define groups of children as ‘learning disabled’ despite evidence that the meaning of learning disabled varies in different academic domains and even in different countries (Fletcher et al., 2002). Although the PRS is divided into verbal and nonverbal subscales, it is difficult to specify what problems the children have, by relying simply on the results of the PRS. When screening out a child with developmental dyslexia, which is considered a common subtype of learning disability, objective reading and writing tests are necessary. More importantly, the use of objective reading and writing tests would bring the understanding of what kind of literacy problem a child has. Such as a specific identification of reading and/or writing difficulties can then directly link to intervention.

Study1-2: Cognitive Abilities Related to Reading and Writing Skills in Intermediate Grade Mainland Chinese Children

Ⅰ. Purpose

In the present study, we conducted a number of the cognitive ability tests deployed in previous pieces of research on Chinese word reading development, including visual skills, phonological skills, RAN, and vocabulary knowledge, in order to determine the reading and writing-related skills of Mandarin-speaking children in intermediate grade, as well as to make a comparison with studies that have conducted similar tests among children from Taiwan and Hong Kong.

Ⅱ. Methods

1.Participants.

The same participants in Study 1-1.

2.Measures

(1) Reading tests.

The reading tests comprised tests focusing on both reading accuracy and reading fluency. In the reading accuracy test, two sub-tests were included: word reading and non-word reading tasks. In the reading fluency test, three sub-tests were included: rapid word reading, rapid non-word reading, and rapid paragraph reading tasks.

a. Reading accuracy tests.

The word reading (the same measure in Study 1-1) test consisted of 40 words (see Appendix A), while the non-word reading test consisted of 40 non-word stimuli (see Appendix B). Each test included 20 one-character and 20 two-character stimuli in Chinese. For both tests, 10 out of 20 one-character and 20 two-character words were contained in typical reading patterns, as well as 10 in atypical ones. The stimuli were printed on two A4 size sheets, with the participants required to read them aloud. All of the word stimuli were selected from textbooks that had already been studied by the participants.

The one-character non-word stimuli were the component characters of disyllabic words, which did not comprise meaningful words in and of themselves. The two-character non-word stimuli were created by replacing the characters used in the two-character word reading test. In the reading accuracy tests, each participant's score was the number of correctly pronounced stimuli.

b. Reading fluency tests.

The rapid word reading test (the same measure in Study 1-1) consisted of 18 word stimuli (see Appendix C and D) and the rapid non-word reading test consisted of 18 non-word stimuli, with each consisting of 10 one-character and 8 two-character stimuli in Chinese. All of the word stimuli were selected from textbooks that had already been taught and were therefore familiar to the children. The one-character non-word stimuli were the component characters of disyllabic words, which did not comprise meaningful words in and of themselves. The two-character non-word stimuli were created by replacing the character in the two-character compound word. For the rapid paragraph reading test (the same measure in Study 1-1), we used an original story created by ourselves (see Appendix E). This paragraph consisted of 336 words.

In the fluency test, the participants were required to read the word, non-word, and paragraph as fast as possible. The duration of each task was estimated by the experimenter using a stopwatch, and this measure represented the participant's score.

(2) Word-writing test.

The same measure in Study 1-1 (see Appendix F).

(3) Phonological awareness tests.

The phonological awareness tests, which included an onset deletion and a rime deletion task, were modified from the phonological tests administered by Lin and Uno (2015). The testing methods and scoring procedures were same as their tasks, while the stimuli were different from those used in their study. In two practice runs and five trials each, the participants were required to delete the onset or rime from the syllables and answer orally. Each sub-task included five items, making a total of 10 real syllables. Each syllable was orally presented to the children, and they were then required to repeat the syllable. Following this, they were asked to repeat the syllable, but to omit a target sound which was either the onset or rime of the syllable. Each participant's score for both the onset and rime deletion tasks was the number of correct answers out of the 5 items.

(4) Phonological memory test.

In two practice runs and ten trials, the participants were asked to complete non-word repetition tests in which the stimuli consisted of 3-9 syllables. This measure was modified form the phonological memory task used in the study of Chan et al. (2006). The testing method was same as their task, while the stimuli were different from those used in their study. The participants were first required to listen to each non-word and then to repeat them. The stimuli were ordered in terms of the increasing length of the syllables. For the non-word repetition test, however, the real syllables were combined in a random order. Each participant's score was the number of correctly pronounced non-words out of the 10 items.

(5) Rey-Osterrieth Complex Figure Test (ROCFT).

The ROCFT (Osterrieth, 1993) includes copy drawing, immediate recall, and delayed recall tasks. The participants were required to copy a complicated figure (copy drawing), after which they were required to draw the figure again without the target stimulus for reference (immediate recall). After about 30 minutes, the children were then asked to draw the figure again (delayed recall). The maximum score for each task was 36, calculated according to the ROCFT scoring manual. In order to minimize the impact of motor skills on the visual memory task, the immediate recall and delayed recall scores were divided by the score of copy task and the ratios of short-term visual memory and long-term visual memory were calculated and used in the analysis.

(6) Rapid automatized naming (RAN).

RAN tests, which were developed by Kaneko and colleagues (2004), were also administered to the participants. The children were asked to name, as fast as possible, drawings of objects and digits that were printed in rows on A4 size paper. The RAN tests consisted of one practice and three trials. The time used to name all the stimuli was also accounted for in each trial and the average duration of the three trials was used as the participant’s score in the analyses.

(7) Standardized Comprehension Test of Abstract Words (SCTAW).

The SCTAW, a standardised test developed in Japan (Uno, Haruhara & Kaneko, 2002), was conducted in order to test the participants’ vocabulary knowledge. The participants were given the target word orally and were then presented with six pictures of each item on a slide projector screen. The participants were required to repeat the word orally twice after the experimenter, and were then asked to select one picture and circle the corresponding number on the paper. As the test was originally conducted in Japanese, the Chinese target words were based on those used in a study by Lin and Uno (2015). Each participant's score was the number of correct answers.

(8) Nonverbal intelligence test.

Raven’s Coloured Progressive Matrices (RCPM). The same measure in Study 1-1.

3. Procedures.

The individual tests were administered in quiet rooms in the participants’ school, while the group tests were administered in their classrooms. The individual sessions lasted approximately 15-20 min, while the group sessions lasted 35-40 min.

4. Statistical Methods.

The RCPM mean score was 29, while the standard deviation was 4. Data from participants who obtained RCPM score below -1.5 SD of the mean score, as well as from participants who did not participate in all the tests, were excluded. This resulted in the exclusion of seven children. As a result, 133 children in total were included in the analysis (71 boys and 62 girls). The statistical analysis methods used in the current study were partly referenced to the study of Park and Uno (2015). Because the main purpose of this study was to clarify the characteristics of the cognitive abilities that are predictors of Chinese reading and writing abilities, exploratory factor analysis (principal factor method, varimax rotation) and multiple regression analyses were conducted. The exploratory factor analysis was conducted to summarise the correlation structure of 8 variables. After selecting the factors, multiple regression analyses were conducted to determine how effectively those factors predicted reading and writing abilities.

Ⅲ. Results

Table 8 shows the descriptive statistics for each test regarding the 133 children.

Table 8. Descriptive statistics on the nonverbal intelligence test, reading tests, writing test, and cognitive abilities tests

Measures	Maximum	Minimum	Mean	SD
Nonverbal intelligence test				
RCPM (36)	36.00	19.00	28.63	4.13
Reading tests				
Word reading test (40)	40.00	32.00	38.08	1.80
Non-word reading test (40)	40.00	25.00	33.85	3.19
Rapid word reading test (sec)	29.55	5.97	14.46	4.17
Rapid non-word reading test (sec)	59.50	8.54	18.70	6.05
Rapid paragraph reading test (sec)	166.60	42.77	85.38	20.12
Writing test				
Word-writing test (12)	12.00	0.00	7.96	3.02
Cognitive abilities tests				
Onset deletion (5)	5.00	0.00	4.44	0.93
Rime deletion (5)	5.00	0.00	4.17	1.23
Non-word repetition	10.00	3.00	7.18	1.56
ROCFT copy drawing (36)	36.00	9.50	32.34	4.25
Ratio of ROCFT immediate recall	1.68	0.01	0.62	0.23
Ratio of ROCFT delayed recall	1.58	0.15	0.65	0.22
RAN (sec)	23.30	8.91	13.43	2.65
SCTAW (16)	15.00	4.00	9.92	2.12

A correlation analysis of the literacy tests revealed that the performances on all the reading and writing tests were significantly correlated (p<0.01).

A correlation analysis of the variables indicated that word reading was significantly correlated with the ROCFT immediate recall (r=0.208, p<0.05), ROCFT delayed recall (r=0.183, p<0.05), RAN (r=-0.203, p<0.05), and non-word repetition (r=0.285, p<0.01) tests. On the other hand, non-word reading had correlations with the ROCFT immediate recall (r=0.177, p<0.05), onset (r=0.175, p<0.05), rime deletion (r=0.190, p<0.05), and non-word repetition (r=0.222, p<0.05) cognitive tests. Rapid word reading (r=0.445, p<0.01) and rapid non-word reading (r=0.401, p<0.01) were also significantly correlated with RAN, while rapid paragraph reading had low-to-moderate correlations with the ROCFT immediate recall (r=-0.205, p<0.05), ROCFT delayed recall (r=-0.175, p<0.05), RAN (r=0.498, p<0.01), and non-word repetition (r=-0.209, p<0.05) cognitive tests. The word-writing test was significantly correlated to RAN (r=-0.264, p<0.01), onset deletion (r=0.191, p<0.05), and non-word repetition (r=0.196, p<0.05).

ROCFT immediate (r=0.190, p<0.05) and delayed recall (r=0.244, p<0.01) had low correlations with SCTAW. Moreover, ROCFT immediate recall was significantly correlated with ROCFT delayed recall with a high correlation (r=0.920, p<0.01), as well as RAN (r=-0.201 p<0.05). Non-word repetition was significantly correlated with onset deletion (r=0.211, p<0.05) and ROCFT immediate recall (r=0.179, p<0.05) with low correlations. Furthermore, onset deletion was significantly correlated with rime deletion (r=0.287, p<0.01). Table 9 shows the results of the correlation analyses.

Table 9. Pearson correlation analyses of all variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(1) SCTAW	–													
(2) ROCFT copy	0.040	–												
(3) ROCFT imm	**0.190***	0.014	–											
(4) ROCFT del	**0.244****	0.003	**0.920****	–										
(5) RAN	-0.095	-0.099	**-0.201***	-0.147	–									
(6) onset Del.	0.021	0.085	-0.032	-0.025	-0.062	–								
(7) rime Del.	0.022	-0.151	0.026	0.045	-0.098	**0.287****	–							
(8) non-word rep	0.084	0.097	**0.179***	0.114	-0.035	**0.211***	0.080	–						
(9) W Reading	0.137	0.091	**0.208***	**0.183***	**-0.203***	0.082	-0.013	**0.285****	–					
(10) NWReading	0.030	-0.014	**0.177***	0.142	-0.146	**0.175***	**0.190***	**0.222***	**0.612****	–				
(11) Rap WReading	-0.034	-0.085	-0.059	-0.035	**0.445****	-0.065	-0.060	-0.019	**-0.374****	**-0.371****	–			
(12) Rap NW Reading	-0.006	0.034	-0.097	-0.095	**0.401****	-0.071	-0.068	-0.007	**-0.404****	**-0.459****	**0.732****	–		
(13) Rap Par Reading	-0.103	-0.114	**-0.205***	**-0.175***	**0.498****	-0.131	-0.139	**-0.209***	**-0.558****	**-0.602****	**0.663****	**0.710****	–	
(14) W Writing	0.085	0.140	0.167	0.164	**-0.264****	**0.191***	0.126	**0.196***	**0.501****	**0.498****	**-0.325****	**-0.343****	**-0.515****	–

Note. *p<0.05. **p<0.01. ***p<0.001.

In terms of the exploratory factor analysis, Factor 1 consisted of two variables: ROCFT immediate recall (0.971) and ROCFT delayed recall (0.945). This factor appeared to include variables measuring visual processing skills, such as visual short-term and long-term memory (Park & Uno, 2015), and, consequently, Factor 1 was labelled 'Visual memory'. Factor 2 included two variables: onset deletion (0.619) and rime deletion (0.521). This factor appeared to consist of a variable correlated with phonological processing skills, such as skills in identifying, manipulating, and reproducing phoneme units (Park & Uno, 2015). As a result, Factor 2 was labelled 'Phonological awareness'. Factor 3 included one variable: ROCFT copy drawing (0.557). This factor appeared to consist of information regarding visual perceptual skill, and thus Factor 3 was labelled 'Visual perception'. The results of the exploratory factor analysis are shown in Table 10.

Table 10. Factor analysis of the correlation structure of 8 variables

	Factor 1 Visual memory	Factor 2 Phonological awareness	Factor 3 Visual perception	Communalities
ROCFT imm	**0.971**	-0.018	-0.016	0.944
ROCFT del	**0.945**	-0.026	-0.064	0.897
SCTAW	0.234	0.068	0.052	0.062
RAN	-0.191	-0.134	-0.082	0.061
Onset Del.	-0.014	**0.619**	0.109	0.395
Rime Del.	0.040	**0.521**	-0.314	0.372
Non-word rep	0.162	0.281	0.160	0.131
ROCFT copy	0.037	0.045	**0.557**	0.314
Contribution of factor	1.957	0.760	0.461	
Cumulative contribution ratio	24.458	33.954	39.716	

Multiple regression analyses were administered in order to confirm how effectively 'Visual memory', 'Phonological awareness', and 'Visual perception' would predict reading and writing abilities. Following the procedure of Park and Uno (2015), we used the performance in the ROCFT immediate recall, onset deletion, and ROCFT copy drawing as the representative values of each factor in the factor analysis for multiple regression analyses, because these factors had greater variable loading on each factor. The SCTAW, RAN, and non-word repetition loading on each of the three factors were relatively low. In previous studies, Pan and colleagues (2011) reported that vocabulary knowledge was a unique developmental predictor of reading ability, reading fluency, and dictation regarding Chinese characters. Rapid naming significantly predicted word reading and spelling ability among Hong Kong Chinese students from grades 1 to 4 in Chan and colleagues' study (2006), as well as Mainland Chinese students in grades 5 and 6 in research by Shu and colleagues (2006). It would also be interesting to understand the role of SCTAW and RAN performances on reading and writing acquisition. Therefore, we used the performances in these tests in the multiple regression analyses in order to determine the relationship between the dependent variables (reading and writing performances) and the independent variables, with SCTAW and RAN labelled as 'Receptive vocabulary' and 'Naming speed', respectively. Thus, participants' performances in ROCFT immediate recall, onset deletion, ROCFT copy drawing, SCTAW, and RAN were used as representative values for each variable ('Visual memory', 'Phonological awareness', 'Visual perception', 'Receptive vocabulary', and 'Naming speed') in multiple regression analyses.

The results of the multiple regression analyses revealed that 'Visual memory' ($\beta=0.193$, $p<0.05$) significantly predicted two-character word reading ($F(5, 126)=3.56$), while 'Phonological awareness' ($\beta=0.191$, $p<0.05$) was a unique predictor of two-character nonword reading ($F(5, 126)=1.67$). Furthermore, the results indicated that rapid word reading, rapid non-word reading, and rapid paragraph reading ($F(5, 126)=6.38$, 5.20, and 9.58, respectively) were all significantly predicted by 'Naming speed' ($\beta=0.446$, $p<0.001$, $\beta=0.405$, $p<0.001$, $\beta=0.461$, $p<0.001$, respectively). Furthermore, word writing performance (*F* (5, 126) =3.69) was also significantly predicted by both 'Phonological awareness' (β=0.176, $p<0.05$) and 'Naming speed' (β=-0.215, $p<0.05$) when the cognitive ability measures were used as the independent variables. The finding in previous studies suggests that reading ability strongly associated with Chinese writing (Tan et al., 2005; Chan et al., 2006). The results of Cheng-Lai, Li-Tsang, Chan and Lo's study (2013) reported that Chinese character naming was a unique predictor correlated with word dictation. It was of interest to examined the association between reading and writing performance with other cognitive abilities in the same context. In the present study, participants' performance in word writing (F (7, 124) =10.00) was significantly predicted by their performances in word reading (β=0.268, $p<0.01$) and non-word reading (β=0.296, $p<0.01$) when word reading and non-word reading measures were added as the independent variables. 'Visual perception' and 'Receptive vocabulary' did not predict Chinese reading or writing performance. The results of the multiple regression analyses are shown in Table 11 to 13.

Table 11. Multiple regression analysis between the scores on reading accuracy and each variable

Variables	β coefficient	t	p	Adj.R^2
Two-character word reading				0.089
Visual memory	0.193	2.227*	0.028	
Phonological awareness	0.097	1.155	0.250	
Visual perception	0.139	1.653	0.101	
Receptive vocabulary	0.139	1.631	0.105	
Naming speed	-0.099	-1.155	0.250	
Two-character non-word reading				0.025
Visual memory	0.114	1.277	0.204	
Phonological awareness	0.191	2.194*	0.030	
Visual perception	-0.029	-0.338	0.736	
Receptive vocabulary	0.003	0.034	0.973	
Naming speed	-0.090	-1.018	0.311	

Note. N=133 *$p<0.05$.

Table 12. Multiple regression analysis between the scores on reading fluency and each variable

Variables	β coefficient	t	p	Adj. R^2
Rapid word reading				0.170
Visual memory	0.031	0.374	0.709	
Phonological awareness	-0.049	-0.537	0.592	
Visual perception	-0.039	-0.487	0.627	
Receptive vocabulary	-0.002	-0.029	0.977	
Naming speed	0.446	5.441***	0.000	
Rapid non-word reading				0.138
Visual memory	-0.023	-0.278	0.781	
Phonological awareness	-0.051	-0.626	0.533	
Visual perception	0.078	0.952	0.343	
Receptive vocabulary	0.026	0.308	0.758	
Naming speed	0.405	4.849***	0.000	
Rapid paragraph reading				0.247
Visual memory	-0.108	-1.367	0.174	
Phonological awareness	-0.099	-1.302	0.195	
Visual perception	-0.057	-0.742	0.460	
Receptive vocabulary	-0.036	-0.470	0.639	
Naming speed	0.461	5.913***	0.000	

Note. N=133 *p<0.05. **p<0.01. ***p<0.001.

Table 13. Multiple regression analysis between the scores on writing accuracy and each variable

Variables	β coefficient	t	p	Adj.R^2
Word writing				0.093
Visual memory	0.124	1.432	0.155	
Phonological awareness	0.176	2.102*	0.038	
Visual perception	0.101	1.202	0.232	
Receptive vocabulary	0.023	0.275	0.784	
Naming speed	-0.215	-2.515*	0.013	
Word writing				0.325
Visual memory	0.032	0.425	0.671	
Phonological awareness	0.106	1.439	0.153	
Visual perception	0.096	1.316	0.190	
Receptive vocabulary	0.000	0.005	0.996	
Naming speed	-0.143	-1.908	0.059	
Word reading	0.268	2.857**	0.005	
Non-word reading	0.296	3.184**	0.002	

Note. N=133 *p<0.05. **p<0.01.

Ⅳ. Discussion

1. Cognitive Predictors for Reading and Writing Abilities of Mainland Chinese Children in Intermediate Grade

The results of present study showed that phonological awareness significantly predicts non-word reading. The results of our study are in line with previous studies on alphabetic languages (e.g., Castles & Coltheart, 1993; Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996). For alphabetic languages, phonological decoding skills are often assessed by requiring participants to read non-words (Rack, Snowling & Olson, 1992). Previous research has classified children who mainly have difficulties in phonological processing skills into a phonological dyslexia subtype (Ho, Chan, Tsang & Lee, 2002). These children usually provide poor performances in pseudo-word reading tasks but adequate performances in exception-word (irregular word) reading (e.g., Castles & Coltheart, 1993; Manis et al., 1996). Furthermore, compared to younger children matched for reading levels, children with dyslexia were found to be particularly poor in terms of reading non-words (e.g., Snowling, 1981; Siegel & Ryan, 1988). Similar to the results of alphabetic language studies, Ho and Bryant (1997a) found that there were significant correlations among Chinese pseudo-character reading and rhyme detection in first grade children. Unlike Ho and Bryant's study (1997a), which used pseudo-characters as stimuli, our study administered a non-word reading task in which the stimuli were created by replacing the characters used in the two-character word reading task. Although the stimuli used in Ho and Bryant's study (1997a) are different from ours, a similar result was obtained. That is, phonological awareness affects a student's performance in Chinese non-word or pseudo-character reading.

It is interesting that in our study, phonological awareness predicted non-word reading, but not word reading. The findings of previous studies (e.g., Huang & Hanley, 1995; Lin & Uno, 2015; McBride-Chang, Cho, & Muse, 2005) demonstrate that phonological awareness is not a universal predictor of children's Chinese word-reading acquisition, which is supported by our findings. However, in contrast to our results, many studies have reported that performance on phonological awareness tasks is significantly correlated to Chinese word reading skills (e.g., Ho & Bryant, 1997b; Huang & Hanley, 1997; Hu & Catts, 1998; Siok & Fletcher, 2001; McBride-Chang & Kail, 2002). In addition, the tasks to measure phonological awareness were different across the studies mentioned above. These different findings can be accounted for the following reasons: the participants varied in age and reading experience from pre-schoolers (Ho & Bryant, 1997b) to third graders (Huang & Hanley, 1995); moreover, the tasks to measure phonological awareness, reading and writing abilities differ across previous studies.

The results of the multiple regression analyses revealed that visual memory significantly predicted Chinese word reading accuracy of intermediate grade children. This finding is consistent with previous results suggesting that visual skill contributes to Chinese reading ability (Ho & Bryant, 1999; Lin & Uno, 2015; Siok & Fletcher, 2001). Visual skills, including the ability to recognise, discriminate, and remember unfamiliar figures, are critical for learning Chinese characters. Huang and Hanley's (1995) study found that visual skill is the strongest predictor of reading performance in children from both Taiwan and Hong Kong. Furthermore, in the study of Huang and Hanley (1995), performance on the visual memory test (visual paired associates) was more powerfully correlated with reading performance than the visual perceptual test (visual form discrimination). Furthermore, in studies seeking to identify children at the greatest risk of dyslexia at a very young age, McBride-Chang and colleagues (2008, 2011) found a relationship between visual skills and early Chinese word recognition, suggesting that visual skills may influence Chinese literacy acquisition among at-risk readers.

In line with studies conducted by Huang and Hanley (1995) and Lin and Uno (2015), we found that the score on the visual memory test (measured by ROCFT immediate recall) was the most powerful predictor of word reading performance, rather than the visual perceptual test (measured by ROCFT copy drawing). It appears that visual memory is strongly correlated with the ability to learn new Chinese characters. Given that the Chinese education system requires that children should be able to identify about 4,000 different characters by the end of primary school education (Huang & Hanley, 1995), excellent visual memory skills may facilitate children's ability to learn to read Chinese characters. In contrast, according to Huang and Hanley’s (1995) study, visual skills were not a significant predictor of reading abilities in children who speak alphabetic language (i.e., English). Our finding that visual memory ability is an important predictor of Chinese word reading ability is consistent with many prior studies, indicating that visual memory is more important in terms of the acquisition of the visually complicated Chinese orthographies than alphabetic ones.

This study also found that naming speed, as measured by the RAN test strongly predicted the reading fluency of words, non-words, and paragraphs. The correlation analyses suggest that RAN shows a powerful association with rapid reading tasks rather than reading tasks in intermediate grade. RAN has been reported to be an important predictor of reading attainment in Chinese in many existing studies (e.g., Lei, Pan, Liu, McBride-Chang, Li, Zhang, Chen, Tardif, Liang, Zhang & Shu, 2011; Liao et al., 2008;

McBride-Chang & Ho, 2005; Shu et al., 2006). Prior research into Chinese speaking subjects has found that RAN is significantly related to character reading among children ranging from kindergarten to third-grade in Hong Kong and Taiwan (Lin & Uno, 2015; Hu & Catts, 1998; Chow, McBride-Chang & Burgess, 2005; Chen, Hao, Geva & Zhu, 2009). The findings of present study support the observation in the study of Wolf and Bowers (1999) that RAN is correlated with reading fluency more strongly than with reading accuracy. Previous research involving Japanese students has shown that the ability of automatization, as measured by RAN, significantly predicts Japanese Kana reading performance (one of the Japanese writing systems, which represents the syllable, or mora, of the Japanese language) and paragraph reading speed (Haruhara, Uno, Asahi, Kaneko & Awaya, 2011). Similar to the findings in both alphabetic languages and Japanese (e.g., Georgiou, Parrila & Kirby, 2009; Haruhara et al., 2011), RAN was correlated more strongly with reading fluency than with reading accuracy in intermediate grade in Chinese. The RAN task in the present study was used in order to measure the ability to retrieve phonological information from symbols or semantic information. The process during performing the RAN task is same as the process involved in the rapid reading task, in which the children retrieve the phonological representation from characters or words as quickly as possible. Therefore, it is likely that we obtained the result showing a strong association of the RAN performance with reading speed.

In this study, none of the analysed cognitive abilities successfully predicted Chinese writing ability when the performance on the word and non-word reading tests were used as predictive variables in multiple regression models. This finding suggests that reading ability is the most important predictor for accurate Chinese writing, and the importance of reading attainment in terms of the development of writing accuracy is in line with previous studies (Chan et al., 2006; Tan et al., 2005; Treiman, Tincoff, Rodriguez, Mouzaki & Francis, 1998). The results of Cheng-Lai and colleagues' (2013) study reported that Chinese character naming was a unique predictor for word dictation. Tan and colleagues (2005) have also found that writing performance was strongly correlated with Chinese reading in beginning and intermediate level readers. In Chinese, there are lots of homophones, and this causes the phonology-to-orthography correspondence relatively inconsistent. In the present study, stimuli of the writing task were printed out in Pinyin, and the children were required to write down the corresponding Chinese words. Chinese children who are skilled readers are good at the use of mappings between characters and sounds. Proficient reading skills may facilitate their abilities to retrieve the orthographic forms of the words from the sounds and meanings of the target words in their mental lexicon during the writing task (Cheng-Lai et al., 2013).

2. Comparison of Our results with the Findings of Previous Studies in Hong Kong and Taiwan

Consistent with the previous researches conducted in Hong Kong and Taiwan which use traditional Chinese characters, visual skills are important predictors for Chinese reading ability in Mandarin speaking children of this study who use simplified Chinese characters. The results of the present study revealed that especially visual memory is important in Chinese word reading even for intermediate grade children. This finding indicates that visual skills are correlated with the acquisition of Chinese characters or words, including both traditional or simplified characters.

On the other hand, in contrast to the reports that phonological awareness played an important role in the Chinese word reading ability of younger children in Taiwan and

Hong Kong, we found that phonological awareness is significantly correlated with Chinese non-word reading but not word reading. The participants in this study were intermediate grade children who were not in early stage of learning to read and write. Therefore, in order to compare our findings with those relating to children from Taiwan and Hong Kong, the relationship between reading acquisition and the phonological skills of younger readers in Mainland China should be investigated in the later studies. The result that phonological awareness predicted Chinese non-word reading is in accordance with the findings of previous studies regarding alphabetic orthographies (Rack et al., 1992). This result revealed that phonological awareness may be a universal predictor of non-word reading across orthographies.

The results of the present study indicate that naming speed contributes to reading fluency, which is consistent with the findings of previous studies involving alphabetic languages (e.g., Georgiou et al., 2009; Wolf & Bowers, 1999) and replicated the findings regarding Chinese children in Taiwan and Hong Kong (e.g., Liao et al., 2008; McBride-Chang & Ho, 2005). Moreover, the results of this study have also revealed that performance in word and non-word reading tasks successfully predicts writing performance, which is also supported by the results of existing studies conducted in Hong Kong and Taiwan (e.g., Chan et al., 2006; Cheng-Lai, et al., 2013). Since the current study provides evidence that both reading and writing abilities are significantly correlated, teachers might improve students' writing skills by instructing them in the skills of reading.

3. Limitations

Although the interpretations offered in Study 1-2 may still be tentative, these results provide a general profile of Chinese literacy acquisition in Chinese children in intermediate grade. It is unclear whether the profile obtained in intermediate graders is same as that of other graders. In addition, there are some methodological limitations. Recent studies found that expressive vocabulary knowledge was an influential predictor of the acquisition of reading skills in Chinese (e.g., Liu, McBride-Chang, Wong, Tardif, Stokes, Fletcher & Shu, 2010; Pan et al., 2011). In addition, prior researches demonstrated that morphological awareness contributed uniquely to various Chinese literacy performances including character recognition, character writing, reading fluency, and reading comprehension (McBride-Chang, Shu, Zhou, Wat & Wanger, 2003; Shu et al., 2006; Tong et al., 2011). However, these cognitive-linguistic abilities were not evaluated in Study 1-2. Furthermore, although we did not find that phonological memory significantly predicted any literacy performance of children in Study 1-2, prior studies have found that phonological memory is associated with reading acquisition of first grade children in Taiwan (Hu & Catts, 1998). We might need to add another phonological memory task such as a naming non-words back span, in order to provide a more comprehensive view of the phonological memory in relation to literacy performance. In addition, phonological awareness tasks, which were measured with onset deletion and rime deletion in Study 1-2, appeared to have a ceiling effect among the intermediate grade children. A different level of phonological awareness task, such as the onset and rime production tasks should be administered to the older children. Thus, the further research will need to re-investigate the predictive power of vocabulary knowledge and cognitive abilities for reading and writing abilities of children across different graders by adding morphological awareness and expressive vocabulary to multiple regression models. These issues were addressed in Study 2.

Chapter3

Study2: A Cross-sectional Study of Cognitive Abilities Underlying Acquisition of Reading and Writing in Mandarin Chinese

Ⅰ. Purpose

In Study 1-2, the following questions remain: does the relationship between cognitive abilities and literacy performance differ among different grades? Or would the results obtained in Study 1-2 vary if other reading-related variables that was reported as significant predictors in previous studies (Shu et al., 2006; Liu et al., 2010; Pan et al., 2011) (e.g., morphological awareness and expressive vocabulary knowledge) are included in multiple regression models? In order to solve these issues, we added tasks to measure morphological awareness and expressive vocabulary knowledge and administered a non-word back span test as an additional phonological memory task. Moreover, we recruited children from grade 1 to grade 6 as participants so that we could clarify the differences of literacy acquisition trajectories in children with various ages. The aim of the current study was to determine the cognitive abilities that exert a unique influence on reading and writing abilities among Mainland Chinese children, and determine whether they remain influential at different grades.

Ⅱ. Methods

1. Participants

A total of 672 native Chinese children from two primary schools (located in Ningbo and Hangzhou) participated in our study from 2018 to 2019. There were 128 children in grade 1, 102 in grade 2, 103 in grade 3, 101 in grade 4, 119 in grade 5, and 119 in grade 6. Participants that took all of the tests and had Raven Coloured Progressive Matrices (RCPM) (Raven, Court, & Raven, 1995) of more than -1.5 SD of the mean score were included in the analysis.

2. Measures

(1) Word Reading test:

The word reading test in grade 1 consisted of 40 word stimuli, which included 20 one-character and 20 two-character stimuli in Chinese (see Appendix G). The word reading test in grade 2 consisted of 20 word stimuli, which included 10 one-character and 10 two-character stimuli (see Appendix G). From grades 3 to 6, the word reading test only included 10 two-character stimuli (see Appendix H). The stimuli were printed on two A4 size sheets, and the participants were required to read them aloud. All of the word stimuli were selected from textbooks that had already been studied by the participants and were different across grades.

For the stimuli in grade 1 and 2, a character was classified as compound character if it was constituted by phonetic radical and semantical radical; otherwise, it was classified as non-compound character. Furthermore, compound character was classified as regular one if it has the same pronunciation as its phonetic radical; otherwise, it was classified as irregular character. For the stimuli in grade 3 to 6, a character was classified as typical if the pronunciation of it was the most common pronunciation used in characters containing the same phonetic radical. A character was classified as atypical, if the pronunciation of the character was not the most common in characters containing the same phonetic radical (Fang, Horng & Tzeng, 1986). In addition, the frequency of word was referred to The Modern Chinese Frequency Dictionary (1986). The frequency of word higher than 0.001 was classified as high frequency, while the frequency of word lower than 0.0001 was classified as low frequency. The stimuli of word reading tasks vary in different grades in order to prevent floor or ceiling effects.

(2) Word Writing test:

To evaluate word-writing accuracy, the word dictation tasks were conducted. Two-character compound words were selected as the stimuli and these were derived from the textbook of each grade. For grade 1 and 2, the word dictation test included 10 two-character stimuli (see Appendix I), while 12 two-character stimuli were selected for grade 3 to 6 (see Appendix J). After the words were orally presented in mandarin Chinese twice by the experimenter, and the children were then required to write down the corresponding Chinese words. The score of each participant was determined by totalling the number of correctly spelled words. A point was only awarded when both of the characters in a stimulus were spelled correctly.

(3) Phonological tests:

a. Phoneme deletion and phoneme production.

An onset deletion (Onset) task and a rime deletion (Rime) task were administered to first and second graders, while an onset production task and a rime production task were administered to the children from grades 3 to 6. The phoneme deletion tests were modified from the phonological tests administered by Lin and Uno (2015). The testing methods and scoring procedures were same as their tasks, while the stimuli were different from those used in their study. In the phoneme deletion tasks, the participants were required to delete the onset or rime from the syllables and answer orally. In the phoneme production tasks, children were asked to say a different syllable that has the same onset or rime as the presented syllables. Each sub-task included five items, making a total of 10 real syllables. Each participant's score for the deletion or production tasks was the number of correct answers he/she gave out of the 10 items. Different levels of phonological awareness tasks were administered to different graders in order to prevent floor or ceiling effects.

b. Non-word repetition tests (NonwordRep).

In two practice runs and ten trials, the participants were asked to complete non-word repetition tests (NonwordRep) in which the stimuli consisted of three to nine syllables that were ordered in terms of the ascending length. This measure was modified form the phonological memory task used in the study of Chan et al. (2006). Non-words were used as the stimuli so that children need to maintain and processed phonological information in memory without lexical support (Gathercole & Baddeley,1990). The testing method was same as their task, while the stimuli were different from those used in their study. The participants were required to listen to each non-word and then repeat them. Each participant's score was the number of correctly pronounced non-words out of the 10 items.

c. Non-word backward span (NonwordBackSpan).

The stimuli were five non-words with two to five syllables. This measure was adapted from the backward digit span task used in the study of Liu et al. (2019) and Chung et al. (2009), in which the participants were asked to repeat digit strings arranged in order of increasing length. The testing method and scoring procedure of the current study were also same as Liu et al.'s (2019). We used non-word syllables replacing digit strings as the stimuli in our study in order to be consistent with the non-word repetition tests. For each trial, the participants were required to listen to a non-word carefully and then repeat it. After the children repeated the non-word correctly, they were asked to repeat it in reverse. The number of correct responses was calculated.

(4) Visual skill tests:

Visual skill tests included copy drawing, immediate recall, and delayed recall tasks. For copy drawing, the children were asked to copy a complicated figure (FigureCopy), after which they were required to draw the figure again without the target stimulus for reference (FigureImm). After about 30 minutes, the children were asked to draw the figure for a third time (FigureDel). The Rey-Osterrieth Complex Figure Test (ROCFT) was administered for children from grades 2 to 6, while the Three Figures (Inomata, Uno, & Haruhara, 2013) were administered for first graders. A different visual skill test was selected for children in grade 1 in order to prevent the floor effect.

(5) Rapid automatized naming (RAN): The same measure in study 1.

(6) Vocabulary tests:

a. Standardised Comprehension Test of Abstract Words (SCTAW). The same measure in study 1.

b. Expressive vocabulary (KABC).

This task was adapted from the expressive vocabulary test in the Japanese version of the Kaufman Assessment Battery for Children (KABC-Ⅱ, 2013) to measure children's vocabulary knowledge. Coloured pictures of some objects were presented to the children, and they were instructed to name the objects one by one. Scoring procedures of this task were based on the local norm established by the Japanese version of the KABC-II. Each word that was matched to the picture was equal to one mark.

(7) Morphological awareness tests:

a. Morphology judgement (MorphologyJud).

This measure was modified from the morpheme judgment task administered by Wei, et al. (2014). The testing method was same as their task while the stimuli were different from those used in their study. In this task, the experimenter orally presented the child with two-morpheme Chinese words. In each word pair, there was a syllable that shared the same sound and the written form (e.g. a shared syllable '友' in '朋友' meaning 'friend' and '友情' meaning 'friendship'). For each word pair, children were asked to judge whether a shared syllable had a similar or different meaning to the other words.

b. Morphology production (MorphologyProd).

Following the previous study (Shu et al., 2006), we conducted a morphology production task to the older Chinese school children in order to prevent the ceiling effect of morphology judgement task. This measure was modified from the morpheme production task used in the study of Shu et al. (2006). The testing method and scoring procedure were same as their task while the stimuli were different from those used in their study. The experimenter orally presented a two-character Chinese word and a target constituent character of this word to each child. Children were asked to say two words that had the target character. When answering, children were required to produce a word whose target character shared the same meaning as that of the presented word, as well as a word whose target character had a different meaning from the character of the presented word. For example, the word '花朵' meaning 'flower' with the target character '花' was presented. Two possible answers are '鲜花', meaning 'fresh flower', and '花钱', meaning 'to spend money'. This task had five trials, and it was administered to children in grades 3 to 6.

3. Procedures

For the word-reading task, phonological tests, RAN tests, expressive vocabulary task, morphology production task, each child was tested individually, and the examiners recorded errors. Each child's responses were also audiotaped for later verification. In the group tests' sessions, RCPM, SCTAW, visual skill tests, morphology judgement task and word writing test, were administered to participants. The individual tests were administered in quiet rooms at the participants' school, while the group tests were administered in their classrooms. The individual sessions lasted approximately 15-20 min, while the group sessions lasted 35-40 min. The present study was approved by the Ethics Committee of the University of Tsukuba (Graduate School of Comprehensive Human Sciences).

Ⅲ. Results

In the present study, the purpose was to determine the predictive variables of reading and writing performance across different grades as well as to figure out the development of reading and writing strategy in Chinese children. Because the main purpose of this study was to clarify the characteristics of the reading-related abilities for children at different developmental stages, analysis of variance (ANOVA) and multiple regression analyses were conducted. The analysis of variance was conducted to examine the interaction and main effect of grades with cognitive abilities. After confirming the interaction effects of grades with cognitive abilities, multiple regression analyses were conducted to determine which cognitive variables predicted reading and writing abilities in different graders.

1. Word reading

Pearson's correlation analyses were conducted on cognitive test scores and word-reading performance. Table 14 presents the results of Pearson's correlation.

Table 14. Results of the Pearson Correlation Analysis between Scores of Cognitive Ability measures and the Word Reading Test

Variable	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
RAN	**-0.206***	**-0.225***	-0.188	**-0.390****	-0.132	-0.174
FigureCopy	**0.277****	0.098	0.134	-0.037	0.118	0.100
FigureImm	**0.347*****	0.024	0.110	-0.076	-0.002	-0.054
FigureDel	**0.190***	-0.042	0.088	-0.021	0.121	0.030
SCTAW	-0.145	0.053	0.083	**0.302****	**0.365****	0.175
KABC	0.078	**0.337*****	0.186	0.020	**0.339****	**0.297****
Onset	**0.229***	**0.253***	-0.148	0.107	0.136	**0.300****
Rime	**0.225***	0.193	**0.247***	**0.257***	**0.244***	**0.306****
NonwordRep	**0.182***	**0.378*****	**0.357****	**0.212***	**0.289****	0.083
Nonword BackSpan	**0.189***	**0.280****	**0.297****	**0.342****	**0.329****	**0.264****
MorphologyProd			0.029	0.078	**0.338****	0.178
MorphologyJud	0.153	0.171	-0.077	-0.117	-0.071	0.170

Note: RAN = Rapid Automatized Naming; FigureCopy = Three Figures or ROCFT Copy Drawing; FigureTimm = Three Figures or ROCFT Immediate Recall; FigureDel= Three Figures or ROCFT Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion or Production; Rime = Rime Deletion or Production; NonwordRep = Non-word Repetition; NonwordBackSpan = Non-word backward span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*: $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

(1) Grades 1 and 2

RAN (grade1: $r=-0.21$, $p<0.05$; grade2: $r=-0.23$, $p<0.05$), Onset (grade1: $r=0.23$, $p<0.05$; grade 2: $r=0.25$, $p<0.05$), NonwordRep (grade1: $r=0.18$, $p<0.05$; grade2:$r=0.38$, $p<0.001$) and NonwordBackSpan (grade1: $r=0.19$, $p<0.05$; grade2: $r=0.28$, $p<0.01$) were significantly related to word reading in grades 1 and 2. The correlation analyses showed that FigureCopy ($r=0.28$, $p<0.01$), FigureImm ($r=0.35$, $p<0.001$), FigureDel ($r=0.19$, $p<0.05$), and Rime ($r=0.23$, $p<0.05$) were correlated with grade 1 but not with grade 2, whereas KABC ($r=0.34$, $p<0.001$) was related to grade 2 but not grade 1.

We tested whether there are significant interactions between grades and each test performance correlating with reading performance of either grade 1 or grade 2 through a series of model comparisons. It was revealed that the scores in FigureImm had a significant interaction with grade, because there was a change in model fit when the interaction was excluded from the regression model with the interaction and main effect ($p<0.05$); the following regression models in the multiple regression analysis did not combine grade 1 and grade 2.

a. Results of multiple regression analysis in grade 1.

The multiple regression analysis in grade 1 was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm, SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan and MorphologyJud. The regression model consisted of the z-scores on the word reading test of grade 1 as the dependent variable, and those ten cognitive tests z-scores as the independent variables. For children in grade 1, word-reading performance was significantly predicted by the scores in FigureImm ($\beta=0.31$, $t=2.91$, $p<0.01$), RAN ($\beta=-0.19$, $t=-2.15$, $p<0.05$) and SCTAW ($\beta=$-

0.21, t=-2.33, p<0.05). Even when FigureDel, together with other ten cognitive tests, were entered into the multiple regression analysis simultaneously, word reading performance in grade 1 was still significantly predicted by the same variables as the FigureDel was excluded.

b. Results of multiple regression analysis in grade 2.

The multiple regression analysis in grade 2 was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan and MorphologyJud. The regression model consisted of the z-scores on the word reading test of grade 2 as the dependent variable and those ten cognitive tests z-scores as the independent variables. Word reading performance was significantly predicted by the scores on the KABC (β=0.27, t=2.74, p<0.01) and NonwordRep (β=0.35, t=3.72, p<0.001). When FigureDel, replacing FigureImm, was entered into the multiple regression analysis, word reading performance in grade 2 was significantly predicted by the same variables.

(2) Grades 3 and 4

Rime (grade3: r=0.25, p<0.05; grade4: r=0.26, p<0.05), NonwordRep (grade3: r=0.36, p<0.01; grade 4: r=0.21, p<0.05), and NonwordBackSpan (grade3: r=0.30, p<0.01; grade4: r=0.34, p<0.01) were significantly related to word-reading scores in both grades 3 and 4. The correlation analysis also showed that the RAN (r=-0.39, p<0.01) and SCTAW (r=0.30, p<0.01) were correlated with grade 4 but not with grade 3. The comparisons between a model with only main effects and a model consisting of main effects and the interaction revealed that none of scores on RAN or SCTAW had a significant interaction with grade, due to no significant change in model fit (p>0.1).

Therefore, the remaining regression models in the multiple regression analysis combined grades 3 and 4.

The multiple regression analysis was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan, and MorphologyPro (or MorphologyJud). The regression model consisted of the z-scores on the word reading test of grades 3 and 4 as the dependent variable and those ten cognitive tests z-scores as the independent variables. As for intermediate graders, word-reading performance were significantly predicted by the scores on the SCTAW ($\beta=0.19$, $t=2.62$, $p<0.05$), NonwordRep ($\beta=0.15$, $t=2.09$, $p<0.05$), and NonwordBackSpan ($\beta=0.20$, $t=2.54$, $p<0.05$). When FigureImm was replaced by FigureDel, or MorphologyPro was replaced by MorphologyJud, to enter into the multiple regression analysis, word reading performance of intermediate graders were significantly predicted by the same variables.

(3) Grades 5 and 6

KABC (grade5: $r=0.34$, $p<0.01$; grade6: $r=0.30$, $p<0.01$), Rime (grade5; $r=0.24$, $p<0.05$; grade6: $r=0.31$, $p<0.01$), and NonwordBackSpan (grade5: $r=0.33$, $p<0.01$; grade6: $r=0.26$, $p<0.01$) were significantly related to word-reading scores in both grades 5 and 6. The correlation analysis also showed that the SCTAW ($r=0.37$, $p<0.01$), NonwordRep ($r=0.29$, $p<0.01$), and MorphologyProd ($r=0.34$, $p<0.01$) were correlated with grade 5 but not with grade 6, while Onset ($r=0.30$, $p<0.01$) was correlated with grade 6 but not with grade 5. The comparisons between a model with only main effects and a model consisting of main effects and the interaction revealed that none of scores on SCTAW, Onset, NonwordRep and MorphologyProd had a significant interaction with grade, due to no significant change in model fit (SCTAW×grade: $p=0.068$; Onset×grade: $p>0.1$; NonwordRep×grade: $p>0.1$; MorphologyProd×grade: $p=0.069$). Therefore, the remaining regression models in the multiple regression analysis combined grades 5 and 6.

The multiple regression analysis was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan, and MorphologyPro (or MorphologyJud). For higher grades, out of those ten cognitive test performances, word reading performance was significantly predicted by the scores of the SCTAW ($\beta=0.18$, $t=2.62$, $p<0.01$), KABC ($\beta=0.16$, $t=2.18$, $p<0.05$), and NonwordBackSpan ($\beta=0.20$, $t=2.82$, $p<0.01$). When FigureImm was replaced by FigureDel, or MorphologyPro was replaced by MorphologyJud, to enter into the multiple regression analysis, word reading performance of higher graders were significantly predicted by the same variables. Table 15 depicts the results of the multiple regression analyses of word reading for grades 1 to 6.

Table 15. Results of the Multiple Regression Analysis between Cognitive Abilities and Word Reading Performance

	Grade 1	Grade 2	Grade 3/Grade 4	Grade 5/Grade 6
Variable	(Adj.R^2=0.234)	(Adj.R^2=0.258)	(Adj.R^2=0.172)	(Adj.R^2=0.198)
RAN	**-0.190***	-0.172	-0.130	0.033
FigureCopy	0.053	0.083	0.037	0.067
FigureImm	**0.314****	-0.062	-0.076	-0.129
SCTAW	**-0.206***	0.084	**0.190***	**0.177****
KABC	0.054	**0.271****	0.023	**0.159***
Onset	0.144	-0.045	-0.172	0.062
Rime	0.123	0.131	0.155	0.127
NonwordRep	0.060	**0.347*****	**0.154***	0.045
Nonword BackSpan	0.092	0.128	**0.196***	**0.204****
Morphology	0.110	0.096	-0.067	0.066

Note: RAN = Rapid Automatized Naming; FigureCopy = Three Figures or ROCFT Copy Drawing; FigureTimm = Three Figures or ROCFT Immediate Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion or Production; Rime = Rime Deletion or Production; NonwordRep = Non-word Repetition; NonwordBackSpan = Non-word backward span; Morphology = Morphology Judgement or Morphology Production

*: $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

2. Word Writing

Pearson's correlation analyses were conducted on cognitive test scores and word writing performance. In Study 1-2, we examined the association between reading and writing performance with other cognitive abilities in the same context. However, in this study, since the purpose was to examine which cognitive abilities could predict Chinese word writing performance, we did not include word reading scores as the independent variable in the multiple regression analyses of writing performance. Table 16 presents the results of Pearson's correlation.

Table 16. Results of the Pearson Correlation Analysis between Scores of Cognitive Ability measures and the Word Writing Test

Variable	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
RAN	**-0.188***	-0.023	-0.008	**-0.457****	-0.154	**-0.313****
FigureCopy	**0.280****	**0.227***	0.113	0.169	0.068	**0.205***
FigureImm	**0.337*****	**0.225***	0.078	0.066	0.047	0.029
FigureDel	0.184	0.184	0.181	0.072	0.172	**0.223***
SCTAW	-0.119	0.117	**0.265****	**0.235***	**0.276****	0.162
KABC	0.039	0.132	0.018	0.078	**0.216***	**0.232***
Onset	**0.218***	0.087	-0.155	0.059	0.193	**0.439****
Rime	0.142	0.010	-0.008	0.217*	**0.272****	**0.266****
NonwordRep	**0.226***	0.168	0.038	0.006	**0.195***	0.077
Nonword BackSpan	**0.240***	**0.237***	0.020	0.184	**0.202***	**0.288****
MorphologyProd			0.106	0.126	**0.384****	0.139
MorphologyJud	0.136	-0.094	-0.098	-0.108	0.029	0.167

Note: RAN = Rapid Automatized Naming; FigureCopy = Three Figures or ROCFT Copy Drawing; FigureTimm = Three Figures or ROCFT Immediate Recall; FigureDel= Three Figures or ROCFT Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion or Production; Rime = Rime Deletion or Production; NonwordRep = Non-word Repetition; NonwordBackSpan = Non-word backward span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*: $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

(1) Grades 1 and 2

FigureCopy (grade1: r=0.28, p<0.01; grade2: r=-0.23, p<0.05), FigureImm (grade1: r=0.34, p<0.001; grade 2: r=0.23, p<0.05), and NonwordBackSpan (grade1: r=0.24, p<0.05; grade2: r=0.24, p<0.05) were significantly related to word writing in grades 1 and 2. The correlation analyses showed that RAN (r=-0.19, p<0.05), Onset (r=0.22, p<0.05), and NonwordRep (r=0.23, p<0.05) were correlated with grade 1 but not with grade 2.

We tested whether there are significant interactions between grades and each test performance correlating with writing performance of grade 1 only through a series of model comparisons. The comparisons between a model with only main effects and a model consisting of main effects and the interaction revealed that none of scores on RAN, Onset or NonwordRep had a significant interaction with grade, due to no significant change in model fit (p>0.1). Therefore, the remaining regression models in the multiple regression analysis combined grades 1 and 2.

The multiple regression analysis was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan, and MorphologyJud. The regression model consisted of the z-scores on the word writing test of grades 1 and 2 as the dependent variable and those ten cognitive tests z-scores as the independent variables. As for lower graders, word writing performance was significantly predicted by the scores on the FigureImm (β=0.21, t=2.54, p<0.05), NonwordRep (β=0.14, t=2.12, p<0.05) and NonwordBackSpan (β=0.16, t=2.24, p<0.05). Even when FigureDel, together with other ten cognitive tests, were entered into the multiple regression analysis simultaneously, word writing performance in grade 1 and 2 were still significantly predicted by the same variables as the FigureDel was excluded.

(2) Grades 3 and 4

SCTAW (grade3: $r=0.27, p<0.01$; grade4: $r=0.24, p<0.05$) was significantly related to word writing scores in both grades 3 and 4. The correlation analysis also showed that the RAN ($r=-0.46, p<0.01$) and Rime ($r=0.22, p<0.05$) were correlated with grade 4 but not with grade 3. The comparisons between a model with only main effects and a model consisting of main effects and the interaction revealed that the scores in RAN had a significant interaction with grade. Because there was a change in model fit when the interaction was excluded from the regression model with the interaction and main effect ($p<0.05$); the following regression models in the multiple regression analysis did not combine grade 3 and grade 4.

a. Results of multiple regression analysis in grade 3.

The multiple regression analysis was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan, and MorphologyPro (or MorphologyJud). The regression model consisted of the z-scores on the word writing test of grade 3 as the dependent variable and those ten cognitive tests z-scores as the independent variables. For children in grade 3, word writing performance was significantly predicted by the scores in SCTAW ($\beta=0.30, t=2.47, p<0.05$). When FigureImm was replaced by FigureDel, or MorphologyPro was replaced by MorphologyJud, to enter into the multiple regression analysis, word writing performance of third graders was significantly predicted by the same variables.

b. Results of multiple regression analysis in grade 4.

The multiple regression analysis was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan, and MorphologyPro (or MorphologyJud). Word writing performance was significantly predicted by the scores on the RAN (β=-0.34, t=-3.21, $p<0.01$). When FigureImm was replaced by FigureDel, or MorphologyPro was replaced by MorphologyJud, to enter into the multiple regression analysis, word writing performance of fourth graders were significantly predicted by the same variables.

(3) Grades 5 and 6

KABC (grade5: r=0.22, $p<0.05$; grade6: r=0.23, $p<0.05$), Rime (grade5; r=0.27, $p<0.01$; grade6: r=0.27, $p<0.01$), and NonwordBackSpan (grade5: r=0.20, $p<0.05$; grade6: r=0.29, $p<0.01$) were significantly related to word writing scores in both grades 5 and 6. The correlation analysis also showed that the SCTAW (r=0.28, $p<0.01$), NonwordRep (r=0.20, $p<0.05$), and MorphologyProd (r=0.38, $p<0.01$) were correlated with grade 5 but not with grade 6, while RAN(r=-0.31, $p<0.01$), ROCFTcopy (r=0.21, $p<0.05$), ROCFTdel (r=0.22, $p<0.05$), and Onset (r=0.44, $p<0.01$) was correlated with grade 6 but not with grade 5. The comparisons between a model with only main effects and a model consisting of main effects and the interaction revealed that the scores in Onset ($p<0.05$) and MorphologyProd ($p<0.01$) had a significant interaction with grade. Because there was a change in model fit when the interaction was excluded from the regression model with the interaction and main effect ($p<0.01$); the following regression models in the multiple regression analysis did not combine grade 5 and grade 6..

a. Results of multiple regression analysis in grade 5.

The multiple regression analysis was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan, and MorphologyPro. For children in grade 5, word writing performance was significantly predicted by the scores in MorphologyProd ($\beta=0.36$, $t=3.09$, $p<0.01$). When FigureImm was replaced by FigureDel to enter into the multiple regression analysis, word writing performance of fifth graders were significantly predicted by the same variables.

b. Results of multiple regression analysis in grade 6.

The multiple regression analysis was carried out with variables from ten cognitive abilities tests, including RAN, FigureCopy, FigureImm (or FigureDel), SCTAW, KABC, Onset, Rime, NonwordRep, NonwordBackSpan, and MorphologyPro (or MorphologyJud). Word writing performance was significantly predicted by the scores on the RAN ($\beta=-0.22$, $t=-2.24$, $p<0.05$) and Onset ($\beta=0.34$, $t=3.32$, $p<0.01$). When FigureImm was replaced by FigureDel, or MorphologyPro was replaced by MorphologyJud, to enter into the multiple regression analysis, word writing performance of sixth graders were significantly predicted by the same variables.

Table 17 depicts the results of the multiple regression analyses of word writing for grades 1 to 6.

Table 17. Results of the Multiple Regression Analysis between Cognitive Abilities and Word Writing Performance

	Grade 1/ Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Variable	(Adj.R^2=0.134)	(Adj.R^2=0.017)	(Adj.R^2=0.158)	(Adj.R^2=0.166)	(Adj.R^2=0.228)
RAN	-0.019	-0.064	**-0.343****	-0.008	**-0.215***
FigureCopy	0.114	0.189	0.119	0.104	0.133
FigureImm	**0.206***	-0.115	-0.020	-0.052	-0.699
SCTAW	0.004	**0.295***	0.138	0.115	0.076
KABC	0.012	-0.102	0.158	-0.017	0.109
Onset	0.100	-0.131	-0.223	0.153	**0.343****
Rime	0.031	0.034	0.098	0.107	0.002
NonwordRep	**0.143***	0.038	-0.086	0.075	-0.001
Nonword BackSpan	**0.158***	0.049	0.077	-0.017	0.098
Morphology	0.002	0.054	0.050	**0.355****	-0.072

Note: RAN = Rapid Automatized Naming; FigureCopy = Three Figures or ROCFT Copy Drawing; FigureTimm = Three Figures or ROCFT Immediate Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion or Production; Rime = Rime Deletion or Production; NonwordRep = Non-word Repetition; NonwordBackSpan = Non-word backward span; Morphology = Morphology Judgement or Morphology Production

*: $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

Ⅳ. Discussion

1. Important Predictors for Word Reading in Mandarin Chinese in Different Grades

The results of the multiple regression analyses revealed that visual memory skill, which was measured with Figure immediate recall, was an important predictor of Chinese word reading only in grade 1. In the current study, visual skill was found to be a strong predictor of Chinese literacy performance among only younger children, which is consistent with previous findings (Ho & Bryant, 1999; Siok & Fletcher, 2001). This finding implies the influence of a characteristic of the Chinese writing system, namely, the visually-complexity of character shapes. The visual cognitive task may have captured something important about the relevance of integrated visual processing in Chinese, including both motor functioning as well as short-term memory. As first graders are beginners to learn to read and write, they are usually taught to focus on the visual configurations of characters, and remember their pronunciation and writing. Teachers at primary schools in Mainland China often employ a drilling approach where Chinese characters are presented, read, and repetitively written by children (Chan et al., 2006). Such teaching instruction at lower grades enhances children’s abilities to differentiate between Chinese characters visually; it also makes visual-motor skills an integral part of Chinese reading acquisition through writing each character many times. As children advance into later grades, the number of characters and words in textbooks increases significantly, and then children are taught to remember the orthographic and phonological regularities. Children in upper grades tend to learn characters and words by associating meaning, phonology and orthography with each other rather than rely on the visual configuration only. This difference in learning strategy and teaching method would weaken the contribution of visual skill and would increase the contributions of other cognitive abilities (i.e., phonological memory, vocabulary knowledge and morphological awareness) to word reading abilities. Thus, it is supposed that the influence of visual skill diminishes as Chinese children improve other cognitive abilities, partly as a function of developmental changes in word reading. This might be why the significant contribution of visual skill on reading performance disappeared from grade 2 and above in this study.

Additionally, the current study found that naming speed (measured with RAN) only contributed to reading performance of grade 1. This result was in accordance with the previous findings that the relationship between the RAN test performance and reading accuracy is stronger at the early stages of reading development in English (e.g. Torgesen, Wanger, Rashotte, Burgess & Hecht, 1997; Wanger, Torgesen, Rashotte, Hecht, Barker, Burgess, Donahue & Garon, 1997). Our finding indicated that the predictive power of the RAN test performance for word reading accuracy weaken in upper grades. In contrast to this result, some studies suggested that the predictive power of RAN was higher for intermediate readers than for beginning readers in Chinese (Liao et al, 2008; Tan et al., 2005). However, children's reading abilities were measured within the limited time, in terms of reading fluency in above-mentioned studies. Taking the findings of our study and the previous studies in Chinese, it is supposed that contribution of naming speed (measured by the RAN test) to reading accuracy weakens as the grade goes up, while naming speed continues to contribute to reading fluency even in upper graders. Further research is needed to confirm this.

In contrast to first graders, phonological skills, especially phonological memory, predicted word reading performance of children in grades 2 to 6 significantly.

Phonological short-term memory, which was defined as the ability to maintain phonological information for online processing or storage in the short-term memory (Wanger & Torgesen, 1987), was examined by non-word repetition and non-word back span tasks in this study. The contributions of phonological memory were supported by the study of Chan et al. (2006). According to the study of Ramus et al. (2013), the non-word repetition task was also identified as a kind of phonological representation in the factor analysis, because it appears to more directly reflect the precision format of phonological representations. Our findings suggest that precise phonological representation, in addition to phonological memory, might also be associated with reading abilities in Chinese. The characteristics of languages with different script-sound correspondence or languages that are non-alphabetic, such as Chinese, may contribute to the differences in the types of cognitive deficits encountered by struggling readers (Chan et al., 2006). The phonological deficit hypothesis is widely accepted and received support from previous studies on different languages, including both alphabetic English and logographic Chinese (e.g. Goswanmi, 2002; Ho & Brant, 1997b; Hu & Catts, 1998; McBride-Chang & Kail, 2002; Siok & Fletcher, 2001). However, we found that phonological memory, rather than phonological awareness, makes a significant contribution to reading development in Chinese. Almost all Chinese characters have only one-to-one correspondence with a single Chinese syllable; expert readers barely need to analyse the syllable in smaller phonological units (such as onset and rime) when they are in more advanced grades of reading acquisition. Instead, Chinese children need to memorise many whole character-sound mappings compared to alphabetic readers. Although there are some regularities between phonetic radicals and the pronunciations of compound Chinese characters, the correspondence of phonetic radicals to characters' pronunciation is only 40% (Zhou, 1978). When children enrol in more advanced grades, they tend to encounter more Chinese words and characters than they do in lower grades. Since Chinese orthography does not have grapheme-phoneme correspondence, children may be required to memorise the correspondences between character-or-word spelling and its sound and extract the sounds of words or characters from memory. Therefore, it is supposed that the significant contribution of phonological memory rather than phonological awareness was observed in children from grade 2 and upper grades.

In addition to phonological memory, the current results also found that vocabulary knowledge made important contribution to reading acquisition in Chinese. This result is consistent with prior findings (e.g. Liu et al., 2010; Pan et al., 2011). Furthermore, the role of vocabulary becomes more crucial in the later stages of development when it comes to Chinese reading abilities. It seems that vocabulary knowledge facilitates Chinese children's ability to read words and thus helps them become proficient readers. This was also in accordance with the study of Japanese logographic Kanji word reading conducted by Uno et al. (2009). In Uno and colleagues' study (2009), they found that the vocabulary size (measured by SCTAW) was the most important predictive variable in accounting for Kanji word reading abilities of Japanese primary school children from grade 2 to 6, and suggested that an increase in vocabulary size linked to a better performance on Kanji word reading. Compared with alphabetic orthographies, Chinese characters (part of a logographic language) are relatively meaning-based. Knowing the meaning of words may help children master the reading of words that were previously known only from the oral lexicon (Pan et al., 2011). The results of the present study demonstrate that vocabulary development is closely related to performance in older children who are reading Chinese words. Children with large vocabulary sizes could pronounce words efficiently because children in advanced grades tend to be exposed to a large amount of new words.

In summary, this study found that visual skills, phonological memory and vocabulary-knowledge predicted reading accuracy in Chinese children. Importantly, the predictive power of each variable changed as the school year goes up: visual skills contribute to reading accuracy in grade 1, however such a significant contribution disappears in second and upper graders; in contrast, the contributions of phonological memory and vocabulary-knowledge to reading accuracy emerge and increase when a child grows up. These changes might be caused by the difference of learning strategy and teaching method between lower and upper graders.

2. Important Predictors for Word Writing in Mandarin Chinese in Different Grades

The results of multiple regression analyses revealed that visual memory was an important predictor of Chinese word writing in grade 1 and 2. It seems that young children with limited orthographic knowledge tend to learn to recognize new writing stimuli based on visual cues. More orthographic units need to be learned in Chinese compared to alphabets. Compared to about 22-30 letters in an alphabetic orthography, there are approximately 1000 unique radicals and thousands of different characters in Chinese orthography (McBride, 2016). This large number of visual units to store in memory and manipulate makes the process of learning to read and write Chinese need excellent visual skills, especially visual memory skill. For lower grades children in China, they need to memorize many characters as a new visual configuration. Along with this, the traditional teaching methods in word reading and spelling focused on repetition and copying, which also facilitate children's sense of writing patterns in Chinese (e.g. Tong & McBride-Chang, 2010).

Furthermore, phonological memory also plays an important role in Chinese word writing at lower graders, while phonological awareness significantly predict word writing in higher graders. This finding, to some extent, is in accord with the findings of Chan et al.'s (2006) study, which reported that phonological memory predicted Chinese word spelling (i.e. word dictation) significantly. Shen and Bear (2000) investigated Chinese spelling development among Chinese children in grade 1 to 6 in Mainland China. They demonstrated that phonological skills are important in the development of writing abilities among early elementary graders. In writing tests of the present study, children were instructed to write down the corresponding Chinese words after the target words were orally presented. This process needed these young children to differentiate the specific phonological representations of target words, and memorize the phonological form the examiner presented in their short-term memory before they retrieve the orthographic form of the stimulus. Our results might have reflected the fact that phonological memory tasks which tapped the format of phonological representations more directly made great contribution to word writing performance.

On the other hand, our study found that for children in the higher grades, phonological awareness plays a relative important role in the dictation task. There are a large number of homophones as well as words sharing similar sounds in Chinese. It was reported that each Chinese syllable has five homophones on Mandarin approximately (Packard, 2000). This unique characteristic of Chinese may need older children have good phonological sensitivity to discriminate which words were presented during the dictation task, since they have learnt thousands of words as the advanced graders. Therefore, we suppose that phonological awareness rather than phonological memory contributed to word writing performance of upper graders since phonological awareness is related to sensitivity of the phonological constructs.

In the present study, receptive vocabulary knowledge (measured with SCTAW) makes a unique contribution to word writing of only third graders. The effect of receptive vocabulary knowledge on writing accuracy was not surprising, given the writing to dictation task used in the present study required the children discriminating the sounds as well as the meaning of the words. It is therefore possible that receptive vocabulary could be a significant predictor for performance on the dictation task since word dictation require children to not only pay attention to the orally presented words stimuli and but also discriminate the meaning of them. Thus, children who with better vocabulary knowledge might promote their abilities to access to the accurate meaning of the words.

Furthermore, naming speed predicted writing accuracy in grades 4 and 6. The study of Chan et al. (2006) found that naming speed predicted Chinese word reading and writing among grade 1 to 4 children. The associations of the RAN test performance to dictation in Chinese have been moderate to high in previous work across grade levels (e.g., Chan et al., 2006; Ding, Richman, Yang & Guo, 2010). Manis et al. (1999) suggested that RAN is important for highlight an 'arbitrariness' factor in reading because naming task capitalizes on the fact that symbols and their oral presentations are arbitrary. Chinese was considered as an opaque language, because the reliability of the phonetic radicals in presenting the phonological information of characters is relatively low (Yeung, Ho, & Lo, 2013). At the same time, the phonology-to-orthography correspondences in Chinese is opaque. The rapid automatized naming task is correlated with the skill of forming arbitrary relationships between visual symbol and sound (Manis et al., 1999), thus it is supposed that the RAN test performance predicted writing performance of children in multiple grades.

In the present study, morphological awareness was a significant predictor for word writing performance in only grade 5. This result was partly supported by the previous findings (Shu et al., 2006; Tong, McBride-Chang, Shu & Wong, 2009; Yeung, Ho, Chik, Lo, Luan, Chan & Chung, 2011). There are several different aspects of morphological awareness, with lexical compounding awareness (e.g. morpheme construction skills) and homophone awareness (e.g. skills of discriminating among homophones and homographs with different meanings) being the two most important skills (Liu, McBride-Chang, Wong, Shu & Wong, 2003; McBride-Chang et al., 2003; Shu et al., 2006). Morphological awareness tasks used in our study evaluated children's knowledge of both homophones and morpheme construction skills. Given that this study tested the two major aspects of morphological awareness, it was not surprise to find that performance on the morphological awareness tasks became a significant predictor for writing performance. In the writing tasks, we selected compound words which seldom have homophones in the word-level as the stimuli to avoid confusing children. However, in writing Chinese words, children still need to identify the particular morphemes that constituted the compound words. They had to discriminate the homophones between characters that have the identical sound before retrieving the specific orthographic forms related to the target words. Therefore, the skill of discriminating the different morphemes sharing the same pronunciation is essential in writing Chinese words.

Collectively, phonological skills, visual skill, morphological awareness, vocabulary knowledge and naming speed are all important predictive factors for writing development in Chinese children. As knowledge in these domains increase, children's literacy skills may gradually become more sophisticated. Importantly, contributions of the above predictive variables seem to change across school years. We found that cognitive-linguistic variables did not predict word writing performance in sequential school years, this being contrast to the findings that the same cognitive-linguistic abilities predicted word reading performance from grade 2 to 6. It is suggested that spelling development is a gradual but not a stage-like process (Treiman & Cassar, 1997). It is not appropriate to consider the writing development as qualitatively different steps because children may use several strategies simultaneously when learning to write. This suggestion needs confirmation by future research. In addition, we obtained not only same significant predictors but also different significant predictors, between word reading and writing accuracies. This might indicate that there are also many differences between the reading and writing processes, although the development of word reading and writing in Chinese reflects some overlapping processes (Tong et al., 2011).

3. Limitations

There are some limitations in the present study. The first limitation, in contrast to previous studies, is that morphological awareness did not predict word-reading accuracy at any grade in the multiple regression analysis. Some prior studies had emphasised the important contribution of this measure for Chinese literacy abilities in early stage (McBride-Change, Wagner, Muse, Chow & Shu, 2005; Shu et al., 2006). However, we did not find a significant relationship between morphological awareness and word reading abilities among primary school children in this study, except for a relatively weak correlation with reading ability of children in grade 5. This might be due to the nature of the task used to measure morphological awareness. Although the morphological awareness did not significantly contribute to reading performance in the current study, it is still possible that such relationship could be found by using various tasks in the future work. Second, another unexpected predicting result was related to the receptive vocabulary knowledge (measured by SCTAW) predicting reading performance of children in grade 1 negatively. To examine the relationship between receptive vocabulary knowledge and reading acquisition of Chinese school children in lower grade, a different measure should be developed and tested for Mainland Chinese children in the future studies. Third, the results of the present study did not replicate the finding in Study 1-2. In contrast to the finding in Study 1-2, visual memory did not predict word reading performance, instead, vocabulary knowledge and phonological memory made significant contribution to word reading in third graders. Vocabulary knowledge instead of naming speed or phonological skills predicted writing performance in third graders in the present study. These differences may be attributed to the different cognitive-linguistic tasks included, and the different analysis method conducted in current cross-sectional study. We need to conduct a further study to examine which cognitive abilities are reliable longitudinal predictors to children's later literacy skills after controlling their earlier literacy performance. This issue was addressed in Study 3.

Despite these limitations, however, the present study has yielded important findings of the relationship between literacy performance and these different cognitive skills. According to our findings, visual memory skills strongly contribute to Chinese literacy achievement in lower grades of schooling. In contrast with lower graders, phonological memory and vocabulary knowledge predicted reading abilities from grades 2 to 6 significantly. In addition, morphological awareness emerged as a relatively important skill in relation to writing ability in fifth grade only.

Chapter4.

Study3: A Longitudinal Study of Cognitive Abilities Underlying Development of Reading and Writing in Mandarin Chinese

Ⅰ. Purpose

Study 2 revealed that reading and writing abilities in Mainland Chinese children are influenced by six cognitive-linguistic abilities (naming speed, visual skills, phonological awareness, phonological memory, morphological awareness and vocabulary knowledge), although the contribution of each factor to literacy development differs across different school years as well as between reading and writing tests. Based on previous researches (e.g., Yeung, Ho, Wong, & Lo, 2013; Pan et al., 2016), in the present study, we explored longitudinal predictors of Mainland Chinese children's reading and writing across 2 years in this chapter. The present study focuses on the above-mentioned effect of six cognitive-linguistic abilities on word reading and writing development. We aimed to clarify which cognitive abilities might be reliable longitudinal predictors to later literacy skills when earlier reading or writing performance were controlled.

Ⅱ. Methods

1.Participants

The present study was conducted in the same elementary school in Ningbo, Zhejiang in 2018 and 2019. Cognitive abilities were measured in the 2018, which was considered as Time 1 (T1). Data on literacy skills were collected in 2019, which was considered as Time 2 (T2). There were still 389 children remaining in the study in Time 2, which included 84 children in grade 2, 105 in grade 3, 67 in grade 4, 60 in grade 5, and 73 in grade 6. Participants that took all of the tests in two times of investigation, and who had Raven Coloured Progressive Matrices (RCPM) (Raven, Court, & Raven, 1995) of more than -1.5 SD of the mean score were included in the analysis. In the following context, the participants' grades were referring to their initial grades at T1.

2. Measures

The same measure used in Study 2.

3. Procedure

The statistical analysis methods in the current study were partly referenced to the study of Li et al. (2012). In order to estimate the risk of multicollinearity, the tolerance and variance inflation factors (VIFs) values of the T1 cognitive abilities in the regression analysis were checked. The tolerance and VIF values were all smaller than 10, indicating that multicollinearity was not a problem in the current study, thus we included the scores of T1 cognitive abilities and vocabulary knowledge into the multiple regression analyses as the predictive variables. To examine the causal relation between T1 cognitive-linguistic skills and T2 Chinese word reading and writing performance, hierarchical multiple regression analyses were conducted. In order to identify the unique contributions of T1 cognitive-linguistic abilities to T2 literacy achievement, T1 literacy abilities was entered in the equation at step 1 to control for their variance, all of the cognitive abilities and vocabulary knowledge measures were entered at step 2 all together.

Ⅲ. Results

Hierarchical multiple regression analyses were performed to investigate how T1 cognitive abilities and vocabulary knowledge measures contributed to the T2 literacy skills. The multiple regression model consisted of z-scores on T2 literacy achievement tests as the dependent variable, and z-scores on T1 cognitive-linguistic abilities tests as the independent variables. R^2 change and beta coefficients for each step are reported in Table 18 through 27.

1. Word reading

Table 18 shows that when T1 word reading was statistically controlled, T1 RAN (β=-0.28, $p<0.01$) uniquely explained T2 word reading of grade 1. The unique variance in T2 word reading of grade 1 explained by T1 RAN was 4%. Table 19 and 20 show that neither cognitive abilities nor vocabulary knowledge were uniquely associated with T2 word reading of grade 2 or grade 3, with T1 word reading was statistically controlled. As for grade 2, T1 word reading (β=0.65, p<0.001) by itself predicted a unique 39% of the variance in T2 word reading. As for grade 3, T1 word reading (β=0.58, p<0.001) by itself predicted a unique 33% of the variance in T2 word reading. Table 21 shows that T1 MorphologyProd (β=0.47, p<0.05) was a significant predictor of T2 word reading of grade 4. The unique contribution of T1 MorphologyProd to T2 word reading was 10%. Table 22 shows that T1 KABC (β=0.30, p<0.05) significantly contributed to T2 word reading of grade 5, with T1 word reading was statistically controlled. T1 KABC predicted a unique 12% of the variance in children's T2 word reading in grade 5.

2. Word writing

In addition, the effects of T1 cognitive abilities and vocabulary knowledge measures to T2 word writing were tested. Table 23 shows that T1NonwordBackSpan (β=0.27, p<0.05) significantly predicted T2 word writing of grade 1, with T1 word writing was statistically controlled. The unique variance in T2 word writing of grade 1 explained by T1 NonwordBackSpan was 5%. Table 24 shows that with the initial word writing ability of T1 statistically controlled, T1 ROCFTcopy (β=-0.22, p<0.05) uniquely explained T2 word writing of grade 2, but in a negative way. The model fit was reduced (ΔR^2=-0.02) when T1cognitive abilities and vocabulary knowledge were included into the regression model as the predictors. Thus, T1 word writing by itself predicted a unique 33% of the variance in children's T2 word writing in grade 2. Table 25 shows that when T1 word writing was statistically controlled, T2 word writing of grade 3 were significantly predicted by T1 RAN (β=-0.38, p<0.05), SCTAW (β=-0.42, p<0.05), Rime (β=0.39, p<0.05), and MorphologyJud (β=0.35 p<0.05). The unique variance in T2 word writing of grade 3 explained by RAN, SCTAW, Rime and MorphologyJud together were 31%.

Moreover, table 26 shows that T2 word writing of grade 4 were significantly predicted by T1 ROCFTdel ($\beta=0.61$, $p<0.05$), SCTAW ($\beta=-0.26$, $p<0.05$), MorphologyProd ($\beta=-0.37$, $p<0.01$), and MorphologyJud ($\beta=-0.27$, $p<0.05$), with T1 word writing was statistically controlled. As for T2 word writing of grade 4, the contribution of ROCFTdel, SCTAW, MorphologyProd and MorphologyJud together were 27%. Table 27 shows that when T1 word writing was statistically controlled, T2 word writing of grade 5 were significantly predicted by T1 RimeProd ($\beta=0.29$, $p<0.05$), MorphologyProd ($\beta=0.29$, $p<0.05$). RimeProd and MorphologyProd contributed 17% of the variance to T2 word writing of grade 5.

Table 18. Hierarchical Regression Analyses of T2 Word Reading in grade 1.

Variable	β	Adjusted R^2	R^2 change	F (8,70)
Step1				
T1WordReading	0.73***	0.52		
Step2				
T1WordReading	0.58***	0.56	0.04	1.73
RAN	-0.28**			
SCTAW				
KABC				
Onset				
Rime				
NonwordRep				
NonwordBackSpan				
MorphologyJud				

Note: RAN = Rapid Automatized Naming; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion; Rime = Rime Deletion; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Table 19. Hierarchical Regression Analyses of T2 Word Reading in grade 2.

Variable	β	Adjusted R^2	R^2 change	F (11,89)
Step1				
T1WordReading	0.65***	0.39		
Step2				
T1WordReading	0.75***	0.37	-0.02	0.74
RAN				
ROCFTcopy				
ROCFTimm				
ROCFTdel				
SCTAW				
KABC				
Onset				
Rime				
NonwordRep				
NonwordBackSpan				
MorphologyJud				

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion; Rime = Rime Deletion; NonwordRep = Non-word Repetition; NonwordBackSpan = Non-word backward span; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Table 20. Hierarchical Regression Analyses of T2 Word Reading in grade 3.

Variable	β	Adjusted R^2	R^2 change	F (12,33)
Step1				
T1WordReading	0.58***	0.33		
Step2				
T1WordReading	0.63**	0.22	-0.11	0.44
RAN				
ROCFTcopy				
ROCFTimm				
ROCFTdel				
SCTAW				
KABC				
Onset				
Rime				
NonwordRep				
NonwordBackSpan				
MorphologyProd				
MorphologyJud				

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Table 21. Hierarchical Regression Analyses of T2 Word Reading in grade 4.

Variable	β	Adjusted R^2	R^2 change	F (12,26)
Step1				
T1WordReading	0.47***	0.08		
Step2				
T1WordReading		0.19	0.11	1.42
RAN				
ROCFTcopy				
ROCFTimm				
ROCFTdel				
SCTAW				
KABC				
Onset				
Rime				
NonwordRep				
NonwordBackSpan				
MorphologyProd	0.47*			
MorphologyJud				

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Table 22. Hierarchical Regression Analyses of T2 Word Reading in grade 5.

Variable	β	Adjusted R^2	R^2 change	F (12,43)
Step1				
T1WordReading	0.39***	0.16		
Step2				
T1WordReading	0.34**	0.28	0.12	1.75
RAN				
ROCFTcopy				
ROCFTimm				
ROCFTdel				
SCTAW				
KABC	0.30*			
Onset				
Rime				
NonwordRep				
NonwordBackSpan				
MorphologyProd				
MorphologyJud				

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Table 23. Hierarchical Regression Analyses of T2 Writing in grade 1.

Variable	β	Adjusted R^2	R^2 change	F (8,70)
Step1				
T1Writing	0.38***	0.13		
Step2				
T1Writing	0.39***	0.18	0.05	1.61
RAN				
SCTAW				
KABC				
Onset				
Rime				
NonwordRep				
NonwordBackSpan	0.27*			
MorphologyJud				

Note: RAN = Rapid Automatized Naming; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion; Rime = Rime Deletion; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyJud = Morphology Judgement.

*$p<0.05$. **$p<0.01$. ***$p<0.001$.

Table 24. Hierarchical Regression Analyses of T2 Writing in grade 2.

Variable	β	Adjusted R^2	R^2 change	F (11,89)
Step1				
T1WordWriting	0.62***	0.33		
Step2				
T1WordWriting	0.63***	0.31	-0.02	0.80
RAN				
ROCFTcopy	-0.22*			
ROCFTimm				
ROCFTdel				
SCTAW				
KABC				
Onset				
Rime				
NonwordRep				
NonwordBackSpan				
MorphologyJud				

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Deletion; Rime = Rime Deletion; NonwordRep = Non-word Repetition; NonwordBackSpan = Non-word backward span; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Table 25. Hierarchical Regression Analyses of T2 Writing in grade 3.

Variable	β	Adjusted R^2	R^2 change	F (12,33)
Step1				
T1WordWriting	0.44***	0.16		
Step2				
T1WordWriting	0.48**	0.47	0.31	3.19**
RAN	-0.38*			
ROCFTcopy				
ROCFTimm				
ROCFTdel				
SCTAW	-0.42*			
KABC				
Onset				
Rime	0.39*			
NonwordRep				
NonwordBackSpan				
MorphologyProd				
MorphologyJud	0.35*			

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Table 26. Hierarchical Regression Analyses of T2 Writing in grade 4.

Variable	β	Adjusted R^2	R^2 change	F (12,26)
Step1				
T1WordWriting	0.57***	0.34		
Step2				
T1WordWriting	0.49***	0.61	0.27	3.17**
RAN				
ROCFTcopy				
ROCFTimm				
ROCFTdel	0.61*			
SCTAW	-0.26*			
KABC				
Onset				
Rime				
NonwordRep				
NonwordBackSpan				
MorphologyProd	-0.37**			
MorphologyJud	-0.27*			

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*$p<0.05$. **$p<0.01$. ***$p<0.001$.

Table 27. Hierarchical Regression Analyses of T2 Writing in grade 5.

Variable	β	Adjusted R^2	R^2 change	F (12,43)
Step1				
T1WordWriting	0.64***	0.36		
Step2				
T1WordWriting	0.49***	0.53	0.17	2.57*
RAN				
ROCFTcopy				
ROCFTimm				
ROCFTdel				
SCTAW				
KABC				
Onset				
Rime	0.29*			
NonwordRep				
NonwordBackSpan				
MorphologyProd	0.29*			
MorphologyJud				

Note: RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

*p<0.05. **p<0.01. ***p<0.001.

Ⅳ. Discussion

1. Longitudinal Predictors for Word Reading in Different Grades

For Chinese word reading, the result of the present study showed that when T1 word reading was statistically controlled, T1 RAN uniquely explained T2 word reading in grade 1. This result was in accordance with previous findings among Hong Kong children (Tong et al., 2009; Yeung et al., 2011; Yeung, Ho, & Lo, 2013), which found that naming speed is an important predictor of Chinese word reading among younger participants. The skills underlying the RAN tasks reflect the ability to learn arbitrary associations which are required in early stage reading. Furthermore, naming speed was not a significant longitudinal predictor of subsequent word reading in grade 2 or higher grades. This result supported the suggestion that the contribution of naming speed in word reading is taken up by other cognitive skills as children advance into higher grades (Yeung, Ho, & Lo, 2013). T1 RAN seems has a strong effect on T2 reading in grade 1, presumably reflecting the greater role of naming speed in reading at initial stage than the higher grades level.

The result of present study shows that with the initial word reading statistically controlled, T1 morphological awareness (morphology production measure) was a significant predictor of T2 word reading in grade 4. The findings on morphological awareness in relation to reading replicated previous work in Chinese word recognition (e.g., Tong et al., 2009) in relatively higher grades. Morphological awareness is considered as an essential skill in reading development because of the characteristics of the large amounts of compound words and homophone in Chinese language (McBride-Chang, Wanger, & Shu, 2005). In Chinese, morphemic unit is a salient characteristic, in which lots of vocabulary are built by combining morphemes via compounding. It was reported that approximately 65% of Chinese words are comprised of two or more characters (Tan & Perfetti, 1999). McBride-Chang el al. (2003) suggested that sensitivity to the morphemic structure of Chinese might promote children's ability to read and write. Since the same morphemes can share the same meaning, good morphological awareness could facilitate the recognition of words based on constituent morphemes in compound words. Thus, learning to read Chinese may require the ability to recognize and memorize many morphemes sharing identical sounds or written forms (Tong et al., 2011).

The result of hierarchical regression analyses showed that with T1 word reading was statistically controlled, T1 vocabulary knowledge still contributed a unique variance to T2 word reading for children in grade 5. This means that the potential strong association of vocabulary knowledge and Chinese reading abilities was extracted. Based on this result, vocabulary knowledge becomes a relatively important factor underlying the development of reading skills, perhaps because Chinese has a unique characteristic in terms of a comparatively opaque script that is heavily focus on meaning-related aspects (e.g., McBride-Chang et al., 2003; Shu et al., 2006).

The results of this study found that cognitive abilities could not explain unique variance in T2 word reading of grade 2 and 3, when T1 reading skills were statistically controlled. Indeed, the fact that the model fit of the regression model was reduced when entering T1 cognitive abilities in the hierarchical regression analysis. This suggests that the relation between T1 cognitive abilities and T2 reading performance might be mediated by T1 reading skills. Even in grades other than the second and third grades of elementary school, T1 reading skills predicted T2 reading skills significantly. The result of our study confirms the important role of early literacy skills for later literacy development.

2. Longitudinal Predictors for Word Writing in Different Grades

Compared with the abundant evidence on the importance of cognitive abilities on Chinese word reading, previous studies exploring effects of cognitive-linguistic skills on longitudinal Chinese word writing are relatively limited. In hierarchical regression analyses with T1 word writing controlled, T1 phonological memory uniquely explained T2 word writing in grade 1. Thus, T1 phonological memory seems to have an impact on T2 writing in grade 1. Importantly, it is found that the role of phonological memory in writing at initial stage is more important than that role in the upper grade level, because such a significant predictive power of phonological memory was not observed in any other grades. Studies of Chinese children in Hong Kong have demonstrated that phonological memory is longitudinally associated with Chinese word writing of grade 1 to grade 4 students (e.g., Chan et al., 2006), which is different from our finding.

Surprisingly, visual skill (ROCFT copy drawing measure) was negatively associated with T2 writing in grade 2 when T1 writing was controlled. However, given the adjusted R^2 was reduced when the cognitive abilities were included in the multiple regression equation (i.e., Step 2), it is likely that cognitive abilities could not explain unique variance in T2 word writing in grade 2 when T1 writing skill were statistically controlled. The result indicated that T1 word writing entirely mediated the relationship between T1 cognitive abilities and T2 word writing of grade 2.

In contrast, T1 visual memory (ROCFT delayed recall measure) significant associated with T2 writing performance in grade 4 even with the T1 writing was controlled. This result shed light on the importance of visual memory for later Chinese writing of school children. Chinese is regarded as a visual complex orthographic system (Chen & Kao, 2002). Visual skills also have been reported as an essential ability for literacy development in Chinese children (Siok & Fletcher, 2001; McBride-Chang, Chow, Zhong, Burgess, & Hayward, 2005). The complexity of the Chinese orthography may emphasize the importance of the ability to discriminate or memorize orthographic symbols for facilitating children to recognize and encoding the characters sharing slightly different visual-orthographic patterns (Tong et al., 2011). Compared to Roman letters, Chinese characters are constituted by more strokes and arranged in visually complex arrays (Su, Peyre, & Shu, 2017). This visual feature would give a heavy load on visual memory, when a child memorizes and recalls the shape of characters. Thus, it is supposed that visual memory predicted later writing performance.

RAN significantly predicted word writing of grade 3 in the multiple regression equation. Georgiou and Parrila (2008) reported that the RAN test performance in grade 1 related to their performance in spelling on a dictation task from first to third grade of children in Taiwan. Our result replicated their findings partly. The relatively strong association between RAN and spelling performances is observed in other previous cross-sectional and longitudinal studies in both of Chinese (e.g., Chan et al., 2006; Ding et al., 2010) and alphabetic languages (e.g., Savage, Pillay & Melidona, 2008; Sunseth & Bowers, 2002). Naming speed measured by the RAN test has been viewed as an important part of Chinese reading acquisition and impairments, because Chinese script has relatively arbitrary associations between print and sound (McBride-Change & Ho, 2000;). Mains et al. (1999) demonstrated that RAN reflects an automatic processing which involved in retrieving verbal representations from orthographic patterns in the mental lexicon, and mapping of arbitrary symbols to spoken language. For this reason, the ability underlying good performance on the RAN test is crucial to the writing development of

Chinese children, due to opaque relationships between orthography and phonology in Chinese.

The present study found that T1 phonological awareness (particularly rime awareness) in third and fifth graders significantly explained their T2 word writing performance with their T1 writing controlled. In the writing task, children were orally presented with the Chinese compound words. In order to correctly spell the target words, children may need to identify the target words according to the phonological information. Onset and rime are the core segmental aspects of phonology in Chinese. In addition, children in Mainland China can recognize the phonological structure of a word and segment the word sound into onset and rime easily since Pinyin is used as a coding system that aid children learning to read in initial teaching stage. Therefore, when a child uses phonological information to write a word, the child might tend to pay attention to the phonological structure, i.e., the segments as onset and rime. If it is true, phonological awareness, especially rime awareness would play an important role in writing development in Chinese children, as shown in our study.

In addition to rime awareness, morphological awareness also longitudinally predicted word writing in grade 3 and 5. In morphology production task, children were expected to produce a word whose target character shared the same meaning with that of the presented word, as well as a word whose target character had a different meaning from the character of the presented word. In order to produce the correct answers, children need to be able to distinguish the meaning of morpheme contained in stimuli first, and then reminded themselves a compound word in which constituted morphemes have the same meaning, as well as a compound word in which the shared morphemes have different meaning. The morphological awareness task somewhat shared the similar process with our writing tasks.

To be skilled at writing to dictation of Chinese words, children needed to identify the specific target character and discriminate the different meaning of them with other homophones in character level. These kinds of sensitivity to the homophone may facilitate children's abilities to map specific sounds with specific morphemes (Tong et al., 2011). In our study, in the word dictation test, stimuli consisted of two characters and they were orally presented to children. First, the children had to distinguish the pronunciations correctly. Given the great number of homophones in Chinese characters, Chinese children had to discriminate among the homophones with different meanings then write down the one with the target meaning (Yeung, Ho, & Lo, 2013). In this case, phonological awareness and morphological awareness play a more essential and significant role on writing to dictation. Therefore, we obtained results showing that phonological awareness and morphological awareness were the significant longitudinal predictors for writing skills in Chinese children in some grades.

Unlike third and fifth graders, morphological awareness of fourth graders negatively associated with their later word writing performance with the early word reading abilities controlled. The other unexpected predicting result was related to the T1 vocabulary knowledge (SCTAW measure) which predicted T2 Chinese writing of grade 3 and 4 negatively. With T1 word writing statistically controlled, vocabulary knowledge was negatively associated with later writing in intermediate grades. One plausible reason for these findings is that the relatively few data have been retained in T2 of these grades. We need to include more participants into the longitudinal study in the future research. It is noted there are still unclear relationships between cognitive abilities and Chinese writing since the number of previous studies is limited. It may be important to continue to explore in future studies until we can find out more effective task for different ages Chinese children.

3. Comparison of the Findings in Cross-sectional Study and Longitudinal Study

In the cross-sectional study (Study 2), we found that cognitive-linguistic abilities related to Chinese words reading differ across children's development stages. In other words, naming speed and visual memory played important role on reading acquisition of younger Mainland Chinese children, while vocabulary knowledge and phonological memory were crucial for older children in words reading. This was supported partly by our longitudinal results in grade 1 and 5. T1 naming speed still explained T2 word reading in grade 1, and moreover T1 vocabulary knowledge still contributed a unique variance to T2 word reading for children in grade 5. These results confirm the contributions of naming speed and vocabulary knowledge to early and late reading development, respectively. On the other hand, the longitudinal study did not obtain any results suggesting the important role of visual memory and phonological memory on reading development. Importantly, we also had some new finding in longitudinal study: the significant contribution of morphological awareness in grade 4 was shown in longitudinal study but not cross-sectional study. This finding was supported by the previous researches which suggested morphological awareness contributed to Chinese reading development of intermediate grade children (Liu & McBride-Chang, 2010; Wei et al., 2014).

Results of the longitudinal study on Chinese word writing development seemed to be similar to those of the cross-sectional study, in that cognitive-linguistic variables did not predict word writing performance in sequential school years. For example, T1 morphological awareness and phonological awareness predicted T2 word writing performance in grade 3 and 5 but not grade 4. Furthermore, phonological memory only predicted word writing performance in grade 1. In addition, naming speed only contributed to writing performance in grade 3, and visual memory only made contribution to writing performance in grade 4. These findings suggest that learning to write Chinese words is gradually development instead of a stage-like process.

Overall, the present study revealed that various cognitive constructs relate to literacy development in Mainland Chinese children. The finding in our study indicated that some cognitive-linguistic abilities not only contribute to children's current reading/writing performance but also remain impact on their later literacy. However, most of the predictive cognitive abilities for literacy skills change with children's development. The relationships between various cognitive abilities and literacy development are not all that straightforward. It may be due to that children are likely to capitalize on all the strategies and knowledge available to them in learning to read and write (Yeung, Ho, & Lo, 2013). Importantly, the present study found that T2 literacy skills across grades were facilitated by T1 literacy skills. Along with specific cognitive abilities, some attention to early literacy skills may additionally facilitate the understanding of this complex process.

Chapter5. General Discussion and Conclusions

In the present study, we examined the applicability of the PRS as a screening checklist for developmental dyslexia, as well as the relationship between a comprehensive set of cognitive abilities and reading as well as writing skills in elementary school children in Mainland China. Our study also tested the predictive power of cognitive abilities for children's literacy performance at different grades, and examined what extent early cognitive abilities influence later literacy abilities when children's early literacy performance is controlled.

1. The Applicability of PRS for Developmental Dyslexia for Mainland Chinese Children

In Study 1, we examined the validity of the PRS by conducting a series of literacy and cognitive tests for intermediate graders in Mainland China. However, none was identified as a child suspected of learning disability when using PRS, although 18% of the students did show low performance on objective reading and/or writing tests (hereafter the RWD group). Although the RWD group's PRS scores were significantly lower than those of the Normal group, none of the children in the RWD group met the PRS diagnostic criteria. These results suggest that the use of only the PRS could not detect a child with reading and/or writing deficits, i.e., developmental dyslexia. Moreover, even if the PRS scores are divided into verbal and nonverbal subscales, it is difficult to specify what problems of basic academic skills and literacy-related cognitive skills the children have, by relying simply on the results of the PRS. This is because the PRS contains no subscales relating to reading and writing abilities as well as to significant cognitive predictors for Chinese reading and writing development. In conclusion, objective reading and writing tests as well as cognitive-linguistic skills measures are necessary to detect a child with developmental dyslexia and provide an effective intervention based on cognitive deficiency she/he has.

2. Cognitive Skills Related to Literacy Development in Mainland Chinese Children

In Study 2, i.e., a cross-sectional study, we tested the predictive cognitive abilities for children's literacy performance at different grades. We found that the predictive power of each vocabulary knowledge and each cognitive ability depends on a kind of literacy skills and children's ages.

According to our findings, visual skills, especially visual memory, significantly contribute to reading and writing achievement in Mainland Chinese children in lower grades. Our cross-sectional study found that visual memory, which is relatively rare investigated in the previous researches, plays important roles in the development of reading and writing in younger Chinese children. The predictive pattern of visual skills in our study is consistent with those findings reported in Hong Kong and Taiwan. In a longitudinal study of McBride-Chang, Chow, and Hayward (2005), they found that the kindergartners who learn simplified Chinese script tended to develop their visual skills better comparing to the children learn traditional Chinese script in the early stages of literacy development.

For Chinese script, simplified character is used in Mainland China and Singapore, while traditional character is used in Hong Kong and Taiwan (McBride, 2016). About 50% of the most common 2000 characters are the same between simplified and traditional characters, while the other differ substantially in look from on another (Rohsenow, 2001) (e.g., traditional character: 僅，歡，葉; simplified character 仅，欢，叶 which mean 'only', 'happy' and 'leaves', respectively). Although simplified Chinese characters are relatively less visually-complicated than traditional characters, it seems that visual skills still contribute to learning to read and write simplified Chinese character, as were shown in this study. McBride (2016) suggested that traditional characters are easier to read but more difficult to write than simplified characters. According to Gao and Kao (2002), traditional Chinese characters contain about 22.5% more visual feature information than simplified characters on average. The additional visual information contained in traditional characters are supposed to facilitate visually discrimination between different characters (McBride, 2016). Based on the difference of visual features between simplified and traditional characters, Visual skills will play a more important role on learning simplified Chinese characters, since reading process need Mainland Chinese children focus on the written forms of characters to differentiate the orthographical symbols which are less regular than traditional one. As the traditional characters are simplified, phonetical radicals which provide phonological information become less reliable for children to read (e.g. the sound of traditional character 僅, jin, correspond to its phonetical radical 堇, jin, while the sound of simplified character 仅, jin, is not same as its phonetical radical 又). For simplified character, a phonetical radical will not help Chinese learners guess the simplified character's correct pronunciation. Therefore, children learning simplified Chinese characters might need to memorize the visual shape of each whole character and mapping between the character and its sound. Indeed, our results support this idea that visual skills are essential for Chinese reading development for the simplified characters used in Mainland China.

In contrast to lower graders, phonological memory and vocabulary knowledge predicted reading abilities from grades 2 to 6 significantly, suggesting that phonological memory plays an important role on children's literacy acquisition across different grades. This result replicated the findings reported in previous researches that demonstrated the importance of phonological memory in learning to read Chinse (e.g., Chan et al., 2006). There are two reasons for the importance of phonological memory in learning to read Chinese. First, since phonological information contained in phonetic radicals are relatively unreliable in Chinese, Chinese learners who rely solely on phonetic radicals to read Chinese characters will not read the characters correctly. Thus, it is necessary to memorise the orthography-phonology correspondences at character and word levels in learning to read and write. Second, this result may be also accounted by the instruction method and learning method used in Mainland China, namely recitation. Children are usually encouraged to recite the poetries or passage in the textbooks them learn from memory. This method might facilitate Chinese children's ability to utilize their phonological memory during the process of learning to read.

In our study, we also found that vocabulary knowledge significantly predicted literacy performance of children from grade 2 and above. Expressive vocabulary knowledge also uniquely predicted later reading performance in grade 5. These results support the suggestion that vocabulary knowledge is important in learning to read Chinse regarding Chinese children in Mainland China (e.g., Pan et al., 2011).

In the longitudinal study (Study 3), we examined to what extent early cognitive abilities influence later literacy abilities after controlling the children's early literacy performance. Morphological awareness predicted children's later writing performance in third and fifth grades in addition to phonological awareness. Although we did not find that morphological awareness predicted reading of younger children in contrast to reading performance of children in Hong Kong (McBride-Chang et al., 2003), morphological awareness did significantly contribute to literacy performance in upper grades in both the cross-sectional and longitudinal investigations (Study 2 and 3). The 2-years longitudinal investigation of this study found that morphological awareness in early year contributed to literacy development in advanced grade. These findings are compatible with previous longitudinal studies in Hong Kong (Yeung, Ho, & Lo, 2013). Tan and Perfetti (1999) found that approximately 65% of Chinese words are comprised of two or more characters. Thus, older children who learn to read words comprised of two or more morphemes are prone to utilize their knowledge of morphemes and observe how these morphemes are repeated across words (Mc-Bride, 2016). When these children can discriminate these characters as morphemes and they recognize that the same morphemes appear across different words, morphological awareness can facilitate their literacy development and made them become skilled readers. Thus, it is supposed that, regardless of whether a child learns simplified characters or traditional characters, morphological awareness contributes to the literacy development in especially upper graders.

As for lower graders, the RAN performance was important predictors for reading and writing abilities, in addition to visual skills. The importance of naming speed (measured by RAN) is also observed in previous studies conducted in Hong Kong (e.g. McBride-Chang et al., 2012; Yeung, Ho, & Lo, 2013) and Taiwan. (e.g. Liao et al., 2008).

In addition, phonological awareness, especially rime awareness, emerged to be significant predictor for later writing abilities in this study. The results of longitudinal study are consistent with not only the findings of previous studies in alphabetic languages but also the findings regarding Chinese children in Taiwan and Hong Kong (e.g. Hu and Catts, 1998; Chan et al., 2006). However, the longitudinal contributions of phonological awareness were limited in our study. We obtained results showing that sensitivity to onset and rime was associated with Chinese word writing in not all grades, i.e., only grade 3 and 5. In addition, phonological awareness did not predict reading performance of our participants in any grades. The limited contributions of phonological awareness might be due to characteristics of Chinese writing system. In Chinese, onset and rime are important segmental aspects of Chinese phonology. Learning Pinyin helps a child recognize the phonological structure consisting of onset and rime because Pinyin is a coding system of Chinese phonology. Importantly, the acquisition of Pinyin is relatively easy because the way to code onset and rime and rules of pronunciations in Pinyin are regular. Therefore, even if a child has potentially poor phonological awareness, the child would be able to recognize of Chinese phonological structure, i.e., segments of onset and rime, through learning Pinyin. The awareness of the phonological structure would develop the use of phonetic radicals which represent character sounds to read Chinese words. However, the mappings between a phonetical radical and its sound are inconsistent. Therefore, a Chinese learner who has excellent phonological awareness may still be unable to utilize phonetic radical information contained in Chinese compound characters (which include phonetical and semantical radicals in character) in order to infer their pronunciations (McBride, 2016). This implies that the use of phonetical radicals to guess the reading of characters is not necessarily useful, which would not encourage a child to rely on phonological information from phonetical radicals. Considering that the use of phonetic radicals to read Chinese words corresponds to the sub-lexical reading process for English words that is usually influenced by phonological awareness (Stuart & Masterson, 1992), the useless phonological information from phonetical radicals may account for the limited influence of the phonological awareness on Chinese literacy development.

In conclusion, there are three important findings in our study. First, each cognitive-linguistic skill examined in our study to some extent made contribution to reading and/or writing performance of Mainland Chinese children at different ages. Second, the contribution of cognitive-linguistic skills to reading and writing accuracy varied across different ages. Especially, naming speed and visual skills are essential for younger children's reading, but the contribution of these cognitive abilities decrease as children advanced into the higher grades. Moreover, morphological awareness significantly contributed to older children's reading and writing performance. In addition, phonological memory, instead of phonological awareness, plays an important role in Mainland Chinese children's reading abilities. Third, findings of the longitudinal study showed that apart from the main cognitive-linguistic abilities of interest in our study, early Chinese literacy were an important predictor of all subsequent literacy abilities.

Table 28. Significant predictors for literacy performance of different graders in cross-sectional study

	Grade1		Grade2		Grade3		Grade4		Grade5		Grade6	
Predictors	R	W	R	W	R	W	R	W	R	W	R	W
RAN	○							○				○
ROCFTcopy												
ROCFTimm	◎	◎		◎								
ROCFTdel												
SCTAW	○				◎	◎	◎		◎		◎	
KABC			◎						◎		◎	
Onset												◎
Rime												
NonwordRep		◎	◎	◎	◎		◎					
NonwordBackSpan		◎		◎	◎		◎		◎		◎	
MorphologyProd										◎		
MorphologyJud												

Note: R = Reading; W = Writing; RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

◎ = Significant predictor (positive)

○ = Significant predictor (negative)

Table 29. Significant predictors for literacy performance of different graders in longitudinal study

	G1→G2		G2→G3		G3→G4		G4→G5		G5→G6	
Predictors	R	W	R	W	R	W	R	W	R	W
T1 Literacy			◎	◎	◎					
RAN	○					○				
ROCFTcopy										
ROCFTimm										
ROCFTdel								◎		
SCTAW						○		○		
KABC									◎	
Onset										
Rime						◎				◎
NonwordRep										
NonwordBackSpan		◎								
MorphologyProd							◎	○		◎
MorphologyJud						◎		○		

Note: R = Reading; W = Writing; RAN = Rapid Automatized Naming; ROCFTcopy = Rey-Osterrieth Complex Figure Copy Drawing; ROCFTimm = Rey-Osterrieth Complex Figure Immediate Recall; ROCFTdel= Rey-Osterrieth Complex Figure Delayed Recall; SCTAW = Standardized Comprehension Test of Abstract Words; KABC = The Expressive Vocabulary Test of K-ABC II; Onset = Onset Production; Rime = Rime Production; NonwordRep = Nonword Repetition; NonwordBackSpan = Non-word Backward Span; MorphologyProd = Morphology Production; MorphologyJud = Morphology Judgement.

◎ = Significant predictor (positive)

○ = Significant predictor (negative)

3. The Implication for Assessment and Interventions for Reading/Writing Difficulties in Mainland Chinese Children

Our studies have yielded some potentially important findings to consider in future researches on literacy development in Mandarin Chinese. These findings are novel within the domain of Mainland Chinese children's literacy acquisition and development, also carry important implications for the assessment of reading/writing difficulties and the development of effective intervention strategies.

First of all, objective reading and writing tests are necessary when screening out children who are suspected to have reading and writing difficulties. Also, cognitive-linguistic skills measures are crucial to detect a child with developmental dyslexia and then provide an effective reading and writing training with the child. Educators in Mainland China may find it valuable to include the tests used in the current study as the assessment tools for detecting reading and writing difficulties in primary school children. For example, the result of present study suggested that RAN affect Chinese reading in early stage. Determining that early RAN skills can predict later word reading of younger children, and to some extent the writing performance of upper graders, might encourage educators to consider using RAN as rough screening measures for subsequent reading/writing difficulties and to contemplate interventions based on such screenings earlier. As for the advanced graders, morphological awareness, especially morpheme awareness seems to be important for their reading and writing development. Teachers could apply the morphological awareness task conducted in our study to estimate children's understanding of morphemes in Chinese words.

Second, the findings from the present study have several practical implications, especially for the instructional strategies for Chinese school children. The benefits of early diagnosis and remediation of development dyslexia has been well reported in previous studies (e.g. McBride-Chang et al., 2005; Tong et al., 2009). Tong et al. (2009) and Yeung et al. (2016) suggest that the earlier the intervention program for reading is provided, the better its effectiveness. The present study confirms the important role of early literacy skills as well as the impact of early cognitive abilities on later literacy performance. This finding implies that teachers should use a training method to associate word meanings, phonology and orthography with each other, instead of a training method focusing on the visual forms of words. It is also important to apply teaching methods according to the development stages of children.

4. Conclusions and Limitations

(1) Conclusions

The present study revealed that reading and writing development of Mainland Chinese children from first to sixth grades were influenced by a comprehensive set of cognitive-linguistic abilities. Importantly, predictors of reading and writing performance differed across ages. This finding indicates that the learning strategies of children change as their reading and writing experience increasing. Moreover, we obtained both consistent and inconsistent results with the findings of previous studies in Hong Kong and Taiwan, in terms of significant predictors of reading and writing abilities. This implies that the results of our study not only reflect the universality of the mechanisms of Chinese reading and writing development reported in Hong Kong and Taiwan, but also some specificity of the developmental mechanisms of reading and writing in Chinese children in Mainland China. We suppose that the inconsistent results were observed due to the differences of the instruction methods of teachers and the used scripts (i.e., simplified characters or traditional characters), between Mainland China and Hong-Kong/Taiwan. Since linguistic-cognitive factors relating to reading and writing abilities of children in Mainland China were not completely the same as those of children in Hong-Kong and Taiwan, the findings obtained in Hong Kong and Taiwan should not be applied to the understanding of the underlying mechanisms of the reading and writing development in Mainland Chinese children.

The findings of this study are expected to be utilized as screening test for Mainland Chinese children who are suspected to have difficulties in reading and/or writing. More importantly, specific identification can then directly link to intervention. Referring to the finding of our studies, classroom teachers could provide more efficient instruction to children after they perceive the association between cognitive-linguistic skills and literacy performance of children in different grades.

(2) Limitations

The present study had some limitations. First, regarding predictors for word writing in Study 2 and 3, coefficient of determination in multiple regression models was low and vocabulary or cognitive factors could not account for writing performance sufficiently. There are two reasons that accounted for these results. This may be due to the fact that the number of participants in our longitudinal study was relatively limited. It is possible that we need to include some metalinguistic skills as variables in multiple regression analyses, apart from the six cognitive-linguistic abilities addressed in this study (i.e., phonological awareness, phonological memory, visual skills, naming speed, morphological awareness, vocabulary knowledge). The recent studies reported the significant relationships between orthographic awareness and literacy development in Chinese (e.g., Wei et al., 2014). In the future studies, we need to include more participants into the longitudinal studies. Moreover, future studies should probe further into the importance of additional metalinguistic skills, such as orthographic awareness for Chinese spelling development.

Second, the present study examined word reading and writing development of grade 1 to 6 children at 2 time points during a 2-year span only. In the literatures on reading and spelling development in alphabetic language, it was found that strategy specialization between reading and spelling are transitory in nature (Yeung, Ho, & Lo, 2013). Bryant and Bradley (1980) indicated that the various skills involved become better integrated as reading and spelling ability advance. Thus, data covering longer periods of Chinese children's literacy development are necessary for verifying these suggestions.

Third, although we developed a series of reading/writing test as well as cognitive abilities tests following the previous researches in Hong Kong and Taiwan, as well as Japan, we have not examined the reliability or validity of these tasks yet in the present study. In order to test the reliability of the tasks, we need to check the internal consistency of each task developed in our study. Moreover, we should compare the screening rate for reading/writing difficulties by our test with that of the standardized tests developed in Hong Kong or Taiwan.

Fourth, we did not conduct a comparison between the typical development group with reading/writing difficult group, or focus on the cognitive characteristics of children who are especially poor in reading and/or writing. Prior researches suggested that some older readers with development dyslexia could apply methods to cover their poor reading and writing as their reading and writing experience increasing (e.g., Pennintong, McCabe, Smith, Lefly, Bookman & Kimberling, 1986; Wolff, Michel & Ovrut, 1990). These studies indicated that the characteristics of cognitive abilities for children with developmental dyslexia may change with age. In the future study, we need to follow up those children with poor reading and writing performance, in order to figure out the characteristics and development trajectories of their cognitive abilities.

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Appendix A

The stimuli of Word-reading task in Study 1

	Character type	
	Typical	Atypical
One-character	跑 棋 飘 颗 极 望 递 诚 抵 练	贫 姐 枯 浇 灭 挂 盼 柴 输 攻
Two-character	傍晚 欺骗 骄傲 叮嘱 结构 议论 富裕 呼唤 旗帜 肌肤	眼睛 姑娘 感恩 价钱 推理 佳话 附近 等待 欣赏 路途

Note: Typical vs Atypical: A character was classified as typical if the pronunciation of it was the most common pronunciation used in characters containing the same phonetic radical. A character was classified as atypical, if the pronunciation of the character was not the most common in characters containing the same phonetic radical (Fang, Horng & Tzeng, 1986).

Appendix B

The stimuli of Non-word reading task in Study 1

	Character type	
	Typical	Atypical
One-character	苹 蚂 芳 汪 讶 翩 郊 龄 阶 骄	孩　玻 杜 怦 决 宙　待 稚 迫 惜
Two-character	傍肌 欺议 富论 结帜 呼构 傲晚 旗唤 骗裕 肤叮 骄嘱	眼附 感佳 姑近 恩途 待钱 欣睛 娘理 推赏 价话 等路

Appendix C

The stimuli of Rapid word-reading task in Study 1

Character type			
One-character		Two-character	
架	笑	辽阔	海洋
笔	睡	勇敢	粮草
捧	桌	检阅	呵护
话	盏	菠萝	视线
短	蝉		

Appendix D

The stimuli of Rapid non-word reading task in Study 1

Character type			
One-character		Two-character	
苍	顺	推念	迅测
造	资	饱批	织钻
经	续	速梯	评想
栏	澡	楼组	温研
珍	秘		

Appendix E

The stimuli of Rapid passage-reading task in Study 1

爷爷坐在院子里扎(zā)灯笼的时候，我就坐在旁边的椅子上画画。我喜欢把爷爷认真工作的样子画下来。夏天的时候，院子里虽然很凉快，爷爷还是不停地用一条水蓝色的毛巾擦(cā)汗。

有一天我放学回到家，看见爷爷扎的灯笼已经堆成了小山。我就坐在旁边把小山一样的灯笼和爷爷画了下来。涂颜色的时候，我发现水蓝色的铅笔用完了，只好用绿色来画爷爷的毛巾。画完之后我拿给爷爷看，爷爷停下手上的活儿，用毛巾擦了把汗。他看着绿色的毛巾问我：“为什么把爷爷的毛巾画成绿色呢？”我说：“水蓝色的铅笔用完了。”爷爷听了，把画还给我，又继续埋头工作。

第二天我放学回到家，发现屋檐(yán)下的灯笼全部不见了。我吃了一惊，赶紧跑进屋里找爷爷。我才踏进屋里，就看到桌子上放着一盒崭(zhǎn)新的画笔。哦，一定是爷爷把灯笼卖了，给我买了画笔当礼物。

Appendix F

The stimuli of Word-writing task in Study 1

Pinyin	Answer
zhù fú	祝福
xiōng pú	胸脯
yuán fèn	缘分
huāng liáng	荒凉
xùn sù	迅速
qiān xū	谦虚
ān wèi	安慰
wēi xiǎn	危险
tǐ tiē	体贴
huó pō	活泼
fēn fāng	芬芳
yī kào	依靠

Appendix G

The stimuli of Word Reading task in Study 2 and 3

	Grade1				Grade2			
	One-character		Two-character		One-character		Two-character	
	Regular	Irregular	Regular	Irregular	Regular	Irregular	Regular	Irregular
Compound Character	把 吗 请 像 们	跑 海 凉 松 跳	植物 伙伴 花园 油彩 蚂蚁	说话 河流 温暖 逃跑 道路	钩 钢	斜 煤	疲倦 纺织 芭蕉	杜绝 环绕 隐约
Non-compound character	众 雪 屋 弯 黄 尘 林 居 办 告		可爱 看见 完全 朋友 高兴 公车 草原 音乐 出发 白云		叠 弱 觅 甚 寿 岩		节省 明显 冒充 从容	

Note: Regular vs Irregular: A character was classified as regular if it has the same pronunciation as its phonetic radical; otherwise, it was classified as irregular.

Appendix H

The stimuli of Word Reading task in Study 2 and 3

	Grade3		Grade4		Grade5		Grade6	
	Typical	Atypical	Typical	Atypical	Typical	Atypical	Typical	Atypical
High frequency	骄傲 傍晚 旗帜	恰巧 讲究	遭遇 逻辑 资源	维护 残酷	锻炼 踌躇 忙碌	寂静 操纵	遭遇 侵蚀 缘故	端详 援助
Low frequency	擦拭 奖励	廉价 消逝 阻挠	呼吁 资源	浑朴 稚拙 饶恕	皎洁 迟钝	贪婪 造诣 鉴赏	驯服 煎熬	尴尬 瞻仰 铸造

Note: Word Frequency was referred to The Modern Chinese Frequency Dictionary (1986). The frequency of word higher than 0.001 was classified as high frequency, while the frequency of word lower than 0.0001 was classified as low frequency.

Appendix I

The stimuli of Word Writing task in Study 2 and 3

Grade1					Grade2				
我们	左右	自己	什么	老师	童年	非常	认真	快乐	办法
耳朵	太阳	生日	上午	小山	蚂蚁	画家	房间	阳光	练习

Appendix J

The stimuli of Word Writing task in Study 2 and 3

	Grade3	Grade4	Grade5	Grade6
High frequency	旗帜 矛盾 谦虚 姑娘 狐狸 杜鹃	承担 疲倦 羡慕 细菌 蔬菜 唾沫	覆盖 恐惧 谈判 皱纹 缝隙 腊月	泛滥 谨慎 挫折 磁场 陶瓷 宴会
Low frequency	纳闷 陪伴 蕴含 钢琴 彩虹 粮草	瞬间 清澈 敏锐 梧桐 冠军 舞蹈	威武 凋谢 魂魄 废墟 山峦 花卉	魁梧 浩瀚 造诣 脸颊 苔藓 眼眸

Acknowledgements

I would like to express my deep gratitude to my supervisor, Associate Professor Hiroki Yoneda. Without his constant advice and enthusiastic encouragement, I would not have been able to complete this research. I also appreciated his suggestions and guidance on improving my manuscript.

I would also like to express my sincere appreciation to Professor Masayoshi Tsuge and Shoko Miyamoto, for providing useful guidance and feedback throughout the process of writing and revising my doctoral dissertation.

I would like to express my sincere gratitude to Dr. Akira Uno, who taught me the necessary steps of the research process and methods of investigation. I am grateful for his constant encouragement for my research and for all of his help during my stay in China.

I express my heartfelt thanks to Dr. Ami Sambai for professional conduct and helpful comments on the manuscript. Her constant encouragement and support is greatly acknowledged and appreciated. I wish to thank Dr. Hong Pei for all her valuable guidance and assistance, including constructive communication with collaborators of investigations.

Also, I wish to warmly thank all the students who participated in these studies, the teachers and the school principals for their time, valuable assistance and support. I am grateful to the children and parents for their support, and to a team of dedicated research assistants for data collection.

I received a lot of encouragement and help from my friends in Japan and China, and I would like to thank all of them. Finally, I express my sincere appreciation to my family for their unconditional support and warmly encouragement. I am very lucky to have such a caring family that has supported me throughout my education and research.

Without the help of so many supportive people, I would not be able to complete this study. I would like to express my heartfelt thanks to all of them.