University of Alberta

The Development of Phonological Awareness, Rapid Naming, and Orthographic Processing in Children Learning to Read Chinese

by

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Abstract

This cross-sectional study examined the relationship between cognitive processing skills and Chinese reading acquisition. The participants were 117 grade 2 and grade 4 children in Taiwan. Phonological awareness, rapid naming speed, orthographic processing, and word reading abilities were examined each with multiple tasks. Results of hierarchical regression analyses indicated that (a) tone sensitivity and rapid naming of characters predicted grade 2 reading performance; (b) onset and rime awareness, rapid naming of digits, rapid naming of Zhu-Yin-Fu-Hao symbols, rapid naming of simple characters, and knowledge of orthographic structure predicted grade 4 reading performance; and (c) orthographic processing skills were more important predictors of reading performance in grade 4 than in grade 2. Present results suggest that phonological awareness and rapid naming are important skills for both grade 2 and grade 4 Chinese literacy development; however, systematic understanding of radical function and internal orthographic structure of characters develops later as reading proficiency advances.

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Dedication

I dedicate this dissertation to my father,

Dr. Shang-Ching Liao,

And

my mother, Mei-Tai Lin Liao

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CHAPTER 1: INTRODUCTION

For researchers interested in cognitive processing and reading acquisition, the morphosyllabic and non-alphabetic characteristics of written Chinese provides a salient contrast to the alphabetic systems (Siok, Perfetti, Jin, & Tan, 2004). Studies that have examined Chinese reading acquisition and underlying cognitive processes have focused mainly on the constructs important for learning alphabetic languages, namely, phonological processing, rapid naming, and orthographic processing.

Phonological awareness defined as the sensitivity to the sound structure of a language and the ability to manipulate segments of words has long been shown to be a strong concurrent and longitudinal predictor of reading in English and a probable cause of reading difficulties (e.g., Parrila, Kirby, & McQuarrie, 2004; Manis, Doi, & Bhadha, 2000; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). Despite the establishment of phonological awareness as sine qua non for reading development in English, its importance in reading Chinese is often debated. The extent of phonological information involved in character identification in non-alphabetic Chinese is an area generating interest in the scientific community (e.g., Hu & Catts, 1993, Ziegler, Tan, Perry, & Montant, 2000).

Rapid naming, or "the speed with which the names of symbols (letters, numbers, colours, or pictured objects) can be retrieved from long-term memory" (de Jong & van der Leij, 2003, p. 23), has been studied extensively in alphabetic languages because of its predictive contribution to reading achievement (e.g., Compton, 2003; de Jong & van der Leij, 2003; Kirby, Parrila & Pfeiffer, 2003; Parrila et al., 2004; Torgesen et al., 1997;

Wagner & Torgesen, 1987). Traditionally, rapid naming is considered to be part of phonological processing. Specifically, it is the ability to rapidly retrieve phonological codes in the mental lexicon via printed stimuli (Wagner & Torgesen, 1987). Wolf and Bowers (1999) proposed an alternative conceptualization, arguing that rapid naming involves multiple processes that are independent of phonological processing and that rapid naming therefore should be categorized as a separate construct. At the same time, Wolf and Bowers also acknowledged that rapid naming is not totally independent of phonological processing. Rapid naming has been found to be related to Chinese character recognition (Hu & Catts, 1998; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; McBride-Chang & Zhong, 2003) and to predict reading ability (McBride-Chang & Zhong, 2003; Chow, McBride-Chang, & Burgess, 2005; Wang, 2005). In studies with Chinese dyslexics, a rapid naming deficit was found to be a core deficit (Ho, Chan, Tsang, & Lee, 2002; Ho, Chan, Lee, Tsang, & Luan, 2004; Lu, 2003). Yet, the theoretical relevance of what is actually captured by rapid naming tasks during Chinese reading remains uncertain (Cheung, McBride-Chang, & Chow, 2006).

Orthographic processing refers to applying orthographic information in one's language to process speech or print (Wagner & Barker, 1994). Studies examining orthographic processing in Chinese have shown that knowledge of orthographic structure is important for efficient character recognition (Chan & Wang, 2003; Chen, Shu, Wu, & Anderson, 2003; Ho & Bryant, 1997a; Ho & Ma, 1999; Ho, Wang, & Chan, 1999; Ho, Yau, & Au, 2003; Ku & Anderson, 2001; Ko & Wu, 2003; Shu & Anderson, 1997,1999; Shu, Anderson, & Wu, 2000; Shu, Chen, Anderson, Wu, & Xuan, 2003; Tsai & Nunes, 2003; Wu, Zhou, & Shu, 1999; Yang & Peng, 1997). Orthographic processing measures were also found to be useful for identifying Chinese dyslexics (Ho et al., 2002; Ho et al., 2004).

Hong Kong and China are the two regions that have generated the most studies in Chinese reading. Compared to Hong Kong and China, little reading research has been done in Taiwan. Chinese usually refers to Mandarin Chinese, which is the official language and medium of instruction in both Taiwan and China. There are also Chinese dialects such as Cantonese, Taiwanese (or Min-Nan), and Hakka. Spoken dialects are distinct from Mandarin but are the same in the written form. In Taiwan and China, two different auxiliary phonetic systems are adopted in the early reading instruction; Zhu-Yin-Fu-Hao and Pinyin. Hong Kong does not incorporate a phonetic system in the reading curriculum.

The purpose of this cross-sectional study was to examine what reading-related cognitive processing skills are associated with Chinese character recognition and word reading in an unselected sample of grade 2 and grade 4 children in Taiwan. The relationship between phonological awareness, rapid naming, orthographic processing, and Chinese character and word reading were explored by undertaking a comprehensive assessment of cognitive skills and reading abilities. It was expected that results obtained from this study would provide important information of the cognitive processes that are important for learning to read Chinese, and also identify useful screening measures for Chinese reading difficulties.

CHAPTER 2: INTRODUCTION TO THE CHINESE LANGUAGE

Chinese is written with a non-alphabetic script that is often described as logographic (Taylor, 2002; Siok & Fletcher, 2001; Shen & Bear, 2000; Shu & Anderson, 1997) or morphosyllabic (McBride-Chang et al., 2003) language. Chinese orthography does not consist of a limited number of symbols such as English and other alphabetic languages; instead, characters are the smallest meaningful units in Chinese writing and represent both syllables and morphemes at the same time. In other words, each character is a morpheme and is articulated as a single syllable (McBride-Chang et al., 2003). Moreover, Chinese is a tonal language. Each syllable is pronounced with a tone that, according to its pitch, defines its meaning (Taylor, 2002). The official language Mandarin, used in China and Taiwan, has four tones, whereas Cantonese, the dialect spoken in Hong Kong and southern China, has nine tones. Every character a reader encounters needs to be pronounced with a tone. For example, in Mandarin 馬 [ma]3 *horse* is pronounced "ma" in the third tone.

Chinese Characters basically fall into two categories: the simple form and the compound form. A simple character is a single, complete character that cannot be decomposed into smaller meaningful units. Conversely, a compound character is a character that can be broken down into smaller constituents (Ho & Bryant, 1999). None of the graphic features in a character specifies the sound structure of the syllable--such as phonemes or tones. Inasmuch as both spoken and written Chinese are very different from alphabetic languages, the following section will serve as an introduction to Chinese.

The Orthographic Structure of Written Chinese

Chinese orthography is structured in three levels: strokes, radicals and characters. The formation of Chinese characters follows the hierarchical order that strokes build up radicals and radicals are combined to form characters.

Strokes

Strokes are the basic units of characters. Strokes come in many different forms (e.g., 一, 丿, 乛, 丨, 丶). The complexity of a character is usually measured by the number of strokes, which implies that the higher the stroke number the more complex is the character (Chan, 1982). Chinese characters can be as simple as one stroke (e.g., 一 *one*), or up to 30 strokes (e.g., 鸝 *oriole*). Strokes are used as building blocks to compose characters and they have no bearing on sound or meaning (Shen & Bear, 2000; Ho & Bryant, 1999). Many characters are visually similar and are differentiated by only one or two strokes (e.g., 大 *big*, 太 *too*, 犬 *dog*, 夭 *dead*, 天 *sky,* 夫 *husband*). Therefore, analyzing graphic details is very important during character recognition.

Radicals

Radicals are combinations of strokes or stroke patterns. Stroke patterns are usually described as subcomponents of radicals. It is estimated that about 650 subcomponents have been used to construct various radicals (Fu, 1985). Some radicals can be components of characters or simple characters in their own right. For example radicals such as 半 [ban]4 *half,* 里 [li]3 *mile*, and 青 [chin]1 *green* can exist in a script independently or be combined with other radicals to form different characters such as 伴 [ban]4 *accompany* , 理 [li]3 *reason*, and 清[chin]1 *clear*. Most Chinese characters are comprised of two radicals and are usually called semantic-phonetic compound characters. A semantic-phonetic compound is a character that contains a semantic radical that provides cues to the meaning of the character and a phonetic radical that provides information on the sound of the character (Ho & Bryant, 1999; Shu et al., 2000; Shu et al., 2003).

The semantic radical is usually simply called a radical. It usually appears on the left or on the top of characters. A semantic radical provides cues to the meaning of the character by placing the character into a certain semantic category. For example, the radical 木 signifies the meaning of wood and provides semantic cues to characters such as 樹 *tree*, 根 *root*, and 枝 *branch* which are directly related to wood. However, the implication of the radical is not always consistent. For example, characters such as 權 *right*, 檢 *check*, and 機 *machine* with the radical 木 are not related to wood (see figure 1.1. for another example of a semantic radical). Moreover, semantic radicals do not provide complete information about the meaning of characters. The precise meaning of characters thus needs to be acquired through individual character learning.

semantic radical	characters that are related to water	characters that are unrelated to water
氵 (water radical)	江 (river)	法 (law)
	海 (ocean)	治 (heal)
	澤 (swamp)	沙 (sand)

Figure 1.1 An example of a semantic radical.

The phonetic radical of a compound character is simply called a phonetic. A phonetic is the phonological feature of Chinese characters and is usually positioned on the right or at the bottom of the characters. The pronunciation information provided by phonetics can range from complete to none. Some phonetics provide complete information of how characters should be pronounced, whereas others give no clue at all. The reliability of phonetics to character pronunciation has been investigated by various researchers (Chen et al., 2003; Shu, 2003; Shu et al., 2003). They have suggested that even though degrees of reliability vary among characters, phonetics are important for pronouncing characters.

Characters

Characters are the smallest complete meaning-bearing units in Chinese writing. Each character has an independent meaning that can be used in a text, whereas semantic radicals provide only "cues" to characters' meaning. A character is both a syllable and a morpheme. This one-on-one relationship is consistent in Chinese writing (Hanley, Tzeng, & Huang, 1999). Therefore, a two-character Chinese word will contain two morphemes and will be pronounced with two syllables. For example, 台北, the capital of Taiwan is pronounced [tai]2 [pei]3 with 台 *Taiwan* and 北 *north* as the two morphemes. In general, Chinese characters are divided into two categories: simple characters and compound characters.

Simple characters are those that contain only a single meaningful component. These characters are considered "simple" because they cannot be further decomposed into sublexical units (Wu et al., 1999). Characters belonging to this category often play double roles in Chinese writing. They can be components of compound characters or independent characters when they appear on their own. Simple characters number about 5% of all the modern characters (Shu et al., 2003).

Compound characters are characters that consist of two to five components, although the majority of compound characters are semantic-phonetic compounds. It has been estimated that about 80% to 90% of modern Chinese characters are semantic-phonetic compounds (Shu et al., 2003). There are about 200 semantic radicals and 1,100 phonetics in Chinese characters that are combined to form around 4,000 common characters of modern Mandarin (Shen & Bear, 2000; Shu, 2003). The large number of radicals and phonetics has generated concerns regarding the practicability of these two components during character recognition.

Furthermore, Mandarin Chinese has only approximately 400 syllables but 4,000 commonly used characters (morphemes). This means that, on average, each syllable is shared by 10 characters (Shen & Bear, 2000; Shu, 2003; Shu et al., 2003). Because a large number of characters are homophonous morphemes, Chinese characters have been termed "heterographic homophones" (Yin & Weekes, 2003), which implies the commonality of sharing sound among graphically dissimilar characters.

Pronouncing Chinese Characters

One of the major features of non-alphabetic Chinese writing is the arbitrary relationship between sound and print. Each character is a syllable and none of the constituents (e.g., strokes) provide phonological structures (e.g., phonemes). Simple characters that are less complicated are usually taught earlier on in reading instruction. Because simple characters are not decomposable they can only be learned by rote. The mastery of simple characters is important for recognition of compound characters because a large number of simple characters become phonetic components of compound characters. Shu et al. (2003) estimated that in China, two-thirds of simple characters learned in the lower grade levels become phonetics of compound characters that are learned in higher grade levels.

The pronunciation of compound characters can usually be obtained directly or partially from their phonetics, or via analogy to their orthographic neighbors (characters that contain the same phonetic component). Studies investigating phonological information provided by phonetics have showed that regularity influences character naming (Chen et al., 2003; Ho & Bryant, 1997a; He, Wang, Anderson, 2005; Shu et al., 2000; Seidenberg, 1985). Regularity of phonetic components refers to the amount of phonological information provided by phonetics for pronouncing compound characters (Chen et al., 2003). Therefore, a regular compound character is pronounced the same as its phonetic component in isolation when it appears alone as a simple character. Since regular compound characters can reliably be pronounced like their phonetics, readers are able to pronounce these characters based on previously learned simple characters. For example, the pronunciation of 伴 [ban]4 *accompany* and 拌 [ban]4 *stir* can be derived directly from their phonetic 半 [ban]4 *half*, which is a simple character when it appears alone. An analysis of Chinese characters taught in primary schools in China reported that 39% of semantic-phonetic compound characters are regular (Shu et al., 2003).

There are also semiregular and irregular compound characters. Semiregular characters are those characters whose phonetic component provides only partial phonological information (such as onset, rime, or tone). Irregular characters are characters that are pronounced completely different than their phonetic components (Shu, 2003). Shu et al. (2003) estimated that about 26% of the characters learned in Chinese schools are semiregular and 15% are irregular. It is difficult for readers to derive the pronunciation of novel semiregular or irregular characters since very limited information is provided within the characters themselves. Therefore, characters belonging to these two groups can be very challenging to pronounce (see figure 1.2. for examples of regular, semiregular, and irregular compound characters).

	regular compound	semiregular compound	irregular compound
character	拌 stir	暗 dark	吠 bark
radical	扌 hand radical	日 sun radical	口 mouth radical
phonetic	半 [ban]4 half	音 [in]1 sound	犬 [cheuan]3 dog
character pronunciation	[ban]4	[an]4	[fey]4

Figure1.2 Examples of regular, semiregular, and irregular compound characters and their components.

A small number of phonetic components are bound, meaning that these phonetics are not independent characters. A bound phonetic is a phonetic that does not have a pronunciation or meaning when it appears on its own. In other words, bound phonetics are not characters in modern Chinese. This group of phonetics can only be combined with radicals to form characters. Even though bound phonetics do not bear sounds themselves, they can still be a good source of phonetic information through analogy. Therefore, many characters having a bound phonetic component can be pronounced with the aid of their orthographic neighbors (Chen et al., 2003; Shu et al., 2003). For example, 惱 [nau]3 *bother*, 瑙 [nau]3 *jade*, and 腦 [nau]3 *brain*, all share the same bound phonetic. Accordingly, if you have already learned one of the characters, the sound of the other two characters can be deduced by analogy (Shu et al., 2000).

Tones

Chinese is a tonal language. Mandarin Chinese has four tones and Cantonese has nine tones. Each Mandarin Chinese character is pronounced with a syllable and a tone. For example, 馬 [ma]3 in the third tone means horse, and 媽 [ma]1 in the first tone means mother. Mandarin has only 400 different syllables that usually consist of an onset and a rime (Taylor, 2002). With the variation of tones, the number of tone syllables increases to 1,200 (Shu, 2003; Shu et al., 2003). Therefore, characters with identical phonetic structure can be differentiated by tone; otherwise, approximately every ten characters would be homophonous (Shu et al., 2000). Tones also function as a suprasegmental phonological feature of Chinese syllables, which implies that tones are attached to the entire syllable as a whole. Accordingly, sensitivity to tones is crucial for understanding Chinese.

It is noteworthy that there are no visual cues provided in Chinese orthography that specify tones. Therefore, in Taiwan and China, an alphabetic phonetic system with tone signification, Zhu-Yin-Fu-Hao (used in Taiwan) or Pinyin (used in China), is adopted to help children acquire the knowledge of tones and subsyllable phonological information.

Instructional Methods in Taiwan, China, and Hong Kong

In Taiwan, children start to learn an alphabetic script called Zhu-Yin-Fu-Hao as soon as they start receiving formal instruction in grade one. Zhu-Yin-Fu-Hao, which literally means "phonetic symbols" in Chinese, is a system where each symbol represents a phonological element of Chinese syllables. Chinese syllables are usually presented in three phonological elements: initial sound, final sound, and tone (Lu, 2003). Zhu-Yin-Fu-Hao consists of 37 symbols: 21 initial sounds and 16 final sounds. These 37 symbols do not map onto the phoneme level but are similar to the onset and rime elements in alphabetic languages (Cheung & Ng, 2003). Among the 16 final sounds, three of the final sounds (ㄧ, ㄨ, ㄩ) can be combined as semi-vowels with other final sounds to form the rimes of syllables. These three symbols are placed in the middle of the syllables when combined with an initial sound and another final sound. Therefore, in this dissertation, these three symbols are referred to as middle sounds. For example, an initial sound ㄓ[zh], a middle sound ㄨ[u], and a final sound ㄢ[an] will form the syllable ㄓㄨㄢ[zhuan]. In addition to these 37 symbols, the system also provides four tone symbols. Zhu-Yin-Fu-Hao was invented to compensate for the lack of phonological information in Chinese characters and to help children to make associations between sound and print in a more efficient and convenient manner. The phonetic symbols are printed on the right side of characters. In Taiwan, children are taught Zhu-Yin-Fu-Hao in the first ten weeks of grade one, and continue to use the system throughout the rest of the primary school years. When children reach higher grades (grade 5 & grade 6), the phonetic symbols are only provided when new characters are introduced (Hanley et al., 1999).

In China, a similar phonetic system known as Pinyin is used. Children in China learn Pinyin in the first few weeks of grade one. It appears with characters in textbooks for the first few years of school. The use of Pinyin decreases when children learn more characters and are able to read Chinese script without the assistance of Pinyin. The difference between Zhu-Yin-Fu-Hao and Pinyin is that Zhu-Yin-Fu-Hao transcribes Chinese syllables by unique symbols at the onset and rime level while Pinyin adopts Roman alphabets and transcribes at the phoneme level (Cheung & Ng, 2003). Otherwise, the function of these two systems is identical. These two systems also serve as a self-teaching instrument enabling children to pronounce novel characters without receiving instruction from teachers (Hanley et al., 1999).

In Hong Kong, children are taught differently. Characters are learned without an auxiliary system. Children learn to identify characters by applying a whole-word approach. They learn new characters by practicing repeatedly the sound and writing. Therefore, children in Hong Kong basically learn characters by rote (Cheung & Ng, 2003; Ho & Bryant, 1997b).

The effect of applying an auxiliary phonetic system in reading instruction was observed by Huang and Hanley (1995; 1997) and McBride-Chang, Bialystok, Chong, and Li (2004). Huang and Hanley (1995) compared two groups of 8-year-old children from Taiwan and Hong Kong. They found that Taiwanese children performed significantly better than Hong Kong children on two phonological awareness tasks: the oddity test and the phoneme deletion task. A longitudinal study (Huang & Hanley, 1997) of reading by Taiwanese first graders found that after 10 weeks of Zhu-Yin-Fu-Hao instruction there is a significant increase in children's performance on phonological awareness tests.

Similarly, McBride-Chang and colleagues (2004) found that Chinese kindergarten and grade 1 children, who have learned Pinyin, outperformed Hong Kong children on the syllable deletion and onset deletion tasks. McBride-Chang et al. suggested that Pinyin training may promote development of phonological awareness. According to the findings of the above studies, the incorporation of the phonetic system in reading instruction improves children's performance in manipulating Chinese syllable segments. However, better phonological awareness skills do not necessarily lead to better reading. McBride-Chang et al., for example, reported that Hong Kong children who did poorer on phonological awareness tasks actually performed significantly better on a character recognition task. The result indirectly questions the role of phonological awareness in Chinese reading.

A cross-sectional study examining reading acquisition in Chinese showed that Pinyin knowledge (measured by reading syllables written in Pinyin) explained a significant portion of the variance in character recognition and word reading in grades 2, 3 and 5, after controlling for the effect of age and IQ (Siok & Fletcher, 2001). The strong association between Pinyin knowledge and reading suggests that the aid provided by the phonetic system is important for Chinese young readers in helping them to establish the link between sound and print while, at the same time, easing the degree of frustration resulting from the laborious learning of complicated graphic units. However, mastering the auxiliary phonetic system is only the beginning of reading and literacy in Taiwan and China. The phonetic system may bridge the gap between print and sound, but efficient and accurate character writing requires substantial practice by repeating each stroke with a preset order. Chinese characters follow rules of order for strokes and stroke patterns.

For example, stroke patterns on the left side of characters should be written first and slanted strokes should be printed prior to the horizontal and vertical ones (see Figure 1.3. for examples of stroke orders). In order to develop children's writing ability, Chinese reading instruction is taught through heavy writing and memorization. It is truly a prodigious task for younger Chinese learners and it is common to see children spending hours writing new characters repeatedly to memorize every single stroke and their order. For this reason, over and above the different systems used to introduce character sound, children in Taiwan, China, and Hong Kong learn Chinese through the equivalent strategy of repeated writing.

Figure1.3 Stroke orders of frequent characters. Ministry of Education, Taiwan, 2003.

To summarize, Chinese is a morphosyllabic, tonal language that contains a large number of homophones. To establish links between sound and print, phonetic systems, Zhu-Yin-Fu-Hao and Pinyin, are taught in Taiwan and China. In addition, studies have shown that learning phonetic systems promote phonological awareness. Yet, whether training in Zhu-Yin-Fu-Hao and Pinyin results in better reading is so far unclear.

CHAPTER 3: LITERATURE REVIEW

In the following section, literature of Chinese reading acquisition is reviewed. First, the contributions of phonological awareness, rapid naming, and orthographic knowledge to Chinese reading are discussed. Following this a summary of the literature is presented, followed by the rationale for the current study.

Phonological Awareness

There is strong empirical support to show that phonological awareness is vital to the development of reading skills. Phonological awareness, the sensitivity to the sound structure of a language and the ability to manipulate segments of words, requires skills of noticing, thinking about, or manipulating the individual sounds in each word (Torgesen & Mathes, 2000; Torgesen et al., 1997). Phonological awareness is often considered to be associated with the understanding of the "alphabetic principle" that letters correspond to sounds (Torgesen et al., 1997; Wagner, Torgesen, & Rashotte, 1994; Wagner & Torgesen, 1987). It usually relies on two skills: analysis, or the ability to break down words or syllables into smaller constituents; and synthesis, or the ability to combine smaller constituents of oral language into words or syllables (Wagner et al., 1997; Wagner et al., 1994; Wagner & Torgesen, 1987). In the following section, I will review studies that have examined phonological awareness and reading acquisition in English and in Chinese.

Phonological Awareness and Reading Acquisition in English

One major advantage of learning an alphabetic script is that once the correspondence between each grapheme and phoneme is learned, one has accomplished the initial stage of accessing the written language (Adams, 1990). Consequently, children's knowledge about the visual forms, names and sounds of letters is considered a preliminary requirement for reading and writing (Treiman, 2006). Along with this view, phonological awareness, the sensitivity to sound structure, is considered the precursor of acquiring alphabetic languages (see reviews in Adams, 1990; Taylor, 2002; Wagner & Torgesen, 1987).

Children achieve different levels of phonological awareness depending on the complexity of the sound units involved. Researchers believe that young children start to develop awareness of bigger sound segments and progress to smaller ones later (Adams, 1990; Treiman & Zukowski, 1996; Torgesen & Mathes, 2000). For example, Adams (1990, p. 296) stated, "their [children's] awareness of spoken phonemes, syllables, and words are consistent with the evidence that each is more difficult and attained later in development than the next." There are three linguistic levels of phonological awareness that are often assessed in studies: syllable awareness, onset and rime awareness, and phonemic awareness. Among these, phonemes are the most often studied phonological units in the English reading literature (Taylor, 2002). There has been a growing body of research demonstrating the superior predictive ability of phonemic awareness over onset and rime awareness in early literacy achievement (e.g., Hatcher & Hulme, 1999; Muter, Hulme, Snowling, & Taylor, 1997; Muter & Snowling, 1998; Nation & Hulme, 1997).

Empirical studies have demonstrated that phonological awareness measured prior to or at the onset of reading instruction successfully predicts reading performance in later years (Kirby et al., 2003; Muter & Snowling, 1998; Muter et al., 1997; Nation & Hulme, 1997; Parrila et al., 2004). Parrila and his colleagues (2004) investigated concurrent and future predictive influence of phonological processing measures on reading development in a 4-year longitudinal study. The results demonstrated that phonological awareness (assessed by sound isolation and blending phonemes) measured in grade 1 was the strongest predictor of grade 3 reading, after controlling for the effect of prior reading skills (word identification measured in grade 1). Furthermore, phonological awareness measured in kindergarten and grade 1 accounted for unique variance in all reading measures, even after measures of other phonological processing variables (articulation rate, verbal short-term memory and naming speed) were taken into account. Similarly, Kirby et al. (2003) asserted that phonological awareness (assessed by sound isolation, phoneme elision, blending onset and rime, and blending phonemes) measured in kindergarten was a successful predictor of reading performance in the first two years of schooling, after controlling for general intelligence and prior reading achievement (measured by letter recognition).

In general, the importance of phonological awareness to learning to read English is well established; however, the same may not apply to learning to read Chinese.

The Role of Phonological Awareness and Learning to Read Chinese

The absence of correspondence between sound and graphic units has led to misconstrued discussions of the irrelevancy of phonology to Chinese reading. Seidenberg (1985) compared whether the naming time for Chinese characters and monosyllabic English words varied as a function of frequency. He asserted that language differences did not affect whether phonological information was processed during word recognition but that frequency of words and characters did. Moreover, whether or not the Chinese characters and English words provided reliable information of their pronunciation had no effect on naming high frequency characters; however for both

Chinese and English, regular low frequency characters and words were read faster than irregular low frequency characters and words. Evidence from Seidenberg's study indicated that phonology enters into the processing of both Chinese characters and English words, but only when low frequency stimuli are used.

Guo, Peng and Liu (2005) adopted the Stroop paradigm to examine the role of phonological activation in character recognition. Participants aged 7 to 23 were asked to name the display colour of Chinese characters. The characters related to their display colours were manipulated so that they were either semantically congruent or incongruent, phonologically congruent or incongruent, or neutral. The study found phonological interference effect in the phonologically incongruent trials and phonological facilitation effect in the phonologically congruent trials. Guo et al. concluded that during character recognition, phonological codes are activated automatically, indicating the relevancy of phonology in Chinese reading.

Increasing number of studies in Chinese have shed light on the association between phonological awareness and early reading acquisition (Chen et al., 2004; Ho, 1997; Ho & Bryant, 1997a, 1997b; Ho et al., 1999; Huang & Hanley,1995, 1997; Hu & Catts, 1998; Li, Anderson, Nagy, & Zhang, 2002; McBride-Chang & Ho, 2000, 2005; McBride-Chang & Kail, 2002; McBride-Chang et al., 2003; McBride-Chang & Zhong, 2003; McBride-Chang et al., 2004; Siok & Fletcher, 2001; So & Siegel, 1997). Several of these studies have provided convincing evidence that phonological awareness is an important component of early Chinese reading, just as it is in English (Huang & Hanley, 1997; Hu & Catts, 1998; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002 Siok & Fletcher, 2001). However, significant and positive correlations between phonological awareness and character recognition do not necessarily indicate that phonology is central for reading morphosyllabic Chinese.

A recent cross-cultural study by McBride-Chang et al. (2005) investigated the association between phonological awareness and character recognition in second grade students from China, Hong Kong, Korea, and the United States. McBride-Chang et al. found that phonological awareness predicted word reading in both Korean and U.S samples, but not in Chinese and Hong Kong samples, after controlling for the effects of vocabulary and morphological awareness. They concluded that even though phonological awareness (measured by syllable deletion and onset deletion) correlated significantly with character recognition in both Chinese and Hong Kong samples, it may be more important for reading development in English and Korean than in Chinese.

Various tasks have been used to assess phonological awareness in Chinese. A very important characteristic of Chinese is the correspondence between syllables and morphemes. Therefore, syllables are the most important sound units in both written and spoken Chinese. Conventionally, syllables are dissected into initial sound (onsets), final sound (rimes), and tones (Li et al., 2002; Lu, 2003). Therefore, phonological awareness studies in Chinese usually focus on awareness of syllables, onsets and rimes, and tones (Li et al., 2002). Generally, syllable awareness tasks are often used with very young children, while onset and rime categorization tasks are more frequently used with children who have already received reading instruction. In contrast to English studies, tasks that examine sensitivity to phonemes in Chinese are often not included in the construct of phonological awareness, and this is because Chinese syllables are traditionally not segmented into phonemes.

McBridge-Chang and Ho (2000), for example, conducted a study that used a syllable deletion task to assess phonological awareness of children aged 3 and 4 in Hong Kong. The task required participants to delete syllables from two- or three-syllable words. The study demonstrated that syllable awareness contributed to the prediction of Chinese character reading with very young children.

Several longitudinal studies (Chow et al., 2005; McBride-Chang & Zhong, 2003; McBride-Chang, Chow, Zhong, Burgess, & Hayward, 2005; McBride-Chang & Ho, 2005) have investigated the association between syllable awareness and early Chinese character recognition. In these studies, syllable awareness has been found to predict Chinese reading one to two years later. For example, McBride-Chang, Chow et al. (2005) found syllable awareness a strong predictor of reading concurrently and longitudinally for a group of Hong Kong and Chinese kindergarten children, even when IQ and vocabulary were controlled. Similarly, McBride-Chang and Zhong (2003) conducted a study with 103 three- and four-year old children from Hong Kong and found that syllable awareness predicted reading a year later, even after differences in other reading related skills (vocabulary, visual processing, speed of processing, and naming speed) and age were taken into account. Interestingly, when previous reading skill was included in the equation, syllable awareness was no longer a significant predictor. McBride-Chang and Zhong concluded that the association between phonological awareness and reading is bidirectional and stated "those who are good readers to begin with also improve their phonological awareness skills by reading more, whereas those who have difficulty reading do little to improve their phonological awareness skills because they avoid reading" (p. 46).

Cross-cultural studies have also demonstrated similar results. In a study with Hong Kong and American kindergarten children, McBride-Chang and Kail (2002) found that syllable awareness was strongly associated with reading ability in both Chinese and English. As well, by investigating the contribution of syllable awareness and phonemic awareness to reading in kindergarten and grade 1 children from Hong Kong, China, and Canada, McBride-Chang et al. (2004) found that syllable awareness was the primary phonological ability that predicted Chinese character recognition, whereas phonemic awareness was more closely related to English word reading. McBride-Chang et al. suggested further that the special status of syllable awareness to Chinese reading was due to the morphosyllabic nature of Chinese, which promotes children's sensitivity to syllables. Interestingly, this study also found that children from Hong Kong, who did not receive Pinyin instruction but recognized more Chinese characters, performed much worse on phonological tasks than children from China who had received Pinyin instruction but were poorer readers. McBride-Chang et al. suggested that phonological awareness may be a product of phonological training rather than reading experience.

In general, studies investigating syllable awareness and Chinese reading have yielded two primary findings: syllable awareness correlates significantly with character recognition, and syllable awareness predicts early reading acquisition.

For elementary school aged children, sound categorization tasks or oddity tests are often used. These tasks are commonly used for assessing sensitivity to onsets and rimes. Research investigating onset and rime awareness has demonstrated a consistent correlational relationship with character recognition (Ho, 1997; Ho & Bryant, 1997a, 1997b; Ho et al., 1999; Huang & Hanley, 1997; Hu & Catts, 1998; Siok & Fletcher, 2001;

So & Siegel, 1997). However, the results of predicting reading ability by onset and rime awareness have been varied. Huang and Hanley (1997) and Siok and Fletcher (2001) found that onset and rime awareness predicted reading ability for children in grades 1 to 5. Interestingly, Ho and Bryant (1997b) found onset and rime awareness to be a good predictor of reading with preschoolers.

In Ho and Bryant's (1997b) longitudinal study, the phonological tasks involved rhyme-tone detection and partial homophone detection. The rhyme-tone detection task required children to find syllables that rhymed and had the same tone. A partial homophone detection task required children to find the syllable that shared the onset and rime but had a different tone. One hundred 3-year-old Hong Kong children who couldn't read any Chinese characters were initially recruited and 45 children were followed for four years. The initial score on the rhyme-tone detection task was found to be predictive of subsequent reading performance four years later after the effects of age, non-verbal intelligence, and mother's education were statistically controlled.

Huang and Hanley (1997) conducted a one-year longitudinal study with 40 first grade students in Taiwan. They investigated whether phonological awareness skills before formal instruction predicted reading a year later. In this particular study, two tasks were administered to assess phonological awareness: an oddity test and a sound deletion task. The oddity test required participants to choose among three syllables the one that was different from the other two in first, middle, or final sound. The sound deletion task required participants to delete an initial sound or a final sound in a syllable. Huang and Hanley found that both phonological awareness tests correlated with character recognition at the three testing times and that sound deletion predicted character recognition at the end of grade 1, after statistically controlling for the effect of IQ. However, the contribution of the sound deletion task diminished after prior reading ability was factored in.

Siok and Fletcher (2001) measured phonological awareness with an oddity test (onset and rime level), a tone sensitivity test, and a sound blending/isolation test (phoneme level) with 154 grade 1, 2, 3, and 5 students in China. The results showed that onset and rime awareness correlated significantly with reading, independent of non-verbal intelligence. In contrast, no association was found between phonemic awareness and reading. Siok and Fletcher suggested that tasks that tap into awareness of onsets and rimes are better tools for measuring phonological awareness in Chinese than those that utilize phonemes.

Phonemic awareness is a less frequently assessed aspect of phonological awareness in Chinese and the few studies that have tested phonemic awareness have produced mixed results. The utility of phonemic awareness in predicting Chinese reading was found in McBride-Chang et al. (2003) study with second graders. They assessed phonological awareness with both syllable deletion (syllable awareness) and onset deletion with 100 kindergarteners and 100 grade 2 students in Hong Kong. They reported that syllable deletion was predictive of character recognition in kindergarten and onset deletion predicted reading in grade 2. The findings of McBride-Chang et al. implicate that reading instruction may prepare children to pay attention to more abstract sound structures.

However, prediction of reading with the performance on phonemic awareness tasks has not always been successful. Wang (2005) conducted a two-year longitudinal study with 87 Chinese children and reported that initial and final sound deletion tasks administered in kindergarten failed to predict character reading two years later. She suggested that the result could be due to the lack of formal phonological awareness training in kindergarten.

Huang and Hanley (1995) conducted a cross-cultural study with 8- and 9-year old children from Taiwan, Hong Kong, and England. Phonological awareness was measured with an oddity test (onset and rime level) and with a phoneme deletion test. Phoneme deletion was the strongest predictor for the English subjects even after the differences in vocabulary and non-verbal intelligence were controlled; however, the same was not found for the Chinese speaking groups.

One phonological awareness skill that is not required in English but is necessary for reading Chinese is tone sensitivity, or the ability to detect tones attached to characters (Li et al., 2002). Chinese syllables need to be pronounced with a tone because meaning is altered when tone changes. In several studies, poor readers have performed significantly worse on tone discrimination tasks than normal readers (Chan & Siegel, 2001; Chen & Tzeng, 1999; Huang & Zhang, 1997). Moreover, significant association has been found between tone sensitivity and grade 2 (Wang, 2005) and grade 4 character recognition (He et al., 2005). In order to learn an increasing number of characters efficiently, children are required to be sensitive to tones. With a large number of homophones in Chinese, readers often come across characters with similar phonological structures but varied tones. Therefore, phonological recoding for Chinese characters should be tone sensitive to effectively assist reading. Children who are poor in detecting tones may have problem in both oral communication and reading.

In general, studies have demonstrated association between phonological awareness and Chinese reading acquisition. The important role of phonological awareness to learning to read in alphabetic languages is partially demonstrated in Chinese early literacy development. However, the special status of phonemes observed with English speaking participants has not been verified in studies with Chinese speaking participants.

Rapid Naming and Reading Chinese

Tasks of rapid naming usually involve naming visual stimuli in a fast and automatic fashion (Hu & Catts, 1998; Landerl, 2001; McBride-Chang & Zhong, 2003; Wagner & Torgesen, 1987). Rapid naming is predictive of individual differences in reading longitudinally in alphabetic languages (Compton, 2003; de Jong & van der Leij, 1999; Kirby et al., 2003; Parrila et al., 2004; Sprugevica & Høien, 2004; Torgesen et al., 1997; Wagner & Torgesen, 1987). Rapid naming tasks are also viewed as an important tool for distinguishing normal and disabled readers (Kirby et al., 2003; Landerl, 2001; Manis et al., 2000; Meyer, Wood, Hart, & Felton, 1998; Wolf & Bowers, 1999; Wolf, Bowers, & Biddle, 2000).

Rapid naming has not yet been extensively studied in Chinese. Existing studies suggest, however, that rapid naming correlates significantly with character recognition (*r*s =.-25 to -.60, respectively). This relation has been observed with first graders in Taiwan (Hu & Catts, 1998), and with kindergartners and second graders in Hong Kong (Chow et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002; McBride-Chang et al., 2003; McBride-Chang & Zhong, 2003) and China (McBride-Chang, Chow et al. 2005; Wang, 2005).

Hu and Catts (1998) reported that rapid naming was more closely related to reading familiar characters than to reading less familiar characters among Taiwanese first grade children. Rapid naming was measured by asking children to name coloured animals in sequence (e.g., red pig, blue cow). Hu and Catts suggested that the primary phonological process in reading familiar characters is the retrieval of phonological codes for visual stimuli.

Studies that demonstrated a connection between rapid naming and subsequent reading abilities were completed by McBride-Chang and Zhong (2003), and Wang (2005). In McBride-Chang and Zhong's study, digit naming measured at the age of 3 or 4 predicted unique variance in character recognition a year later, after age, vocabulary, visual processing skills, speed of processing, and the autoregressive effects of time 1 character recognition were statistically controlled. As well, Wang (2005) reported that picture naming measured in kindergarten predicted reading two years later, after controlling for age and parents' education.

In terms of predicting concurrent reading achievement, McBride-Chang et al. (2003) found that rapid naming, assessed by picture naming and digit naming tasks, predicted unique variance in kindergarten and grade 2 students' reading ability, after differences in age, speed of processing, vocabulary, and phonological awareness were controlled. Similarly, Chow et al. (2005) found that digit naming predicted Chinese word reading in kindergarten. Moreover, Tan, Spinks, Eden, Perfetti, and Siok (2005) found that digit naming explained a significant portion of the variance in character recognition for beginning readers (aged 7-8) and intermediate readers (aged 9-10) after controlling for the effect of IQ. After writing skills were controlled, digit naming still accounted for an additional 10.5% of the variance in character recognition for the intermediate readers. In contrast, McBride-Chang, Chow et al. (2005) reported that picture naming did not predict unique variance in reading abilities of kindergarten children from China and Hong Kong after the effects of age, vocabulary and phonological awareness were controlled.

In the Chinese reading research, rapid naming seems to be most useful in identifying those experiencing reading difficulties. Congruent results have emerged in investigations of reading difficulties in Chinese indicating that rapid naming is important for identifying children with reading problems. Cognitive profiles of Chinese developmental dyslexics suggest that rapid naming may be an efficient screening or diagnostic tool for dyslexia in Chinese (Ho et al., 2002; Ho et al., 2004; Lu, 2003). For example, Ho and her colleagues (2004) concluded that rapid naming deficits were the most dominant type of deficits in Chinese dyslexic children in Hong Kong. In this study, 57% of the dyslexic sample (n = 147, mean age: 8yrs and 3 months) manifested deficits in rapid naming (naming pictures, colours, and digits).

Ho et al. (2002) investigated the cognitive profiles of Chinese developmental dyslexics with 30 dyslexic children in Hong Kong (mean age 8 yrs and 8 months). Rapid naming was again the dominant cognitive deficit, as half of the participants demonstrated difficulty on RAN tasks (naming colours and digits). Ho et al. (2002) concluded that the two core deficits among Chinese dyslexics involve rapid naming and orthographic processing.

Ho and her colleagues (Ho et al., 2002; Ho et al., 2004) have consistently showed that difficulties in rapid access to the lexicon are common in Chinese dyslexic children. They suggest that rapid naming assessment, in the light of empirical studies, may be an efficient screening or diagnostic tool for Chinese children with dyslexia. Moreover, in Chinese research, picture naming and digit naming tasks were often used to assess rapid naming skills. To understand the role of rapid naming skills in Chinese reading, stimuli that incorporate elements of Chinese orthography should be included when rapid naming is assessed.

Orthographic Knowledge of Chinese Characters

The ability to establish an association between visual form, and phonology and semantics is important for fluent character recognition (Chan & Nunes, 2001; Siok & Fletcher, 2001). Due to the large number of homophones in Chinese, readers frequently encounter situations where a familiar syllable maps onto a large number of distinct graphic units in Chinese. In the Chinese communities, a very common way to introduce a person is to illustrate graphic features and meanings of the person's name to avoid ambiguity. For example, the syllable [huei]4 maps onto 50 characters (e.g., 惠, 會, 匯, 繪, 穢, 誨, 賄, 彗, 卉, 喙, 彙). Therefore, a person's name that contains the syllable [huei]4 might introduce her/himself by specifying "my 惠 [huei]4 is "kindness" that has the radical "heart" at the bottom" (a distinct graphic feature in the character). Recall the fact that a limited number of syllables (about 400) are used on 4,000 regularly used characters (or morphemes). The high occurrence of homophones has made clarification of names a common approach for first time introductions.

However, recalling the semantics of characters with the mediation of phonology seems to be inefficient for Chinese reading. Shu, Meng, and Lai (2003) developed a semantic-judgment task to find out how semantics is retrieved during the processing of orthographically dissimilar homophones among good and poor readers. Children were required to decide whether two consecutively shown characters were semantically related or not. Shu, Meng, and Lai found that poor readers reacted significantly slower and made more errors with the homophonic distracters than with the unrelated controls, while good readers did not. These results imply that skilled, or more experienced Chinese readers, often are able to access the lexicon directly from orthographic properties and bypass phonological mediation (Shen & Bear, 2000). In other words, the direct route between print and meaning allows good readers to reduce the distracting effects of homophones and therefore enhance the efficiency and accuracy of character recognition (Shu, Meng, & Lai, 2003).

According to the popular dual-route model, words are recognized by translating graphemes to phonemes or by mapping orthographic properties directly to the lexical entry (Coltheart, 2006). Hypothetically, if the phonological route is what Chinese readers rely on during reading, we would expect a slow reaction time during character recognition. If a visual input (a character) stimulates multiple lexical entries via phonological mediation, it should impede or delay the abstraction of semantics. Assuming that a reader sees the graphic form "惠" [huei]4 and systematically activates 50 characters pronounced [huei]4 in the mental list, it should take some time for his or her brain to decide which one matches "惠" [huei]4. Logically, if the reader is able to utilize direct access to map the orthographic unit to its semantics, this should speed up the process and ease the laborious procedure of transforming print to sound to meaning (Ehri, 1996). Empirical data has suggested that skilled Chinese readers do not decode characters primarily via their phonological representations (Chen, 2003; Ju & Jackson, 1995; Shu & Anderson, 1997; Yeh & Li, 2002) but use an analytical approach that parses characters into functional orthographic units to gain faster access to sound and meaning (Chan & Wang, 2003; Feldman & Siok, 1999a; Leck, Weekes, & Chen, 1995).

There has been some disagreement about the functional orthographic units in Chinese character recognition. Some researchers propose that characters as a whole are the primary units during reading (e.g., Wydell, Butterworth, & Patterson, 1995; Ehri, 1996), while others assert that stroke patterns (e.g., semantic radicals) are the basic functional orthographic units which are decomposed from visual input during character recognition (e.g., Chen, Allport, & Marshall, 1996; Leck et al., 1995; Perfetti, Liu, & Tan, 2005; Wu et al., 1999; Yeh & Li, 2004; Zhou & Marslen-Wilson, 1999).

Lately, increasing numbers of studies have examined related orthographic skills in character recognition. These studies have primarily focused on how subcomponents of compound characters are processed during Chinese reading. The utility of phonetics for pronouncing characters and semantic radicals for providing semantic cues of characters have both been investigated. These two seem to serve as the primary sublexical units during character recognition for both adults (Fang, Horng, & Tzeng, 1986; Feldman & Siok, 1999a, 1999b; Leck et al., 1995; Seidenberg, 1985; Zhou & Marslen-Wilson, 1999) and young readers (Chan & Wang, 2003; Chen et al., 2003; Ho & Bryant, 1997a; Ho & Ma, 1999; Ho et al., 1999; Ho, Yau, & Au, 2003; Ho, Ng, & Ng, 2003; Ku & Anderson, 2001; Ko & Wu, 2003; Shu & Anderson, 1997,1999; Shu et al., 2000; Shu, Meng, & Lai, 2003; Tsai & Nunes, 2003; Wu et al., 1999; Yang & Peng, 1997).

Studies that have investigated the utilization of sublexical units in character recognition have usually focused on the "function" of orthographic components during reading. In these studies, phonetic awareness refers to the ability to use phonetic components for character pronunciation, while radical awareness refers to the ability to use semantic radicals to attain character meaning (Ku & Anderson, 2001; Li et al., 2002; Shu & Anderson, 1997, 1999; Shu, 2003). In addition to these two abilities, there is another aspect of orthographic processing that is largely ignored in the research. This is the knowledge of character structure or awareness of character configuration (Shen & Bear, 2000; Yeh & Li, 2002). In the following section, available literature on phonetic awareness and radical awareness will be presented, followed by a review of existing studies of the role knowledge of character structure plays during character recognition.

Phonetic Awareness in Character Pronunciation

The ability to make the most of phonetic components in pronouncing characters has earned its central status in Chinese orthography research by the virtue of the complicated relationship between print and sound in that language at the oral level. One of the major problems faced by most Chinese is that there is no correspondence between oral and written language. Therefore, to compensate for this gap between sound and print, Chinese skilled readers develop phonetic awareness naturally during the course of time as more reading experience is accumulated. Here "phonetic awareness" refers to a systematic understanding of how phonetic components contribute to character pronunciation (Anderson, Li, Ku, Shu, & Wu, 2003; Ho, Yau, & Au, 2003; Shu et al., 2000), while "naturally" implies that this skill develops without benefit of formal or systematic instruction.

The number of phonetic components available in modern Chinese is around 1,100 (Shu, 2003). Therefore, to utilize phonetics for Character pronunciation efficiently, a large number of characters must be learned (Chen et al., 2003). Ho, Yau, and Au (2003) found that grade 3 children performed significantly better than kindergarten and grade 1 children on a pseudocharacter naming task (the use of phonetics to name the unknown characters). Also, a substantial increase of the mean correct rates was observed among participants with more reading instruction. An increase of 18% to 62% of the mean correct rates between first graders and third graders demonstrates that phonetic awareness begins to develop rapidly as children acquire more reading experience.

Researchers have suggested that phonetic awareness develops in stages according to the number of characters acquired (Anderson et al., 2003; Chen et al., 2003; Chen, 2004). In the initial stage of phonetic awareness, children tend to overgeneralize the strategy and pronounce characters that share the same phonetic with identical syllables. After this stage, a more in-depth and systematic knowledge emerges. The regularity and consistency effects of phonetics begin to get in the way of character pronunciation (Chen et al., 2003).

Regularity and consistency are both related to character naming, but, in fact, each of them represents a different perspective (Chen et al., 2003). Phonetic regularity refers to the relationship between the pronunciation of the character and its phonetic: regular characters are those that sound the same as their phonetic components. Therefore, relying on phonetic regularity to access character pronunciation is restricted "within" the character itself and there is no need to compare one character with any other. In contrast, phonetic consistency refers to the phenomena that characters that share the same phonetic (phonetic neighbours) are often pronounced the same. Therefore, readers who rely on phonetic consistency to derive pronunciation by analogy to phonetic neighbours will need to take other characters into account. In other words, readers need to search the pool of learned characters and systematically organize characters that share the same phonetic and sound together to be able to rely on phonetic consistency. Furthermore, analogy as a strategy requires that sufficient numbers of characters are acquired to allow for systematic character grouping; therefore, the understanding and use of phonetic consistency to name characters should develop as more characters are learned. According to one analysis of school Chinese, an average of 2.21 characters that were taught in grade 1 shared the same phonetic, and this figure increased to 3.23 characters in grade 6 (Shu et al., 2003). As children acquire more characters, more resources are available for analogy and the ability to derive pronunciation of a character by analogy will get more refined over the years of schooling (Chen et al., 2003; Shu et al., 2003). Therefore, awareness of phonetic consistency is presumably a more sophisticated skill than awareness of phonetic regularity (Chen et al., 2003; Shu, 2003).

Studies have found a regularity effect with young readers (Chen & Siegel, 2001; Ho & Bryant, 1997a; Shu & Anderson 1999; Shu et al., 2000; Shu, Meng, & Lai, 2003; Yang & Peng, 1997). For example, Shu and her colleagues (Shu & Anderson, 1999; Shu et al., 2000) asked grade 2, 4, and 6 children in China to write in Pinyin 60 compound familiar and unfamiliar characters with various degrees of regularity. Regularity strongly affected the performance on compound characters, especially for unfamiliar characters.

Similar findings were also demonstrated in studies that employed Chinese grade 3 and 4 children (Yang & Peng, 1997; Shu et al., 2003,), grade 2 and 4 children (He et al., 2005), and Hong Kong grade 1 and 2 children (Ho & Bryant, 1997a).

Another line of evidence indicates that consistency affects the accuracy of character naming (Chan & Wang, 2003; Fang et al., 1986; Ho et al., 1999; Tzeng, Lin, Hung, & Lee, 1995; Yang & Peng, 1997). Tzeng et al. (1995) and Yang and Peng (1997) found that grade 3 and grade 6 children in Taiwan and China performed better when the pronunciation of phonetic neighbours (characters that have the same phonetic) was highly consistent. Ho et al. (1999) employed a pre- and post-analogy training approach to test how well children learn to apply consistency in obtaining the pronunciation of unknown characters. They found that grade 1 and grade 3 children were able to use clue characters that shared the same phonetics and pronunciation taught in the training session to name novel characters. The improvement in performance was especially apparent in grade 3. The results indicated that children as young as 6 or 7 were aware of the fact that characters sharing the same phonetic may also be pronounced the same, while children with more experience in reading seem to have come to an understanding that the consistency of phonetic components is a valuable source of information about character pronunciation.

Radical Awareness in Character Recognition

There is evidence that radical frequency and transparency influence the identification of characters. For example, Leck et al. (1995) and Feldman and Siok (1997, 1999b) report a frequency effect, which they termed "the radical combinability effect", with adult readers. The radical combinability effect refers to the phenomenon that the larger the number of characters that share the same radical, the better the efficiency with which characters are recognized. A radical that is frequently presented within characters becomes more familiar to readers and thus creates a stronger association between visual stimuli and the mental lexicon. This combinability effect was also observed with young readers (Shu, Meng, & Lai, 2003). In a learning-test task, Chinese grade 5 students learned significantly more characters that have many orthographic neighbours (share the same radical) than those with few.

Similarly, characters with morphologically transparent radicals (semantic radicals that signify the meaning of characters) are recognized more accurately, especially when encountering new or unfamiliar characters (Chan & Wang, 2003; Shu & Anderson, 1997, 1999; Tsai & Nunes, 2003). Eighty Taiwanese children from grade 2 to grade 5 participated in a study that investigated the efficacy of learning novel characters that were categorized into sensible and nonsensical stimuli (Tsai & Nunes, 2003). A sensible stimulus was a pseudocharacter that contained a morphologically transparent radical that was related to the presented picture and was pronounced the same as its phonetic. Conversely, a nonsensical stimulus was a pseudocharacter that had a morphologically opaque radical and that was pronounced differently than its phonetic. During the learning session, pictures, pseudocharacters, and pronunciations were presented. In the test session, children were asked to write the pseudocharacters they had just learned when pictures and pronunciations were provided. The results showed that children across all grades learned significantly more sensible items than nonsensical ones. In addition, older children (grades 4 & 5) performed significantly better than younger children (grades 2 & 3).

Chan and Wang (2003) also investigated children's understanding of semantic radicals with a pseudocharacter/noncharacter task. For each item, an object picture, two pseudocharacters (one with a correct semantic radical related to the object; one with an incorrect semantic radical), and two noncharacters (one with a semantic radical in an illegal position; one with illegal graphic patterns that are pictorial patterns that do not exist in Chinese) were presented. Children were asked to select a character that was the most appropriate for the picture. Two hundred five- to nine- year-old children (kindergarten to grade 4, respectively) from Beijing and Hong Kong participated in the study. Chan and Wang found that children as young as five chose pseudocharacters with correct radicals more often than the other three stimuli, while eight- and nine-year-olds chose pseudocharacters with correct radicals about 50 % of the time. Chan and Wang suggested that younger children might have already obtained the knowledge that radicals convey meaning, but the detailed and systematic understanding of radical function and internal orthographic structure might develop later.

An interesting question is whether children acquire basic knowledge of semantic radicals earlier than of phonetic components. Ho and her colleagues (Ho, Yau, & Au, 2003) found that children in kindergarten, grade 1, and grade 3 in Hong Kong showed better knowledge of radicals than of phonetics in their study. They used a radical-match-picture task that required children to select a radical from among four choices that best represented a given picture. The mean correct rate ranged from 58% to 90% from kindergarten to grade 3. In the phonetic reading task (children were asked to read a group of phonetics), correct choices ranged from 36% to 88%. Intriguingly, this trend was reversed on the performance on a pseudocharacter spelling task (inventing pseudocharacters by combining given semantic radicals and phonetics in legal positions that related to the presented pictures and pronunciation), where more children were able to use correct phonetics than correct semantic radicals. It is worth mentioning that the pronunciation was provided for each trial in pseudocharacter spelling. Therefore, in this particular task, to select a correct radical that best represented the picture required more explicit knowledge of radical functions, whereas choosing the correct phonetics was basically a phonetic-match-sound task.

Ho, Yau, and Au (2003) explained the earlier development of basic radical knowledge compared to basic phonetic knowledge as a result of differences in frequency, regularity, and teaching method. First, the fact that phonetic components (about 1,100) outnumber semantic radicals (about 200) in Chinese writing yields a more frequent exposure to semantic radicals than phonetics in early reading acquisition. Therefore, children become more familiar with semantic radicals than with phonetics. Second, the semantic cues provided by semantic radicals are usually found to be more reliable than sound cues provided by phonetics (Shu et al., 2003). Therefore, children may find semantic radicals more informative than phonetics. Third, semantic radicals are usually explicitly taught in Chinese classes because they are needed in using Chinese dictionaries, which are organized by radicals. In other words, characters that share the same radical are categorized in the same group. Thus, children learn basic knowledge of semantic radicals in order to look up unknown characters in the dictionary. On the other hand, the function of phonetics is usually not taught in class and children gain knowledge of phonetics implicitly as more characters are learned.

In general, children seem to acquire a rudimentary understanding of radicals and phonetics fairly early, while refined and explicit orthographic knowledge only develops as children become more experienced in reading. This explicit orthographic knowledge is important for efficient character identification because it allows readers to systematically analyze the internal properties of characters. Therefore, as children get more sophisticated in their orthographic knowledge, they also become more competent in character recognition (Ho, Yau, & Au, 2003; Ko & Wu, 2003; Shu & Anderson, 1999; Shu, 2003).

Knowledge of Orthographic Structure in Character Recognition

The formation of Chinese characters follows a set of graphic principles that involve rules of configuration and positional regularities of constituent components (Chan & Nunes, 2001; Ho, Yau, & Au, 2003; Yeh & Li, 2002). Configuration of characters refers to the arranging of components to form various characters in relation to the appropriate position and proportion within a fixed square unit (Chan & Nunes, 2001; Yeh & Li, 2002). The number of strokes in a character varies from 1 to 30 and the number of components ranges between 1 and 5 (Shen & Bear, 2000). However, regardless of their complexity, all characters are configured to occupy a generally constant square-shaped unit. Accordingly, within-character properties need to be proportionally adjusted to fit the pre-set area. For example, the stroke pattern "日" *sun* in 明 *bright*, 晨 *morning*, 春 *spring*, and 間 *unit* is proportionally different. There are about 20 configurations for forming characters (Shen & Bear, 2000), but these are primarily classified into three categories: horizontal (e.g., 明 *bright*), vertical (e.g., 晨 *morning*), and bounded (e.g., 間 *unit*) (Yeh & Li, 2002).

Positional regularity refers to the legal position components inhabit to form graphically acceptable characters. These can either be real Chinese characters or pseudocharacters. Conversely, components that reside in illegal positions will form noncharacters (Ho, Yau, & Au, 2003). In horizontal and vertical configurations, semantic radicals are usually placed on the left and top of the characters, whereas phonetics typically occupy the right and bottom (Yeh & Li, 2002). Using a priming procedure, Ding, Peng, and Taft (2004) found that facilitation effects occurred only when the prime and target shared a radical in the same position (e.g., 韵 and 歆). When the target and prime were comprised of the exactly the same radicals but in different position (e.g., 部 and 陪), no facilitation was observed.

Yeh and Li (2002) adopted a character sorting task and a visual search efficiency task to examine the role of configuration and constituent components during character visual similarity judgment. They found that for skilled readers in Taiwan, visually similar characters were sorted more on the basis of their configurational structures than on the basis of their components (semantic radicals or phonetics). Similarly, in the visual search task, it was more efficient to search for a target character that was among distracting characters that were different in structure. This indicates that similarity decreased when characters were configured differently. Yeh and Li asserted that configurational structure is important for Chinese character recognition. Moreover, Yeh and Li also reported that the structure seemed to play a more important role in the visual search task when the target-distracter pair shared the same semantic radical. However, when the target-distracter pair shared the same phonetic, both structure and shared component (phonetics) increased the visual similarity.

The authors suggest that semantic radicals are viewed as parts of the structure and do not stand out as independent units during similarity judgment, but phonetics seem to play a more autonomous role. The result is in line with Ju and Jackson's (1995) study. In a backward-masking procedure, skilled Chinese readers identified characters faster that were masked by characters sharing the same semantic radicals than characters that were masked by characters sharing the same phonetics. The result reveals that characters that share the same semantic radicals are graphically similar in Chinese readers' eyes, whereas phonetics are processed independently during character recognition.

Children seem to develop basic knowledge of orthographic structure at an early age. Chan and Nunes (2001) asked children between the ages of 3 and 5 to write their Chinese names. They found that 72% of the subjects could already write their names with some Chinese graphic knowledge, and even when not correctly written, the names were easily distinguishable from drawings. Chan and Nunes also developed a graphic acceptability task for assessing children's awareness of linguistic properties. One hundred 5- to 9- year-old children in Hong Kong were assessed on a task that required children to choose stimuli that were more appropriate for Chinese characters. Three types of stimuli were given: (1) noncharacters with illegal graphic components; (2) noncharacters with conventional stroke-patterns in illegal positions; and (3) pseudocharacters with real components in legal positions. The results showed that children in all age groups accepted more pseudocharacters (71%) than noncharacters with conventional stroke-patterns in illegal positions (39%), and the acceptability of noncharacters with illegal graphic components was the lowest (25%). Children's knowledge of within-character structure also showed a developmental trend. Older children (age 7-9) were able to make a clear distinction between possible (pseudocharacters) and impossible (the two types of noncharacters) graphic formation of Chinese characters. Younger children (age 5-6) tended to accept noncharacters with legal patterns in illegal positions more than the older children.

A similar study that involved children from first, second, fourth, and sixth grades in China was reported by Shu and Anderson (1999). In their study, children were asked to choose real characters among pseudocharacters and noncharacters. The results showed that the rate for choosing ill-formed stimuli (noncharacters) was very low across all grade levels. This indicates that grade 1 children already possessed basic knowledge of orthographic properties and were sensitive to the positions of components.

The results of these two studies (Chan & Nunes, 2001; Shu & Anderson, 1999) provide evidence for children's awareness of formation rules and positional regularity. To distinguish well-formed pseudocharacters and ill-formed noncharacters requires understanding of how components are combined and where these components can be placed. Interestingly, these skills are not systematically taught in formal instruction. It is uncommon for Chinese teachers to explain configurational rules and the legal position of orthographic properties. Therefore, children acquire this sophisticated orthographic knowledge through implicit learning, which in turn facilitates subsequent assimilation of novel characters (Chan & Nunes, 2001; Ho, Yau, & Au, 2003; Tsai & Nunes, 2003).

In the literature on disabilities in Chinese reading, implicit orthographic knowledge is established as an important variable for identifying children with dyslexia (Ho et al, 2002; Ho et al., 2004). Instead of testing children's ability to use each subcomponent for pronunciation and semantic access, implicit knowledge of character structure is assessed. Ho and her colleagues developed a left/right reversal task (children are asked to cross out characters and numbers that are in false orientation), a lexical decision task (children are asked to cross out noncharacters), and a radical position task (children are asked to place semantic and phonetic radicals in their legal position among four choices) to assess crucial aspects of the configuration of Chinese characters (Ho et al., 2002; Ho et al., 2004). Ho and her colleagues concluded that poor or not fully formed understanding of internal orthographic structure may impede and delay character recognition and make reading a laborious and difficult task.

In English, skilled readers possess orthographic processing skills that involve automatic processing of letter sequences or letter chunks that frequently occur together. Recognizing units instead of individual letters in words enable skilled readers to process reading materials in a fluent and speedy flow (Adams, 1990). The important role of phonological processing in English studies is acknowledged; however, orthographic skills explain additional variance in word recognition after the influence of phonological processing is statistically removed (Barker, Torgesen, & Wagner, 1992; Cunningham, Perry, & Stanovich, 2001). One of the issues in measuring English orthographic processing is the development of a valid construct (Cunningham et al., 2001; Foorman, 1994; Wagner & Barker, 1994). The rationale of assessing orthographic processing skills without the influence of phonology remains questionable (Foorman, 1994; Geva & Willows, 1994; Lennox & Siegel, 1995). As Wagner and Barker (1994) pointed out, "orthography and phonology are related integrally to one another" (p. 270). This integration view of orthography and phonology is generally accepted in English (Barker et al., 1992; Cunningham et al., 2001; Foorman, 1994; Geva & Willows, 1994; Lennox & Siegel, 1995; Wagner & Barker, 1994).

In Chinese, the nonalphabetic nature of the orthography allows researchers to assess orthographic processing without interference by phonology. The question here is "What measures orthographic processing in Chinese?" According to the reviewed studies, orthographic knowledge in Chinese reading involves utilizing phonetics for character pronunciation, attending to radicals for semantic information, and acquiring an understanding of the configuration rules of characters. It seems that Chinese orthographic processing actually involves quite distinct abilities. These abilities allow Chinese readers to use graphic components to access linguistic codes acquired previously for sound, print, and meaning. With hundreds of stroke patterns that are combined to produce thousands of characters, orthographic processing appears to be an important skill required in Chinese reading. By systematically analyzing character properties, readers are able to access characters efficiently and prevent arduous rote-memory reading procedures (Chen et al., 2003).

Summary of the Literature

This literature review addressed several important aspects of the cognitive processes associated with the development of Chinese reading skills. First, phonological awareness was found to be correlated to and predictive of reading ability with kindergarten children but not always predictive of reading performance with elementary students (Ho & Bryant, 1997a; Huang & Hanley, 1995). Second, limited empirical data on rapid naming skills is available in Chinese literature. Third, the abilities of utilizing phonetics for character pronunciation, attending to radicals for character semantics, and understanding of the configuration rules of characters appear to be the three major orthographic processes that facilitate fluent Chinese reading (Ku & Anderson, 2001; Li et al., 2002; Shu & Anderson, 1997, 1999; Shu, 2003; Shen & Bear, 2000; Yeh & Li, 2002).

Previous research on phonological awareness generally suggests that phonological processing is associated with Chinese reading (e.g., Ho & Bryant, 1997b; Huang & Hanley, 1995, 1997; Hu & Catts, 1998; Li, et al., 2002; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002; McBride-Chang et al., 2003). However, whether well-developed phonological awareness is imperative to young Chinese readers remains unclear. It seems clear that Chinese readers must know about "smaller-than-a-syllable speech sounds" at some level in order to produce and comprehend spoken language or they would not be able to distinguish syllables that differ only in initial sounds or final sounds. The question is whether phonological awareness relates strongly to children's reading achievement in Chinese. In addition, tone sensitivity was mostly excluded from the construct of phonological awareness in the existing studies. The majority of Chinese reading literature has focused on the level of phonological awareness that is needed to learn to read alphabetic languages. As a result, the unique tonal feature of Chinese has been largely overlooked in the phonological awareness studies.

The contribution of rapid naming to Chinese reading has been ignored in much of the earlier research. In reviewing the literature, only a limited number of studies were found that had examined rapid naming with children who are learning to read Chinese (Chow et al., 2005; Hu & Catts, 1998; Lu, 2003; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002; McBride-Chang et al., 2003; McBride-Chang & Zhong, 2003; McBride-Chang, Chow et al., 2005; Tan et al., 2005; Wang, 2005). Available evidence indicates that rapid naming skills correlate with and predict kindergarten and grade 1 to grade 3 reading performance (Chow et al., 2005; Hu & Catts, 1998; McBride-Chang et al., 2003; McBride-Chang & Zhong, 2003; Tan et al., 2005; Wang, 2005). In addition, McBride-Chang and Zhong (2003) suggested that rapid naming tasks may be a useful in regular classrooms for initial screening of children who are at-risk for experiencing reading difficulties. Moreover, in Chinese research, rapid naming skills have mostly been assessed by picture naming and digit naming tasks. To have better understanding of rapid naming skills in Chinese reading, stimuli that incorporate elements of Chinese orthography should be included in the assessment.

As well, it is evident from the existing literature that orthographic knowledge, such as understanding of character structure and different orthographic components, promotes subsequent reading development. Sufficient knowledge of the orthographic properties of Chinese characters is essential because it allows readers to process written language fluently and efficiently. In previous studies, orthographic skills have usually been examined independently from reading abilities. The few studies that have investigated the association between reading and orthographic processing skills have either excluded both phonological awareness and rapid naming measures (Ho, Ng, & Ng, 2003, Ho, Yau, & Au, 2003) or rapid naming measures (Ho & Bryant, 1997a; Ho et al., 1999; Ho, Law, & Ng, 2000; Siok & Fletcher, 2001). Based on previous research, the relationship of orthographic processing and Chinese reading is still poorly understood, and assessing orthographic processing with a wide range of tasks and together with phonological awareness and rapid naming measures should provide a clearer idea of the significance of this particular skill (or skills).

Rationale for the Current Study

In summary, there are two significant shortcomings in the previous studies on Chinese reading acquisition and cognitive processes associated with it: first, few studies have investigated a skill or ability with multiple measures that would have allowed exploration of different facets of the construct; and second, the three important reading related cognitive processes – phonological awareness, rapid naming, and orthographic processing – have not been included in the same study to provide a more comprehensive set of data to explain the unique contribution of each to reading development of children who are learning to read Chinese. Previous studies have provided evidence that these skills are related to Chinese literacy. However, different constructs and tasks used across the studies make it difficult to integrate the findings and to ascertain unique contributions of each of these skills.

This dissertation investigates the relative importance of phonological awareness, rapid naming, and orthographic processing for predicting individual differences in character and word reading skills of grade 2 and grade 4 children in Taiwan. The constructs of phonological awareness, rapid naming, and orthographic processing are assessed by several tasks to allow examination of the importance of different aspects of each construct. Phonological awareness is assessed by five tasks that involved analyzing and categorizing subsyllabic units and detecting differences in tones. Rapid naming skills were assessed by using four different stimuli: colours, digits, Zhu-Yin-Fu-Hao symbols, and simple Chinese characters. Orthographic processing is particularly emphasized in the present study by employing six different measures that assess knowledge of orthographic structure and speed of orthographic processing. By adopting a more inclusive approach than what has been used in existing studies, the contributions of phonological awareness, rapid naming, and orthographic processing skills to Chinese reading development will hopefully be better understood.

The following are the questions addressed in the present study:

1. What are the associations between various tasks of phonological awareness, rapid naming, and orthographic processing with grade 2 and grade 4 character and word reading?
2. Does performance on phonological awareness tasks, rapid naming tasks, and orthographic processing tasks distinguish reading across grade levels?
3. Does the performance of various aspects of phonological awareness, rapid naming and orthographic processing skills predict unique variance in character and word reading in grade 2 and grade 4?

CHAPTER 4: METHOD AND PROCEDURE

Participants

All participants were recruited from Da-Tung Elementary School in Taichung City, Taiwan. Da-Tung Elementary School serves a community of mainly middle class population. There are about 1,400 students in total in Da-Tung Elementary School. For each grade, there are 6 to 9 classes and approximately 30 students in each class.

Three out of seven homeroom teachers in grade 2 and two out of eight homeroom teachers in grade 4 agreed to participate in the project. One grade 2 student was suspected to be autistic; therefore, he was excluded from the study based on the suggestion from his homeroom teacher. No consent form or information letter was sent to his parents.

Out of ninety-six consent forms sent to the parents of children in grade 2, sixty-three consents were received. In grade 4, fifty-four consents were received after fifty-nine forms were distributed. After obtaining informed consent, 63 second-graders (34 boys, 29 girls) between the ages of 7 years, 3 months and 8 years, 6 months (mean age = 8.00 years; SD = 0.30) and 54 fourth-graders (29 boys, 25 girls) between the ages of 9 years, 2 months and 10 years, 5 months (mean age = 10.01 years; SD= 0.32) participated in the study. All the participants in this study spoke Mandarin.

Instruments

Non-Verbal Intelligence

A measure of non-verbal intelligence was included in the present study because some previous studies have found that Chinese reading is significantly correlated with IQ (e.g., Huang & Hanley, 1995, 1997). The Matrices test from the Das-Naglieri Cognitive Assessment System (CAS; Naglieri & Das, 1997) was used to assess non-verbal intelligence in this study. This subtest of CAS required participants to select one of six options that best completed a matrix with a part missing. The items in this task are organized in terms of difficulty. The test was computerized and presented through DirectRT v2004 (Empirisoft, 2006) program. The presentation was discontinued after 4 consecutive errors, and the score was the number of correctly completed items. Naglieri and Das (1997) reported split-half reliabilities of .86 for grade 2 and .90 for grade 4.

Reading

Graded Chinese Character Recognition Test (Character Recognition; Huang, 2001). This is a standardized group administered reading measure with 200 single-syllable characters graded in difficulty. The test is frequently used in Taiwan for measuring reading ability in grades 1 to 9. Participants were asked to write down the names of each character using Zhu-Yin-Fu-Hao. The score of the test was the number of characters named correctly in 30 minutes. Huang (2001) reported test-retest reliabilities of .89 for both grade 2 and grade 4.

One-Minute Reading. This is a subtest of the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (HKT-SpLD; Ho, Chan, Tsang, & Lee, 2000) with 90 simple Chinese two-character words. Children were asked to read the characters aloud as fast and accurately as possible for one minute. The score was the number of characters read correctly within one minute. The test was administered individually. Ho, Chan et al. (2000) reported split-half reliabilities of .99 for both grade 2 and grade 4.

Phonological Awareness

Initial Sound Detection. This task was developed for the current study to assess children's sensitivity to the initial sounds of Chinese syllables. Detection of the initial sounds of Chinese syllables was employed because of the presumed onset and rime characteristic of Chinese syllables. Chinese single-syllable words were used in the task. There were 2 practice trials and 12 test trials. Of the 12 test trials, half of the trials involved middle sounds (e.g., ㄍㄨㄟ[guei]1 歸, ㄌㄨㄥ[luong]1 巄, ㄌㄨㄣ[luen]1 掄, ㄌㄨㄛ[luo]1 囉) in the syllables, while the other half did not. (e.g., ㄅㄠ[bao]1 包, ㄇㄚ [ma]1 媽, ㄇㄧ[mi]1 咪, ㄇㄛ [mo]1 摸). Tones of syllables were controlled such that all four syllables in each trial were in the same tone. After listening to four syllables, children were asked to tell which syllable had the different initial sound. For example, after listening to [fu]1 夫, [ma]1 媽, [mi]1 咪, [mo]1 摸, children were asked to choose the syllable that had the different initial sound than the other three. The score was based on the number of correct answers. The reliability coefficients (Cronbach's alpha) for the current sample were .73 for grade 2 and .49 for grade 4.

Final Sound Detection. The task was developed for the current study to assess children's sensitivity to the final sounds of Chinese syllables. There were 2 practice trials and 12 test trials. Of the 12 test trials, half of the trials involved middle sounds in the syllables, while the other half did not. Tones of syllables were controlled such that all four syllables in each trial were in the same tone. After listening to four syllables, children were asked to tell which syllable had the different final sound. For example, after listening to [ba]1 巴, [ma]1 媽, [pa]1 趴, [so]1 搜, children were asked to choose the syllable that had the different final sound than the other three. The score was based on the number of correct answers. The Cronbach's alpha coefficients for the current sample were .70 for grade 2 and .52 for grade 4.

Tone Sensitivity. This test was developed for the current study to assess children's ability to detect differences in tones of real Chinese syllables. Children were asked to identify which syllable was different in tone compared to the other three. For instance, after listening to [ti]2, [tan]2, [tai]1, and [tou] 2, children were asked to choose the syllable that had a different tone than the others. There were 2 practice trials and 12 test trials and the score was the number of correct answers. Of the 12 test trials, half of the trials involved middle sounds in the syllables, while the other half did not. The Cronbach's alpha coefficients for the current sample were .71 for grade 2 and .65 for grade 4.

Initial Sound Isolation. This test was modified from Siok and Fletcher's (2001) sound isolation test to assess children's analyzing skill for Chinese syllables. After listening to a syllable, children were asked to repeat the initial sound of the presented syllable. For example, children were expected to repeat [f] after hearing the syllable [fa]1 發. There were 2 practice trials and 10 test trials. Of the 10 test trials, half of the trials involved middle sounds in the syllables, while the other half did not. All the stimuli were in the first tone. The Cronbach's alpha coefficients for the current sample were .27 for grade 2 and .43 for grade 4.

Final Sound Isolation. This test is similar to the Initial Sound Isolation test. Children were asked to repeat the final sound of the presented syllable. For example, after listening to [ma] 1 媽, children were expected to repeat [a]. There were 2 practice trials and 10 test trials. Of the 10 test trials, half of the trials involved middle sounds in the syllables, while the other half did not. All the stimuli were in the first tone. The Cronbach's alpha coefficients for the current sample were .31 for grade 2 and .52 for grade 4.

Knowledge of Orthographic Structure

Non-Character Recognition. The task is the so-called "lexical decision" test in HKT-SpLD (Ho, Chan et al., 2000). This test was developed to assess children's implicit understanding of the orthographic structure of characters. There are two kinds of stimuli used in this task: rare characters that are unfamiliar to elementary students, and noncharacters that are ill-formed in that they violate Chinese character formation rules. The test consists of a set of 60 items, of which 30 were rare characters and 30 were noncharacters. Participants were asked to cross out characters that are least likely to be Chinese characters. One point was given to each rare character identified (not crossed out) and one point was give to each noncharacter that was crossed out. This group administered test took approximately 10 minutes to complete. The score was the number of characters and noncharacters identified. The maximum score is 60 for this test. Ho, Chan et al. (2000) reported split-half reliabilities of .63 for grade 2 and .79 for grade 4.

Radical Position. The task is one of the orthographic subtests from HKT-SpLD (Ho, Chan et al., 2000). It was developed to measure children's knowledge of positional regularity. Participants were required to choose one of the four given positions (left, right, top, and bottom) that the target radical is supposed to occupy. For example, the female radical 女 appears on the left of characters such as in 媽 mother, 姊 older sister, 妹 younger sister, and 奶 milk. In the above example, children would need to choose the left position to get a correct response for the item. There were 2 practice trials and 20 test trials. Accuracy was recorded. The test was administered in groups. Ho, Chan et al. (2000) reported split-half reliabilities of .71 for grade 2 and .55 for grade 4.

Radical Awareness. This task was modified from Ho, Ng, and Ng (2003) semantic category judgment task. The task was developed to test children's understanding of semantic cues provided by the semantic radicals of the characters. In each trial, a target radical was presented with four picture choices and children were required to choose the picture that best represented the meaning of the target radical. For example, given the radical 木 *wood* and pictures of river, bird, tree, and car, children should choose the picture of tree to indicate the semantic category of wood. There were 2 practice trials and 20 test trials and the test was administered in groups. The score was the number of correct responses. The Cronbach's alpha coefficients for the current sample were .54 for grade 2 and .50 for grade 4.

Speed of Orthographic Processing

Recall of Radicals. This task was developed for the current study to assess children's speed of processing for Chinese radicals. In each trial, children were presented with a target radical for 500ms, followed by a mask "X" for 1000ms, and then four radical choices on the screen. Children were asked to find the target radical among the four choices and press a number key (1 to 4) that corresponds to the selected choice. For example, after presenting the target radical 木 for 500ms, a mask "X" was placed over the spot the target radical occupied for 1000ms, then the four radical choices 木, 工, 石, 金 appeared on the screen. There were two conditions in the 20 trials. In the first 10 trials both the targets and the four alternatives were radicals that are also characters on their own. In the last 10 trials, both the targets and the four alternatives were radicals that can only be used as semantic radicals but not as independent characters in the modern Chinese. The two conditions were scored separately. In this dissertation, the first condition is referred to as Recall of Radicals (1) and the second condition as Recall of Radicals (2). Both accuracy and response time were recorded. The score of the test was the average response time of items that were answered correctly.

Radical Searching. This task was developed for the current study to measure the efficiency of radical searching among various distracters. In each trial, a target radical was presented for 500ms and then masked by four characters. Children were asked to choose the character that contained the target radical. In this test, all the target radicals were characters when they appeared on their own. There were four conditions in the character choices:

a. semantic distracter: the character could be combined with the target radical to form a two-character word but did not contain the target radical itself.

b. homophonic distracter: the character was homophonous to the target radical but shared no graphic similarities.

c. target character: the character was phonologically dissimilar with the target radical but contained the target radical within the character.

d. unrelated control: the character shared no graphic or phonological similarities with the target radical.

For example, after seeing the target radical 木 [mu]4 wood, children were asked to choose among the four choices 1. the semantic distracter:船 [chuan]2 boat, 2. the homophonic distracter: 目 [mu]4 sight, 3. the target character:枝 [zh] 1 branch, and 4. the unrelated control 神 [shen]2 god, the one that contained the target radical 木. There were 2 practice trials and 10 test trials. Both accuracy and response time were recorded. The score of the test was the average response time for items that were answered correctly.

Rapid Naming (RAN)

Four rapid naming tasks were used in the present study: simple character naming (RAN Characters), colour naming (RAN Colours), digit naming (RAN Digits), and Zhu-Yin-Fu-Hao naming (RAN Zhu-Yin-Fu-Hao). Each naming task contained 50 stimuli presented on a computer screen. RAN Characters involved five simple characters, 我, 小, 天, 不, 有, that participants were highly familiar with. RAN Colours involved five colours, namely black, red, yellow, blue, and green. RAN Digits involved five numbers, 1, 4, 5, 7, and 8. RAN Zhu-Yin-Fu-Hao involved the first 5 initial symbols, ㄅ, ㄆ, ㄇ, ㄈ, ㄉ, in the Taiwanese phonetic system. In all tasks, the items were equally distributed in five rows in semi-random order with 10 items in each row. Children were asked to name the items as fast and accurately as possible. A practice trial preceded each test trial to ensure familiarity with the stimuli. All rapid naming tasks were computerized and administered individually. Both accuracy and response time were recorded.

Phonological and Visual Short-Term Memory

Word Series. The test was modified from the Word Series task in CAS by C. P. Deng (personal communication, Feb. 27, 2005). The test required children to repeat the two to nine high-frequency two-syllable Chinese words presented by the examiner. In each item, the examiner would first read the word series at the rate of one word per second. The participant was then asked to repeat the words in the same order as presented by the examiner. The response was scored correct when all the words were repeated in the same order as presented. The task contains 27 items. The presentation was discontinued after 4 consecutive items were repeated incorrectly. The score was the number of correctly reproduced items. The task was administered individually. Naglieri and Das (1997) reported split-half reliabilities of .83 for grade 2 and .82 for grade 4 with the English version of Word Series.

Figure Memory. This is a subtest of the CAS (Naglieri & Das, 1997). This task required the participant to identify a geometric figure embedded in a more complex geometric pattern. In each trial, a target geometric figure was first shown for five seconds. After the target figure was removed, participants were asked to identify the target figure that was embedded in a more complex design. The task contains 27 items. The score was the number of correct responses before four consecutive errors. The test was administered in small groups. Naglieri and Das (1997) reported split-half reliabilities of .84 for grade 2 and .86 for grade 4.

Procedure

All tasks were administered to the participants between March and May 2005. All the computerized tasks were programmed with DirectRT v2004 (Empirisoft, 2006), which allows for precise latency recording and uniform presentation. All the stimuli were presented on a 15.4-inch laptop computer equipped with an Intel® Pentium® M Processor 730.

Non-verbal intelligence, three orthographic processing speed subtests (Recall of Radicals (1), Recall of Radicals (2), and Radical Searching) and the four rapid naming tasks were administered in the computerized testing session. The computerized session lasted approximately 25 minutes.

Paper and pencil tests were presented either in large groups, small groups, or individually. Character Recognition, Radical Awareness, Non-Character Recognition, and Radical Position were administered to up to 30 students at a time in regular classrooms in two different sessions. Character Recognition was administered in session one and the remaining tests in session two. Each session lasted approximately 30 minutes.

Figure Memory was administered in small groups. Each group contained 8 to 10 students. The testing time was approximately 20 minutes.

One-Minute Reading, Word Series, and all phonological awareness tests were administered individually. The testing time was approximately 20 minutes.

CHAPTER 5: RESULTS

Descriptive Statistics

Descriptive statistics including the means, standard deviations, minimum and maximum scores on each test for grade 2 and grade 4 are presented in Table 1. Seven standardized tests were administered in the current study: Graded Chinese Character Recognition test, Matrices, Figure Memory, Word Series, One-Minute Reading, Non-Character Recognition, and Radical Position.

The Character Recognition test was standardized in Taiwan by Huang (2001), Matrices, Figure Memory, and Word Series were standardized in the U.S. by Naglieri and Das (1997), and One-Minute Reading, Non-Character Recognition, and Radical Position were standardized in Hong Kong by Ho, Chan et al. (2000).

In accordance with the norms of the Character Recognition test, fifty percent of grade 2 students in Taiwan were expected to achieve a score above 44 and fifty percent of grade 4 students in Taiwan were expected to achieve a score above 79. Participants in the current study achieved a median score of 60 in grade 2 and 93 in grade 4. A score of 60 is in the 83^{rd} percentile in the grade 2 norm, and a score of 93 is in the 71^{st} percentile in the grade 4 norm, indicating that the current sample was reading well compared to the Taiwanese norms.

In general, grade 2 and grade 4 Taiwanese students in this study scored higher than the U.S. norm sample in Matrices, Figure Memory, and Word Series. The raw scores of these CAS subtests were converted into scaled scores with an expected mean of 10 and a standard deviation of 3. Grade 2 and grade 4 students in Taiwan achieved a

Table 1
Grade 2 and Grade 4 Descriptive Statistics for All Variables

	Grade 2				Grade 4			
	M	*SD*	Min	Max	*M*	*SD*	Min	Max
Reading								
Character Recognition	63.2	21.7	10	116	93.4	26.6	35	154
One-Minute Reading	75.1	16.4	42	108	86.6	14.7	53	115
Non-Verbal IQ								
Matrices	16.5	4.7	6	24	18.1	4.4	7	28
Short-Term Memory								
Figure Memory	11.5	3.6	4	19	15.1	3.4	8	23
Word Series	11.3	2.1	4	19	11.3	1.7	8	15
Phonological Awareness								
Initial Sound Detection	8.7	2.6	2	12	9.5	1.9	5	12
Final Sound Detection	8.2	2.6	2	12	8.9	2.0	5	12
Tone Sensitivity	8.6	2.7	2	12	9.6	2.0	3	12
Initial Sound Isolation	9.7	0.6	8	10	9.8	0.6	7	10
Final Sound Isolation	8.7	1.1	5	10	8.7	1.3	4	10
Rapid Naming								
Colours[1]	54.0	19.3	28.5	145.0	45.3	8.8	26.5	76.5
Digits[1]	28.5	6.9	17.1	49.0	23.8	4.6	17.2	34.7
Zhu-Yin-Fu-Hao[1]	50.8	11.4	33.9	91.4	40.1	8.0	26.7	67.2
Characters[1]	32.0	6.2	19.0	45.4	29.2	5.2	20.1	41.5
Orthographic Processing								
Non-Character Recognition	50.9	5.5	34	60	54.4	4.5	42	60
Radical Awareness	16.0	2.2	11	20	17.4	1.6	13	20
Radical Position	17.6	3.1	3	20	18.4	1.7	10	20
Recall of Radicals (1)[1]	2.4	0.7	1.7	4.8	1.8	0.4	0.9	3.0
Recall of Radicals (2)[1]	2.4	0.7	1.5	5.7	1.8	0.5	1.2	3.9
Radical Searching[1]	3.9	0.9	2.2	6.6	2.9	0.6	1.8	4.1

Note. [1] in seconds.

mean score of 16.5 and 18.1 in Matrices, which translate into scaled scores of 14 and 11. Figure Memory mean scores of 11.5 in grade 2 and 15.1 in grade 4 translate into scaled scores of 13 and 12. Word Series mean scores of 11.3 for both grade 2 and grade 4 are equal to scaled scores of 11 and 10.

In comparison to the Hong Kong norms, grade 2 and grade 4 students in this sample had a better reading rate in One-Minute Reading. The grade 2 average was 75 words/min and the grade 4 average was 87 words/min, compared to 60 words/min and 79 words/min for Hong Kong students in the norm sample. The performance on Non-Character Recognition and Radical Position was comparable to the Hong Kong norms. The means on Non-Character Recognition were 51 and 54 for grade 2 and grade 4 for the current sample, whereas the means were 51 and 55 for the Hong Kong norm sample. The mean scores on Radical Position were 17 and 18 for grade 2 and grade 4 students in the current sample, whereas mean scores of 17 and 19 were reported by the Hong Kong norms (Ho, Chan et al., 2000).

Overall, grade 2 and grade 4 students in the current sample performed at or above average level in all the standardized tests. Students in the current study obtained high reading scores when compared to the Taiwanese or Hong Kong norms. Performance on the cognitive processing tests was generally higher than what would be expected on the basis of the US norms. The results on the standardized tests possibly reflect the fact that the community where the school is located draws mainly families with relatively high socio-economic status.

Distributional Properties

An initial examination of distributional properties of the variables identified problems with three variables. Ceiling effects were present in Initial Sound Isolation, Final Sound Isolation, and Radical Position. Seventy-eight percent of the grade 2 children and 82% of the grade 4 children achieved a perfect score (10 out of 10) in Initial Sound Isolation. Sixty-nine percent of the second grade students and 72% of the fourth grade students scored 9 or 10 out of 10 in Final Sound Isolation. Similarly, 69% of the grade 2 students and 80% of the grade 4 students scored 18 or higher out of 20 in the Radical Position test. The ceiling effects shown in these variables indicate that these tests were too simple for grade 2 and grade 4 students in the current sample and were no longer effective for assessing their abilities in the related areas. Therefore, these tests were excluded from further data analyses.

Grade 2

Distributional properties of the data were evaluated further by identifying outliers with all variables to evade violations of normality. Outliers, the cases with extreme values, were defined as cases which are more than plus or minus two standard deviations from the mean of the variable.

In grade 2, Character Recognition had five outliers; Word Series, RAN Colours, RAN Digits, RAN Zhu-Yin-Fu-Hao, RAN Characters, and Recall of Radicals (1) each had three outliers; Matrices, Non-Character Recognition, and Recall of Radicals (2) each had two outliers; Figure Memory, Initial Sound Detection, Final Sound Detection, Tone Sensitivity, Radical Searching, and One-Minute Reading each had only one outlier. Outliers found in the variables were adjusted by adding or subtracting one unit value (+1 or -1) of the last acceptable scores of each variable.

In addition, a procedure examining distributional properties of the data by inspecting skewness and kurtosis values was performed. A common test for normality is to divide the skewness and kurtosis values by their standard errors (Garson, 2006). The resulting values should be within the -2 to +2 range when the data are normally distributed.

After dividing the skewness and kurtosis values by their standard errors, Non-Character Recognition, Radical Awareness, Initial Sound Detection, Tone Sensitivity, RAN Zhu-Yin-Fu-Hao, Recall of Radicals (1), and Recall of Radicals (2) showed distributions that were significantly different from normal.

The distributions of Non-Character Recognition, Radical Awareness, Initial Sound Detection, and Tone Sensitivity were negatively skewed. These variables were transformed by replacing the raw scores with their respective square roots. After square root transformations, both skewness and kurtosis test values fell within the recommended range.

The distribution of RAN Zhu-Yin-Fu-Hao was positively skewed and a logarithmic transformation was chosen to make the variable less skewed. After transformation, RAN Zhu-Yin-Fu-Hao yielded skewness and kurtosis test values within the acceptable -2 to +2 range.

The distribution of Recall of Radicals (1) was positively skewed. A logarithmic transformation was tried out initially to reduce the degree of skewness. However, a log transformation did not result in normal distribution and a test value of +3 was obtained for skewness after log transformation. Hence, an inverse transformation was applied to the variable. After inverse transformation, both the skewness and kurtosis test values of Recall of Radicals (1) fell within the acceptable -2 to +2 range.

An exception was made with the variable Recall of Radicals (2) that was slightly positively skewed (Skewness: 0.62; Kurtosis: -0.23; Std. Error: 0.30) and yielded a test value that was out of the -2 to +2 range after dividing skewness by the standard error. A preliminary attempt was made by using square root transformation with Recall of Radicals (2). Square root transformation slightly reduced the value of skewness but increased the value of kurtosis. Further examination of the histogram before and after transformation indicated that square root transformation did not result in improved distribution. Therefore, no transformation was applied to Recall of Radicals (2) and the original scores will be used in all analyses below.

Grade 4

In grade 4, Non-Character Recognition and Recall of Radicals (1) had four outliers; Character Recognition, Matrices, RAN Characters, and Recall of Radicals (2) each had three outliers; Figure Memory, Tone Sensitivity, RAN Colours and RAN Digits each had two outliers; RAN Zhu-Yin-Fu-Hao and One-Minute Reading each had only one outlier. Outliers found in the variables were adjusted by adding or subtracting one unit value (+1 or -1) of the last acceptable scores of each variable.

After dividing skewness and kurtosis values by their standard errors, Non-Character Recognition, Radical Awareness, Tone Sensitivity, and RAN Digits did not obtain test values within the -2 to +2 range. The distributions of Non-Character Recognition, Radical Awareness, and Tone Sensitivity were negatively skewed. These variables were transformed by replacing the raw scores with their respective square roots. After square root transformations, the skewness and kurtosis test values fell within the recommended range of -2 to +2.

The distribution of RAN Digits was positively skewed. After a logarithmic transformation, RAN Digits yielded skewness and kurtosis test values within the acceptable range.

Between Grades Differences

A series of multivariate analyses of variance (MANOVA) were carried out to assess if there were differences between grade 2 and grade 4 participants on reading and cognitive processing scores. To assess the effect of grade on each task, follow-up univariate analyses of variance were also examined. Matrices was the only task that assessed non-verbal IQ; therefore, the Matrices data were only examined with univariate analysis of variance. In order to assure that the results were robust, data were analyzed with both raw scores and transformed scores. When the results were consistent with both scores, only the outcomes of analyses with raw scores are reported.

MANOVAs indicated a significant difference between the grades on the reading tests, Wilks' $\lambda = .695$, $F(2, 114) = 24.98$, $p < .001$, short-term memory tests, Wilks' $\lambda = .788$, $F(2, 114) = 15.31$, $p < .001$, rapid naming tests, Wilks' $\lambda = .738$, $F(4, 112) = 9.95$, $p < .001$, orthographic processing accuracy tests, Wilks' $\lambda = .831$, $F(2, 114) = 11.56$, $p < .001$, and orthographic processing speed tests, Wilks' $\lambda = .642$, $F(3, 113) = 21.01$, $p < .001$. No significant difference was found for phonological awareness tests, Wilks' $\lambda = .947$, $F(3, 113) = 2.10$, $p = .103$.

To assess the effect of grade on each test, the results of one-way analyses of variance were further examined. For the reading tasks, the effect of grade was significant for both Character Recognition, $F(1, 115) = 50.05$, $p < .001$, and One-Minute Reading,

$F(1, 115) = 16.42$, $p < .001$. The effect of grade approached significance for Matrices raw score, $F(1, 115) = 3.90$, $p = .051$, and the effect of grade was significant for Matrices scaled score, $F(1, 115) = 20.01$, $p < .001$. For the two short-term memory tasks, the main effect of grade was significant for Figure Memory, $F(1, 115) = 30.77$, $p < .001$, but not for Word Series, $F(1, 115) = .06$, $p =.808$. For the four rapid naming tasks, the main effect of grade was significant for RAN Colours, $F(1, 115) = 11.74$, $p < .01$, RAN Digits, $F(1, 115) = 18.65$, $p < .001$, RAN Zhu-Yin-Fu-Hao, $F(1, 115) = 39.12$, $p < .001$, and RAN Characters, $F(1, 115) = 8.02$, $p < .01$. For the two analyzed orthographic processing accuracy tasks, the main effect of grade was significant for both Non-Character Recognition, $F(1, 115) = 17.74$, $p < .001$, and Radical Awareness, $F(1, 115) = 13.11$, $p < .001$. For the three orthographic processing speed tasks, the main effect of grade was significant for Recall of Radicals (1), $F(1, 115) = 51.83$, $p < .001$, Recall of Radicals (2), $F(1, 115) = 47.37$, $p < .001$, and Radical Searching, $F(1, 115) = 43.07$, $p < .001$. For the three analyzed phonological awareness tasks, the main effect of grade was significant for Tone Sensitivity, $F(1, 115) = 5.88$, $p < .05$, but not for Initial Sound Detection, $F(1, 115) = 3.28$, $p =.073$, and Final Sound Detection, $F(1, 115) = 3.15$, $p =.079$. All of the above results were consistent with both raw scores and transformed scores.

These results indicate that, in general, grade 4 children did better than grade 2 children in most reading and cognitive processing tasks. However, Initial Sound Detection and Final Sound Detection did not differentiate between the two grade levels. Children in Taiwan start intensive Zhu-Yin-Fu-Hao training as soon as they enter grade 1. All the textbooks from grade 1 to grade 4 are written with Zhu-Yin-Fu-Hao on the side of each Chinese character. The high demand of Zhu-Yin-Fu-Hao in classes results in the increase of children's familiarity and sensitivity to the sound structure of Chinese syllables. Also, the outstanding performance on the Matrices task by grade 2 children (their scaled score was significantly better than that of grade 4 children) also indicates that the grade 2 group in this study represents a more selective sample. Therefore, the ability to detect onset and rime difference could be at a comparable stage at both grade levels.

The only phonological awareness task that distinguished grade 2 and grade 4 groups was Tone Sensitivity. The result indicates that this suprasegmental phonological feature of the Chinese language may have a special status in phonological processing. Therefore, Tone Sensitivity could be an appropriate task for assessing growth of phonological awareness in later elementary grades in Chinese speaking children (see also, Siok & Fletcher, 2001).

Error Analysis of Non-Character Recognition and Radical Searching Responses

The main effect of grade was significant for Non-Character Recognition and Radical Searching, as reported previously. However, it was also interesting to examine the errors children made in these two tasks.

Non-Character Recognition consisted of 30 rare characters and 30 ill-formed characters (noncharacters). The results indicated that grade 4 students performed significantly better than grade 2 students with ill-formed characters, $F(1, 115) = 11.56$, $p < .001$. The main effect of grade approached significance for rare characters, $F(1, 115) = 3.7$, $p = .057$. The percentages of correct responses for rare characters and ill-formed characters were 79% and 90% for grade 2, respectively, and 86% and 96% for grade 4.

To examine whether items in rare characters were more difficult than items in ill-formed characters, a paired-sample t test was conducted. The result showed that the main effect of task was significant, $t(116) = -5.22$, $p < .001$. The results showed that rare characters, which were unfamiliar to both grade 2 and grade 4 students, were more challenging and confusing for the participants in the present study. On the other hand, ill-formed characters that violate the formation rules of Chinese characters were relatively easy to reject, especially for the grade 4 children.

Moreover, two types of errors made in Non-Character Recognition were examined to determine whether there were differences in the nature of the errors made by children in these two grades. In grade 2, 69% of the errors included judging rare characters as noncharacters, and 31% of errors resulted from failing to reject ill-formed characters as noncharacters. In grade 4, 76% of the errors included mistakenly identifying rare characters as noncharacters and 24 % of the errors resulted from failing to identify ill-formed characters. To further investigate whether grade 2 and grade 4 differ on the types of error they made, a chi-square analysis was used. This analysis showed that distribution of errors across categories were not equal for the two groups, χ^2 (1, N= 117) = 5.99, $p < .05$. Examination of the differences between expected and observed cell values indicated that the most prominent difference between grade 2 and grade 4 was in their response to noncharacters: Grade 2 students made more noncharacter errors than expected, while the opposite was true for grade 4.

Radical Searching, a speed measure, involved three kinds of distracters in each trial: a semantic distracter, a homophonic distracter, and an unrelated control. In grade 2, 27% of the errors were semantic errors, 65% were homophone errors, and 8% were unrelated errors. In grade 4, 52 % of the errors were semantic errors, 33% were homophone errors, and 14% were unrelated errors. A chi-square analysis showed that the distribution of errors across categories were not equal for the two groups, $\chi^2(2, N= 117) = 10.73$, $p < .01$. Examination of the differences between expected and observed cell values indicated that grade 2 participants made more homophone errors and less semantic errors than expected; grade 4 made more semantic errors and less homophone errors than expected. This pattern of results suggests that the grade 2 participants were more distracted by sound, whereas meaning had more impact on the grade 4 participants.

Correlations Between Dependent and Independent Variables

Grade 2

Table 2 presents intercorrelations among all raw scores for grade 2 participants. In general, age did not correlate significantly with reading and cognitive processing measures in grade 2. The two reading measures, Character Recognition and One-Minute Reading, were highly correlated. The correlation between the two short-term memory measures, Figure Memory and Word Series was not significant ($r = .13$, $p = .30$). The phonological awareness measures, Initial Sound Detection, Final Sound Detection, and Tone Sensitivity, were highly correlated (*rs* = .51 to .68). The rapid naming measures, RAN Colours, RAN Digits, RAN Zhu-Yin-Fu-Hao, and RAN Characters, were moderately to highly correlated (*rs* = .41 to .71). The two orthographic processing accuracy measures, Non-Character Recognition and Radical Awareness also correlated moderately. Finally, the three orthographic processing speed measures, Recall of

Radicals (1), Recall of Radicals (2), and Radical Searching, were all highly correlated with each other (*rs* = .52 to .79).

In terms of correlations across constructs, Matrices correlated significantly with all three phonological awareness measures, RAN Digits, and the two orthographic accuracy measures. In terms of short-term memory, Figure Memory correlated moderately with Tone Sensitivity and mildly with Radical Awareness and Recall of Radicals (1), whereas Word Series correlated with all three phonological awareness measures, RAN Colours, RAN Digits, and RAN Characters. For phonological awareness measures, both Initial Sound Detection and Final Sound Detection correlated moderately with Matrices, Word Series, the four rapid naming tasks, Non-Character Recognition, and Radical Awareness, and Tone Sensitivity correlated significantly with Matrices, the two short-term memory measures, RAN Colours, RAN Digits, RAN Characters, and Non-Character Recognition. Of the rapid naming measures, RAN Colours correlated with Word Series, the three phonological awareness tasks, and Recall of Radicals (1) and (2); RAN Digits correlated with Matrices, Word Series, and the three phonological awareness measures; RAN Zhu-Yin-Fu-Hao correlated significantly with Initial Sound Detection, Final Sound Detection, Radical Awareness, and Recall of Radicals (1); and, finally, RAN Characters correlated moderately with Word Series, the three phonological awareness tasks, and the three orthographic processing speed measures. For orthographic processing, Non-Character Recognition correlated with age, Matrices, all three phonological awareness tasks, and Radical Awareness. Radical Awareness correlated significantly with Matrics, Figure Memory, Initial and Final Sound Detection and RAN Zhu-Yin-Fu-Hao. Recall (1) and (2) both correlated with RAN Colours and RAN Characters, whereas

Recall (1) also correlated significantly with Figure Memory and RAN Zhu-Yin-Fu-Hao. Finally, Radical Searching only moderately correlated with RAN Characters.

In sum, the correlations between rapid naming, phonological awareness, and orthographic processing measures revealed that in grade 2, rapid naming measures showed a slightly stronger relationship with the phonological processing measures than with the orthographic processing measures. In general, the four rapid naming tasks were moderately correlated with the three phonological awareness tasks, whereas the correlations between rapid naming measures and orthographic processing measures ranged from moderate to none.

With regards to the reading tasks, Character Recognition correlated significantly with Matrices, Figure Memory, Initial Sound Detection, Tone Sensitivity, RAN Characters, Non-Character Recognition, Radical Awareness, Recall of Radicals (1), and Radical Searching. One-Minute Reading, in turn, correlated significantly with most cognitive processing measures, with the exceptions of Figure Memory (r = .21, p = .09) and Non-Character Recognition (r = .23, p = .07). Overall, One-Minute Reading was moderately to highly correlated with rapid naming measures (rs = -.47 to -.70), and moderately correlated with phonological awareness (rs = .36 to. 47) and orthographic processing speed (rs = -.33 to -.43) measures.

Correlational analyses with transformed scores were generally consistent with the analyses with raw scores. However, there were three significant correlations with raw scores that were not significant with transformed scores (Initial Sound Detection and Non-Character Recognition, r = .21, p = .09; Tone Sensitivity and Non-Character Recognition, r = .22, p = .09; RAN Zhu-Yin-Fu-Hao and Radical Awareness, r = -.24, p

= .06). As well, there were two non-significant correlations with raw scores that were significant with transformed scores (Word Series and RAN Zhu-Yin-Fu-Hao, $r = -.25$, $p < .05$; Recall of Radicals (2) and RAN Zhu-Yin-Fu-Hao, $r = .25$, $p < .05$). Despite the differences in the significance levels, the correlation coefficients among these variables were fairly similar in both analyses.

Table 2

Correlations Between Grade 2 Measures

Variables	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A Character Recognition	.68**	.15	.36**	.35**	.19	.38**	.21	.45**	-.21	-.24	-.10	-.33**	.28*	.33**	-.30*	-.24	-.25*
B One-Minute Reading		.12	.31*	.21	.25*	.45**	.36**	.47**	-.53**	-.62**	-.47**	-.70**	.23	.37**	-.43**	-.36**	-.33**
C Age			.23	.17	.06	-.04	.06	.08	-.06	.02	-.05	.05	.29*	.12	-.14	-.18	-.20
D Matrices				.25	.11	.41**	.34**	.32**	-.22	-.29*	-.07	-.23	.29*	.33**	-.17	-.11	-.10
E Figure Memory					.13	.18	.16	.38**	-.19	.12	-.30	-.10	.21	.28*	-.30*	-.15	-.24
F Word Series						.39**	.41**	.29*	-.26*	-.26*	-.22	-.40**	.12	.13	-.19	-.19	-.18
G Initial Sound Detection							.68**	.51**	-.34**	-.34**	-.31*	-.41**	.26*	.40**	-.16	-.19	-.02
H Final Sound Detection								.55**	-.39**	-.33**	-.25*	-.31*	.30*	.35**	-.06	-.09	.02
I Tone Sensitivity									-.31*	-.36**	-.21	-.36**	.25*	.23	-.21	-.21	-.08
J RAN Colours										.64**	.41**	.62**	-.13	-.06	.25*	.30*	.24
K RAN Digits											.55**	.71**	-.02	-.07	.18	.23	.13
L RAN Zhu-Yin-Fu-Hao												.45**	-.10	-.27*	.26*	.23	.01
M RAN Characters													-.03	-.16	.40**	.36**	.32*
N Non-Character Recognition														.36**	-.02	-.06	-.15
O Radical Awareness															-.15	-.16	-.21
P Recall of Radicals (1)																.79**	.52**
Q Recall of Radicals (2)																	.53**
R Radical Searching																	

Note. * $p < 0.05$; ** $p < 0.01$.

Grade 4

Table 3 presents intercorrelations among all raw scores for grade 4 participants. Age correlated significantly with Character Recognition and Initial Sound Detection. The two reading measures, Character Recognition and One-Minute Reading, were highly correlated. The correlation between the two short-term memory measures, Figure Memory and Word Series, was not significant ($r = .07$, $p = .60$). The three phonological awareness measures, Initial Sound Detection, Final Sound Detection, and Tone Sensitivity, were moderately to highly correlated. The rapid naming measures, RAN Colours, RAN Digits, RAN Zhu-Yin-Fu-Hao, and RAN Characters, were moderately to highly correlated (*rs* = .43 to .65). The two orthographic processing accuracy measures, Non-Character Recognition and Radical Awareness correlated significantly. Finally, the three orthographic processing speed measures, Recall of Radicals (1), Recall of Radicals (2), and Radical Searching, were highly correlated (*rs* = .56 to .70).

Examining the intercorrelations across constructs, Matrices correlated significantly with Figure Memory, Initial Sound Detection, and Tone Sensitivity. Figure Memory correlated with Matrices, Initial Sound Detection, RAN Characters, and Radical Searching, whereas none of the tasks correlated significantly with Word Series. For phonological awareness, Initial Sound Detection correlated with age, Matrices, Figure Memory, RAN Zhu-Yin-Fu-Hao, RAN Characters, Non-Character Recognition, Radical Awareness, and Radical Searching. Final Sound Detection, on the other hand, only correlated significantly with RAN Zhu-Yin-Fu-Hao. Tone Sensitivity correlated with Matrices, RAN Zhu-Yin-Fu-Hao, RAN Characters, Radical Awareness, and Radical Searching. Of the rapid naming measures, RAN Colours correlated with Non-Character

Recognition and the three orthographic processing speed measures. RAN Digits and RAN Zhu-Yin-Fu-Hao both correlated significantly with all three orthographic processing speed measures while only RAN Zhu-Yin-Fu-Hao also correlated with the three phonological awareness measures. RAN Characters correlated significantly with Figure Memory, Initial Sound Detection, Tone Sensitivity, the two orthographic processing accuracy measures, and the three orthographic processing speed measures.

With regards to the reading tasks, Character Recognition correlated significantly with Figure Memory, all three phonological awareness measures (*rs* = .46 to .64), RAN Digits, RAN Zhu-Yin-Fu-Hao, RAN Characters, both orthographic processing accuracy measures (*rs* = .51 and .54), and with two orthographic processing speed measures, Recall of Radicals (1) and Radical Searching. One-Minute Reading correlated significantly with Initial Sound Detection, Tone Sensitivity, all four rapid naming measures (*rs*= -.48 to -.71), Radical Awareness, Recall of Radicals (1) and Radical Searching.

In grade 4, in general, the rapid naming measures correlated higher with the orthographic processing measures than with the phonological processing measures. RAN Colours and RAN Digits did not correlate significantly with any of the phonological processing measures. In contrast, all rapid naming measures correlated moderately to highly with all three orthographic processing speed measures.

The majority of results were consistent with both raw scores and transformed scores. Four significant correlations with raw scores were not significant with transformed scores (Tone Sensitivity and RAN Characters, $r = -.26$, $p = .053$; Non-Character Recognition and RAN Colours, $r = -.24$, $p = .08$; Tone Sensitivity and Radical

Awareness, $r = .20$, $p = .14$; Non-Character Recognition and Recall of Radicals (1), $r = -.26$, $p = .06$). In spite of the inconsistencies of the significance level, the correlation coefficients were very similar whether the raw scores or the transformed scores were used.

Table 3

Correlations Between Grade 4 Measures

Variables	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A Character Recognition	.61**	.27*	.25	.33*	.12	.64**	.46**	.51**	-.26	-.49**	-.55**	-.54**	.54**	.51**	-.31*	-.23	-.38**
B One-Minute Reading		.22	.19	.08	.16	.36**	.20	.34*	-.48**	-.71**	-.64**	-.56**	.18	.30*	-.40**	-.24	-.37**
C Age			.19	.04	-.17	.31*	.00	.12	-.10	-.10	-.10	.07	.06	.06	-.08	.01	.06
D Matrices				.34*	.04	.43**	.10	.29*	-.16	-.14	.07	-.14	.14	.18	-.08	-.19	.19
E Figure Memory					.07	.38**	.23	.24	-.24	-.01	-.25	-.28*	.21	.21	-.26	-.13	-.28*
F Word Series						.14	.18	.23	-.08	-.12	-.08	-.17	.01	.06	-.24	-.16	-.13
G Initial Sound Detection							.32*	.55**	-.12	-.25	-.31*	-.39**	.29*	.45**	-.24	-.22	-.30*
H Final Sound Detection								.45**	-.20	-.18	-.31*	-.22	.20	.14	-.16	-.13	-.19
I Tone Sensitivity									-.13	-.24	-.39**	-.28*	.08	.29*	-.20	-.24	-.33*
J RAN Colours										.56**	.47**	.43**	-.27*	-.08	.57**	.36**	.49**
K RAN Digits											.65**	.63**	-.19	-.16	.40**	.36**	.38**
L RAN Zhu-Yin-Fu-Hao												.52**	-.24	-.24	.37**	.38**	.57**
M RAN Characters													-.34*	-.28*	.31*	.35**	.53**
N Non-Character Recognition														.27*	-.29*	-.24	-.27*
O Radical Awareness															-.30*	-.15	-.35*
P Recall of Radicals (1)																.70**	.56**
Q Recall of Radicals (2)																	.58**
R Radical Searching																	

Note. * $p < 0.05$; ** $p < 0.01$.

Predicting Character Recognition and One-Minute Reading

A series of fixed-order hierarchical multiple regression analyses was conducted next to investigate the predictive power of the short-term memory, phonological awareness, rapid naming, and orthographic processing tests, with Character Recognition and One-Minute Reading as the dependent variables. The correlation matrixes of grade 2 and grade 4 indicated high intercorrelations among the predictor variables. To minimize the problem of collinearity, the following procedure was applied.

In all regression analyses, age and Matrices were entered first to control for age and non-verbal IQ. In model 1, only the control variables and the short-term memory variables were included. In model 2, the control variables and the phonological awareness variables were included. In model 3, the control variables and the rapid naming variables were included. In model 4, the control variables and the orthographic processing variables were included. In the final model, the significant predictors from model 1 to model 4 were entered into the regression analysis simultaneously to examine the unique variances accounted for by these variables. Standardized beta coefficients and significance levels from these analyses are reported in Tables 4 to 7.

Character Recognition

The regression results for grade 2 Character Recognition are presented in Table 4. Age and Matrices accounted for 13% of the variance in Character Recognition. In model 1, Figure Memory was a significant predictor of Character Recognition, but Word Series was not. In model 2, phonological awareness tasks accounted for an additional 17% of the variance but Tone Sensitivity was the only significant predictor. In model 3 and model 4, none of the rapid naming tasks or the orthographic processing tasks were significant predictors of Character Recognition in grade 2. In the final model, the two significant predictors, Figure Memory and Tone Sensitivity, were entered simultaneously and together accounted for an additional 15% of the variance. Moreover, Tone Sensitivity was the only significant predictor of Character Recognition in the final model. Thus, the results indicate that Tone Sensitivity was the best predictor of Character Recognition in Grade 2.

Table 4
Regression Results Predicting Grade 2 Character Recognition

	Character Recognition				
Predictor Variables	Model 1	Model 2	Model 3	Model 4	Final Model
Control Variables					
Age	.03	.10	.10	-.01	.05
Matrices	.27*	.18	.28*	.22	.20
R Square Change	.13*	.13*	.13*	.13*	.13*
Short-Term Memory					
Figure Memory	.26*				.17
Word Series	.12				
R Square Change	.08				
Phonological Awareness					
Initial Sound Detection		.30			
Final Sound Detection		-.27			
Tone Sensitivity		.38**			.31*
R Square Change		.17**			
Rapid Naming					
Colour			.01		
Digit			.04		
Zhu-Yin-Fu-Hao			.04		
Character			-.33		
R Square Change			.07		
Orthographic Processing					
Non-Character Recognition				.14	
Radical Awareness				.17	
Recall of Radicals(1)				-.23	
Recall of Radicals (2)				.04	
Radical Searching				-.08	
R Square Change				.12	
R Square Change					.15**

Note. * $p < .05$, ** $p < .01$

To examine further whether the final model was the best predictive model for grade 2 Character Recognition, rapid naming and orthographic processing tasks with the highest standardized beta coefficients were added to the final model in step 3. In these analyses, control variables, Age and Matrices, were entered in step 1. In step 2, the only significant predictor, Tone Sensitivity, was added. Finally, in step 3, RAN Characters and/or Recall of Radicals (1) were entered. The results showed that adding RAN Characters and/or Recall of Radicals (1) to the final model did not result in a significant increase in the variance accounted for.

Table 5 presents the results of regression analyses predicting grade 4 Character Recognition. Age and Matrices accounted for 11% of the variance of Character Recognition. In model 1, Figure Memory was the only significant predictor of Character Recognition after age and Matrices were controlled. In model 2, phonological awareness tasks jointly accounted for an additional 39% of the variance after controlling for age and non-verbal IQ. Initial Sound Detection and Final Sound Detection were both significant predictors of Character Recognition, but Tone Sensitivity was not. In model 3, rapid naming tasks accounted for an additional 39% of the variance. RAN Zhu-Yin-Fu-Hao and RAN Characters were significant predictors, whereas RAN Colours and RAN Digits were not. In model 4, orthographic processing tasks significantly accounted for an additional 41% of the variance. Non-Character Recognition and Radical Awareness were the two significant predictors of orthographic processing tasks. In the final model, significant predictors from models 1 to 4 were entered simultaneously and together accounted for 62% of additional variance after controlling for age and non-verbal intelligence. Initial Sound Detection, Final Sound Detection, RAN Zhu-Yin-Fu-Hao, Non-Character Recognition, and Radical Awareness were all significant predictors of grade 4 Character Recognition.

Table 5
Regression Results Predicting Grade 4 Character Recognition

	Character Recognition				
Predictor Variables	Model 1	Model 2	Model 3	Model 4	Final Model
Control Variables					
Age	.26*	.12	.23*	.23*	.16
Matrices	.10	-.04	.19	.06	.02
R Square Change	.11*	.11*	.11*	.11*	.11*
Short-Term Memory					
Figure Memory	.28*				-.01
Word Series	.14				
R Square Change	.09				
Phonological Awareness					
Initial Sound Detection		.47**			.23*
Final Sound Detection		.25*			.20*
Tone Sensitivity		.14			
R Square Change		.39**			
Rapid Naming					
Colour			.17		
Digit			-.05		
Zhu-Yin-Fu-Hao			-.39**		-.20*
Character			-.37*		-.17
R Square Change			.39**		
Orthographic Processing					
Non-Character Recognition				.39**	.27**
Radical Awareness				.33**	.20*
Recall of Radicals(1)				.01	
Recall of Radicals(2)				.03	
Radical Searching				-.19	
R Square Change				.41**	
R Square Change					.62**

Note. * $p < .05$, ** $p < .01$

One-Minute Reading

Table 6 presents the results of regression analyses predicting grade 2 One-Minute Reading. Age and Matrices accounted for 10% of the variance of One-Minute Reading. In model 1, neither Figure Memory nor Word Series was a significant predictor. In model 2, phonological awareness tasks accounted for an additional 20% of the variance after controlling for age and non-verbal IQ, but Tone Sensitivity was the only significant predictor among the phonological tasks. In model 3, rapid naming tasks accounted for 47% of additional variance after age and Matrices were controlled. Of the rapid naming tasks, RAN Characters was the only significant predictor. In model 4, orthographic processing tasks accounted for an additional 22% of the variance, but none of the tasks were significant predictors. In the final model, significant predictors, Tone Sensitivity and RAN Characters, were entered in the equation and together accounted for an additional 47% of the variance after controlling for age and Matrices; both Tone Sensitivity and RAN Characters remained significant in the final model. Consequently, in grade 2, Tone Sensitivity and RAN Characters were the best predictors of One-Minute Reading. To examine the unique contribution of Tone Sensitivity and RAN Characters to One-Minute Reading, the orders of these two predictors were manipulated. RAN Characters accounted for an additional 32% of the variance when Tone Sensitivity was controlled. However, when the effect of RAN Characters was removed, Tone Sensitivity only accounted for 4% of additional variance.

To further examine the best predictive model for grade 2 One-Minute Reading, the orthographic processing task with the highest standardized beta coefficient was added to the final model in step 3. Therefore, in step 1, control variables, Age and Matrices, were entered. In step 2, the significant predictors, Tone Sensitivity and RAN Characters, were added. Finally, in step 3, Recall of Radicals (1) was entered. The results showed that the amount of variance accounted for did not increase significantly with Recall of Radicals (1) added to the model.

Table 6

Regression Results Predicting Grade 2 One-Minute Reading

	One-Minute Reading				
Predictor Variables	Model 1	Model 2	Model 3	Model 4	Final Model
Control Variables					
Age	.03	.09	.11	-.03	.12
Matrices	.25*	.09	.12	.16	.07
R Square Change	.10*	.10*	.10*	.10*	.10*
Short-Term Memory					
Figure Memory	.12				
Word Series	.20				
R Square Change	.06				
Phonological Awareness					
Initial Sound Detection		.29			
Final Sound Detection		-.05			
Tone Sensitivity		.31*			.22*
R Square Change		.20**			
Rapid Naming					
Colour			-.04		
Digit			-.13		
Zhu-Yin-Fu-Hao			-.15		
Character			-.50**		-.62**
R Square Change			.47**		
Orthographic Processing					
Non-Character Recognition				.09	
Radical Awareness				.21	
Recall of Radicals(1)				-.31	
Recall of Radicals (2)				-.02	
Radical Searching				-.09	
R Square Change				.22**	
R Square Change					.47**

Note. * $p < .05$, ** $p < .01$

Table 7 presents the results of regression analyses predicting grade 4 One-Minute Reading after controlling for age and Matrices. In model 1, only the two short-term memory tasks were entered and neither was a significant predictor of One-Minute Reading. In model 2, phonological awareness tasks were entered and none of the tasks were significant predictors. In model 3, rapid naming tasks accounted for an additional 54% of the variance. Of the rapid naming task, RAN Digits and RAN Zhu-Yin-Fu-Hao significantly predicted One-Minute Reading. In model 4, orthographic processing tasks were entered and accounted for an additional 19% of the variance which approached significance (p = .053). In the final model, the two significant predictors, RAN Digits and RAN Zhu-Yin-Fu-Hao, were entered and together accounted for an additional 52% of the variance after age and Matrices were controlled.

To further examine the best predictive model for grade 4 One-Minute Reading, phonological processing tasks and orthographic processing tasks with the highest standardized beta coefficient were added to the final model in step 3. Therefore, in step 1, control variables, Age and Matrices, were entered. In step 2, the two significant predictors, RAN Digits and RAN Zhu-Yin-Fu-Hao, were added. Finally, in step 3, Initial Sound Detection, Tone Sensitivity, and/or Recall of Radicals (1) were entered. The results showed that the amount of variance explained did not increase significantly when the three variables in step 3 were entered simultaneously or separately.

Table 7
Regression Results Predicting Grade 4 One-Minute Reading

Predictor Variables	One-Minute Reading				
	Model 1	Model 2	Model 3	Model 4	Final Model
Control Variables					
Age	.22	.13	.14	.18	.11
Matrices	.14	.03	.11	.09	.13
R Square Change	.07	.07	.07	.07	.07
Short-Term Memory					
Figure Memory	.01				
Word Series	.20				
R Square Change	.04				
Phonological Awareness					
Initial Sound Detection		.19			
Final Sound Detection		.05			
Tone Sensitivity		.19			
R Square Change		.11			
Rapid Naming					
Colour			-.03		
Digit			-.38**		-.47**
Zhu-Yin-Fu-Hao			-.29*		-.33**
Character			-.15		
R Square Change			.54**		
Orthographic Processing					
Non-Character Recognition				.00	
Radical Awareness				.12	
Recall of Radicals(1)				-.29	
Recall of Radicals(2)				.13	
Radical Searching				-.23	
R Square Change				.19	
R Square Change					.52**

Note. * $p < .05$, ** $p < .01$

In sum, Tone Sensitivity appeared to be the most powerful predictor of Character Recognition in grade 2. In grade 4, the two sound detection tasks, RAN Zhu-Yin-Fu-Hao, Non-Character Recognition, and Radical Awareness all predicted Character Recognition. For One-Minute Reading, Tone Sensitivity and RAN Characters were the best predictors in grade 2 and RAN Digits and RAN Zhu-Yin-Fu-Hao were the best predictors in grade 4.

CHAPTER 6: DISCUSSION

The main purpose of the present study is to investigate the relative importance of various cognitive processing skills for Chinese reading acquisition in grades 2 and 4. The participants were 63 grade 2 and 54 grade 4 elementary school students in Taiwan. In this study, phonological awareness skills, rapid naming skills, and orthographic processing skills were examined with a battery of tasks. The results show that these cognitive skills were associated with Chinese reading acquisition. In the following section, the major findings are discussed.

Phonological Awareness Skills and Chinese Reading Acquisition

Two primary findings of phonological awareness emerge from this study. First, different types of phonological awareness tasks have different associations with grade 2 and grade 4 reading abilities. Second, Tone Sensitivity was the only phonological awareness test that distinguished grade 2 from grade 4.

Both Sound Detection (onset and rime awareness) and Tone Sensitivity correlated significantly with reading measures in both grades, with two exceptions: Final Sound Detection in grade 2 did not correlate significantly with Character Recognition, and Final Sound Detection in grade 4 did not correlate significantly with grade 4 One-Minute Reading. A particularly high correlation of .64 was found between grade 4 Character Recognition and Initial Sound Detection. The results are consistent with previous studies which have consistently demonstrated a correlational relationship between phonological awareness and character recognition (Ho, 1997; Ho & Bryant, 1997a, 1997b; Ho et al., 1999; Huang & Hanley, 1997; Hu & Catts, 1998; Siok & Fletcher, 2001; So & Siegel, 1997; Wang, 2005). However, Sound Detection tasks and Tone Sensitivity seemed to play different roles in the development of grade 2 and grade 4 reading. In grade 2, Tone Sensitivity not only correlated with the reading tasks but it was also a significant predictor for Character Recognition after controlling for age, IQ, and Figure Memory and One-Minute Reading after controlling for age, IQ, and rapid naming. Onset (Initial Sound Detection) and rime (Final Sound Detection) awareness tasks, on the other hand, were more strongly associated with grade 4 reading and predicted significantly grade 4 Character Recognition after controlling for differences in age, IQ, rapid naming, and orthographic processing. These results suggest that the associations of different aspects of phonological awareness and Chinese reading varied with the developmental level of the child.

In Mandarin Chinese, tones function as a suprasegmental phonological feature to Chinese syllables. Tones are attached to the entire syllable and cannot be separated. It is noteworthy that there are no visual cues provided in Chinese orthography that specify tones. Accordingly, attending to tones is required for children to clarify the meaning of characters with identical phonetic structure that are only differentiated by tone. Thus, it is expected that Chinese children who are relatively insensitive to tones may get confused more often during reading, speaking, and listening.

Huang and Zhang (1997) investigated the differences in tone sensitivity between grade 2 children with reading disabilities and normally reading grade 2 children in Taiwan. They reported that tone sensitivity differentiated the reading disabled group from the normally reading children. They also reported that tone sensitivity predicted reading ability in the reading disabled group but unfortunately they did not report whether tone sensitivity predicted reading in the normally reading group. In the present study, however, Tone Sensitivity was found to predict reading in an unselected sample of grade 2 children with good character reading skills. These findings suggest that grade 2 children who are sensitive to tones have better character recognition skills than children who have trouble detecting tones. Therefore, a tone sensitivity test may serve as an useful index for screening of children with reading difficulties.

It is conventional to dissect Chinese syllables into onsets (initial sound) and rimes (final sound). For example, in the Zhu-Yin-Fu-Hao system, there are 21 symbols for the initial sounds and 16 symbols for the final sounds. These 37 symbols map onto the onset and rime level of alphabetic languages. Therefore, the ability to perceive subsyllabic phonological units is required daily for reading activities, at least while Zhu-Yin-Fu-Hao is still employed in the script.

The present study's finding that onset and rime awareness was predictive of grade 4 Character Recognition is similar to the finding in Siok and Fletcher's study (2001). Siok and Fletcher investigated the role of onset and rime awareness in Chinese reading and reported that onset and rime awareness accounted for 15.2 % of the variance in grade 5 character recognition after the effects of age and IQ were controlled.

However, Siok and Fletcher (2001) also reported that onset and rime awareness predicted reading in grade 2, but tone sensitivity did not. Contrary to their results, the present study found that Tone Sensitivity predicted grade 2 reading, whereas onset and rime awareness did not contribute unique variance. There are a few possible explanations for the different results obtained in these two studies. First, in the current study, the three phonological awareness tasks in grade 2 were highly correlated (*r*s = .51 to .68) and these predictor variables contained much of the same information. Moreover, in the present study, the three phonological awareness tasks were entered into the regression equation at the same time after controlling for age and IQ, whereas in Siok and Fletcher's study, each phonological awareness task was entered separately. To examine whether onset and rime awareness contributes significantly to Character Recognition when Tone Sensitivity is not controlled, a regression analysis with only onset and rime awareness and the controlled variables was conducted. After the effects of age and IQ were removed, the contribution of onset and rime awareness approached significance ($p =. 065$) and the two tasks together explained 8% of unique variance.

Second, different stimuli used in the two studies may also contribute to the differences in results. The tone sensitivity task in the present study was likely more difficult than the one used by Siok and Fletcher. In Siok and Fletcher's task, the first 10 test trials (out of 16) employed syllables that shared either the same onset or rime. In the present study, only syllables in the first 3 test trials (out of 12) shared the same onset. According to Ho and Bryant (1997b; 1997c), it is easier for children to detect tone differences among a set of syllables when these syllables share an onset or a rime. In other words, it is more confusing for children when they are asked to pick the syllable that is different in tone from the other 3 syllables when all components (onset, rime, and tone) are different between the syllables. Accordingly, Siok and Fletcher reported that grade 2 children performed significantly better on tone sensitivity task than on onset and rime awareness task. In the present study, however, the differences between Tone Sensitivity and onset and rime awareness were not significant in grade 2. This shows that Tone Sensitivity and onset and rime awareness tasks were at a comparable difficulty level for grade 2 participants. Therefore, Tone Sensitivity task in this study could be more predictive to grade 2 reading abilities than Siok and Fletcher's. In addition, Siok and Fletcher employed both Chinese and English stimuli to assess onset and rime awareness in their study. Thus, it is possible that different results were produced by involving two languages in their task.

Another important finding of the present study is that Tone Sensitivity was the only phonological awareness test that distinguished grade 2 from grade 4. In other words, Sound Detection tasks failed to show differences between the two grades. The result could be due to the possibility that using and practicing Zhu-Yin-Fu-Hao frequently facilitates children's perception of the subsyllabic units. Also, grade 2 children in this study preformed extremely well in Character Recognition (86^{th} percentile in the grade 2 norm) and achieved a scaled mean score of 14 (with an expected mean of 10) in the Matrices task. The superb performance in Character Recognition and likely high IQs suggests that grade 2 participants in the present study were not entirely representative of grade 2 children in Taiwan in general, and likely included more high-performing children than the grade 4 sample. Accordingly, it is possible that their ability to detect onsets and rimes could be quite comparable to the grade 4 group.

Surprisingly, the role of tone sensitivity in predicting Chinese reading acquisition hasn't been extensively studied. The majority of Chinese reading acquisition studies have focused on the level of phonological awareness that is needed to learn to read alphabetic languages. The present study provides evidence that tone sensitivity is a strong predictor of grade 2 reading performance and suggests that for beginning Chinese readers, tone sensitivity may be more appropriate measure of the construct of phonological awareness than onset and rime awareness tasks.

In sum, the results of this study suggest that phonological awareness is an important predictor of Chinese reading acquisition, and that different phonological awareness tasks are important predictors of individual differences in reading in grade 2 and in grade 4.

Rapid Naming skills and Chinese Reading Acquisition

Three important findings regarding rapid naming emerged from the present study. First, rapid naming is an important predictor of Chinese reading ability, particularly in grade 4. This finding is in agreement with previous studies that have demonstrated that rapid naming predicts character recognition (Chow et al., 2005; Hu & Catts, 1998; McBride-Chang et al., 2003; McBride-Chang & Ho, 2005; Wang, 2005). Second, rapid naming showed higher correlations with phonological awareness tasks than with orthographic processing tasks in grade 2, but the opposite pattern was found in grade 4. Finally, the graphological rapid naming tasks (digits, Zhu-Yin-Fu-Hao, characters) were better predictors of reading than the nongraphological task (colours).

The four rapid naming tasks administered in this study showed high correlations with each other in both grades (*r*s = .41 to .71), suggesting that these tasks mostly tapped on similar aspects of rapid naming skills. In terms of reading, correlation coefficients suggest that in general, the construct of rapid naming showed a stronger association with One-Minute Reading than with Character Recognition. Astonishingly high correlations of .70 between RAN Characters and One-Minute Reading in grade 2 and .71 between

RAN Digits and One-Minute Reading in grade 4 suggest that the cognitive processes underlying rapid naming are strongly related to Chinese word reading fluency.

One may argue that both RAN tasks and One-Minute Reading were timed measures and therefore the strong association between the two could be accredited to the general speed of processing. While general speed of processing may account for some of the shared variance, the high correlations between the three graphological rapid naming measures (digits, Zhu-Yin, Characters) and grade 4 untimed Character Recognition (*rs* = .49 to .55) indicate that the speed component cannot fully explain the contribution of rapid naming to Chinese reading. Moreover, after controlling for age and IQ, rapid naming still accounted for 47% of unique variance of One-Minute Reading in grade 2 and 39% and 54%, respectively, of unique variance of grade 4 Character Recognition and One-Minute Reading. These results provide strong evidence of the complex and important role of rapid naming in predicting Chinese reading development.

Past research has also found that rapid naming predicts Chinese reading. McBride-Chang et al. (2003) reported that rapid naming tasks (digits and pictures) predicted about 6% of unique variance of character recognition in a grade 2 sample from Hong Kong after other reading related tasks (age, speed of processing, vocabulary, and phonological awareness) were statistically controlled. Hu and Catts (1998) reported that picture naming explained an additional 5% of the variance of accurately recognizing characters that were familiar to first graders in Taiwan after the differences in Zhu-Yin-Fu-Hao reading and visual memory were statistically removed. Although the contribution was not significant, rapid naming predicted 7 % of the variance of grade 2 Character Recognition after controlling for age and IQ. In grade 4, an additional regression analysis was conducted to determine how much unique variance RAN Zhu-Yin-Fu-Hao and RAN Characters explained in Character Recognition after controlling for age, IQ, Initial and Final Sound Detection, Non-Character Recognition and Radical Awareness (the significant variables in final model in Table 5). The result showed that RAN Zhu-Yin-Fu-Hao and RAN Character explained an additional 7% of unique variance of grade 4 Character Recognition. The above results indicate that in the present study, the amount of unique variance in Character Recognition accounted for by rapid naming is very similar to what has been reported before.

However, rapid naming was found to be particularly important predictor of word reading fluency in the current study. Rapid naming explained 47% and 54% unique variance, respectively, in grade 2 and grade 4 One-Minute Reading after age and IQ were controlled. The results indicate that rapid naming is a very strong predictor for Chinese word reading fluency. So far, no existing study has provided comparable data of the predictive power of rapid naming to Chinese word reading fluency, and further investigations are certainly warranted by the current results.

The construct of rapid naming assesses the speed with which children name a continuous series of familiar visual stimuli as rapidly as possible (Wolf, Bowers, & Biddle, 2000). The stimuli are highly familiar to children and are generally overlearned; therefore, it is typically assumed that the naming process is automatized (Bowey, 2005). There is so far no consensus among researchers on what rapid naming actually measures; however, processes that are tapped by the graphological rapid naming tasks (digits, Zhu-Yin-Fu-Hao, characters) should involve phonological processing (Bowey, 2005; Wagner & Torgesen, 1987) and orthographic processing (Wolf and Bowers, 1999; Wolf et al., 2000). Wolf and her colleagues argue the common practice of categorizing rapid naming as a subtest of phonological processing is not warranted. They assert that rapid naming incorporates attentional, perceptual, conceptual, memory, lexical, and articulatory processes in addition to phonological processing and therefore should be required as an independent predictor of reading. Wolf and Bower (1999) suggested further that in addition to retrieving and articulating phonological codes, rapid naming tasks require children to identify items by incorporating visual-orthographic information. These intricate processes involved in rapid naming reflect at least some of the behaviours in text reading that are not captured by phonological processing.

In the present study, rapid naming tasks were associated more closely with different reading-related cognitive processes at different points in development. The pattern of correlations reveals that the rapid naming tasks showed stronger association with the phonological awareness tasks in grade 2 whereas in grade 4, rapid naming and orthographic processing tasks were more strongly correlated. The results suggest that rapid naming reflects different aspects of the reading process as reading proficiency increases.

According to the objectives of elementary school curriculum in Chinese language (Ministry of Education, Taiwan, 2006), children in Taiwan are expected to learn about 1,200 characters by grade 3 and 2,700 characters by grade 6. The substantial increase in the number of learned characters when children enter higher grades may lead children to attend more to the orthographic information than to the phonological codes. Two characteristics of Chinese may contribute to the shift of processes: the large number of homophones and the complexity of character structure. When more characters are acquired, the chance of encountering homophones also increases. Hence, if children rely mainly on phonological information, the process of character identification will be inefficient. Secondly, Chinese characters that are taught in higher grades are more complex and visually more confusing than the characters taught in lower grades. To read the script efficiently, children need to pay attention to the even smaller differences and similarities in orthographic representations. Accordingly, grade 2 children who haven't acquired a large number of characters may be inclined to rely on the phonological information to name a continuous array of items. By grade 4, however, attention to orthographic components and awareness of character structure likely become more important for naming items rapidly.

Finally, in the present study, the graphological rapid naming tasks were better predictors of reading than the nongraphological task. In the regression analyses, RAN Characters predicted grade 2 One-Minute Reading (see Table 6) and RAN Digits, RAN Zhu-Yin-Fu-Hao and RAN Characters predicted grade 4 reading measures (see Tables 5 and 7). A consistent pattern of results emerged in the predictive models that RAN Colours did not predict unique variance in Chinese reading when entered together with the graphological tasks. The results are similar to what have been found in alphabetic languages (Bowey, 2005; Wolf, Bally, & Morris, 1986).

In past research in Chinese, rapid naming has been mainly assessed with pictures and digits. So far, no existing studies provide comparable data of RAN tasks that involved Zhu-Yin-Fu-Hao (or Pinyin) symbols or simple Chinese characters. Thus, whether RAN Zhu-Yin-Fu-Hao and RAN Characters are more adequate measures for rapid naming require further investigation.

In summary, the findings in this study suggest that rapid naming is at least as important to Chinese literacy development as it is to acquiring alphabetic reading skills. However, rapid naming likely reflects different underlying processes in grade 2 than it does in grade 4. Moreover, rapid naming tasks that involve graphological stimuli appear to predict Chinese reading performance better than those involving nongraphological stimuli.

Orthographic Processing and Chinese Reading Acquisition

The primary findings of orthographic processing are: first, knowledge of orthographic structure and awareness of semantic radicals predicted Character Recognition in grade 4 but not in grade 2; and second, error analyses indicated a shift from reliance on the sound of characters in grade 2 to the reliance on the meaning of characters in grade 4.

Orthographic processing in the present study was assessed by the knowledge of orthographic structure and the speed of orthographic processing. The results showed that none of the three tasks that assessed the speed of orthographic processing predicted reading performance in grade 2 and grade 4. However, Non-Character Recognition and Radical Awareness, the two tasks that assessed the knowledge of orthographic structure emerge as significant predictors of grade 4 Character Recognition. Non-Character Recognition assess children's knowledge of character configuration; Radical Awareness, on the other hand, tapped children's understanding of semantic cues provided by the semantic radicals. Non-Character Recognition and Radical Awareness correlated moderately with each other (*r*s = .27 to .36), suggesting that these two tasks measured somewhat different skills. Indeed, these two tasks were developed to investigate different orthographic knowledge related to character recognition.

In the present study, Non-Character Recognition and Radical Awareness were highly correlated with and predictive of grade 4 Character Recognition. Although Non-Character Recognition and Radical Awareness both correlated significantly with Character Recognition in grade 2, these correlations were smaller than those observed in grade 4 (significantly smaller in the case of Non-Character Recognition, $r = .28$ & $r = .54$ $p < .05$). The results suggest that knowledge of orthographic structure and the understanding of the function of semantic radicals are important for processing Chinese characters and the significance of these abilities to Chinese character recognition increases as children advance in grades.

In the Non-Character Recognition task, the grade 4 students achieved a higher score than the grade 2 students by correctly identifying rare characters as real characters. Moreover, error analysis indicated that grade 2 students made significantly more errors than expected by failing to reject characters that were orthographically illegal. The present results are in agreement with Ho, Ng, and Ng (2003) and Chan and Nunes's (2001) findings that older children are better in distinguishing legally formed characters from non-characters than younger children. Ho, Ng, and Ng (2003) reported that children's knowledge of character configuration correlated significantly with Chinese reading and that compared to grade 1 and grade 3 children, a higher proportion of grade 5 children identified rare characters and pseudocharacters as real characters. As well, Chan and Nunes (2001) found that 7 to 9 year-old children performed better than 5 and 6 year-old children by identifying more pseudocharacters than non-characters as character-like.

Pseudocharacters in these studies referred to non-existing Chinese characters with semantic and phonetic radicals residing in their legal positions. Thus, children may judge pseudocharacters as real characters if they already possess some knowledge of character structure and positional regularity. Ho et al. and Chan and Nunes concluded that even younger children have acquired some basic knowledge of how characters are formed, but the explicit understanding of the orthographic structure and positional regularities may develop later.

The results of the Radical Awareness task suggest that children in grade 2 were aware of the semantic cues provided by the semantic radicals; however, the knowledge of semantic radicals was better developed in grade 4 children. Ho, Yau, and Au (2003) assessed children's radical awareness and concluded that Hong Kong first graders may have noticed that characters with the same semantic radicals belong to the same category but the ability of relying on semantic radicals for meaning cues is not well-developed until grade 3. Likewise, Chan and Wang (2003) asked children to select a character among pseudocharacters and noncharacters that was the most appropriate for the presented picture. Chan and Wang found that 8- and 9-year-old children identified more pseudocharacters with the correct radicals that signified the meaning of the picture than 5-to 7-year old children did. Similar to Ho, Yau, and Au (2003), Chan and Wang suggested that the detailed and systematic understanding of radical function and internal orthographic structure might develop later in Chinese reading acquisition. These conclusions are supported by the present study.

The error analysis of the responses children gave on the Radical Searching task indicated that the majority of the errors made by grade 2 children were homophone errors, whereas the majority of the errors made by the grade 4 children were semantic errors. The fact that homophone distracters and semantic distracters had different effects on grade 2 and grade 4 participants indicates that when the target radical was presented for only 500ms, different routes may have been utilized to access the lexical information across the two grades. This interesting finding of orthographic processing suggests that grade 2 children tend to sustain the orthographic information by relying on sound while grade 4 participants depend more on meaning.

The dependence on different access routes across age and reading ability groups was partially demonstrated in a recent study that used the Stroop paradigm. Guo et al. (2005) examined the role of phonological activation in semantic access with children and adults of different reading abilities in China. The stimuli involved four colour-name characters, corresponding homophones of each colour name, and control characters that shared no semantic or phonological relation with the colour names. The participants were asked to say the display color of the character and the reaction time was recorded. Geo et al. reported that the grade 3 group and the lower reading ability group showed greater Stroop effects from the homophones than the grade 6 group and the better reading adults. Guo et al. asserted that younger and poor readers relied more on phonological information during the naming process than the older or more skilled readers.

Guo et al. (2005) suggested that in the initial stage of literacy acquisition, phonological information is important for children to access the mental lexicon, but the dominate role of phonology starts to fade and the links between phonology, semantics and orthography gradually develop as children advance in their reading skills. The results of the Radical Searching task support the above notion that the extent of phonology and semantics involved in orthographic processing vary across grade levels; and the number of characters acquired may alter the role that phonology and semantics play in Chinese reading.

To summarize, the non-alphabetic nature of Chinese writing reinforces the need of Chinese readers to attend to radicals for semantic information, and to acquire an understanding of the configuration rules of characters. These abilities are especially important when reading proficiency is advanced.

Predicting Chinese Reading Acquisition

The results of the present study indicate that phonological awareness and rapid naming are the strongest predictors in grade 2 reading, and phonological awareness, rapid naming, and orthographic processing are the strongest predictors in grade 4. In addition, although both phonological awareness and rapid naming predicted reading performance in grade 2 and grade 4, the contribution of the subtests of these two constructs varied across grades and reading tasks.

In grade 2, only Tone Sensitivity predicted significant unique variance in character recognition, and Tone Sensitivity and RAN Characters predicted significant unique variance in Chinese word reading fluency. Based on these findings, being sensitive to tones attached to Chinese syllables may be the most important phonological awareness skill for grade 2 readers. This result certainly indicates that children's understanding of the unique tone feature of Chinese should be examined when phonological awareness skills of young Chinese readers are assessed.

In grade 4, onset and rime awareness tasks, RAN Zhu-Yin-Fu-Hao, RAN Characters, Non-Character Recognition, and Radical Awareness all predicted significant unique variance in character recognition, whereas RAN Digits and RAN Zhu-Yin-Fu-Hao were the only significant predictors of word reading fluency. In predicting grade 4 Character Recognition, Initial Sound Detection, Final Sound Detection, RAN Zhu-Yin-Fu-Hao, RAN Characters, Non-Character Recognition, and Radical Awareness explained an additional 62% of the variance after age and non-verbal IQ were controlled. For grade 4 One-Minute Reading, RAN Digits and RAN Zhu-Yin-Fu-Hao explained an additional 52% of the variance. These results indicate that the final regression models in Tables 5 and 7 for grade 4 Character Recognition and word reading were very powerful. In addition they indicate that reading success at this stage requires cooperation of phonological awareness, rapid naming, and orthographic processing skills. For grade 4 readers, the abilities to detect sound differences, to name a series of orthographic symbols rapidly, to understand the function of semantic radicals, and to understand positional regularity are all necessary for accurate and efficient character recognition and word reading.

Among the different regression models for predicting individual differences in the reading measures, the results for predicting grade 2 Character Recognition appear to be the weakest. The total amount of variance accounted for by control variables and significant predictors in the final model was only 28%, compared to 57%, 59%, and 73% in the other final models. It is possible that there are other important skills that are strongly associated with grade 2 Character Recognition and that were not examined in the present study. For example, Siok and Fletcher (2001) found that Pinyin knowledge predicted strongly grade 2 character recognition and two-character word reading. Siok and Fletcher reported that 25% and 31% of variance, respectively, was accounted for by Pinyin knowledge after age and IQ were controlled. They suggested that the strong predictive power of Pinyin knowledge is not only because Pinyin is an effective and important tool for beginning Chinese readers but also because the frequent usage of Pinyin establishes strong bonds between Chinese reading and Pinyin knowledge. In Siok and Fletcher's study, Pinyin knowledge was assessed by asking children to read Chinese syllables written in Pinyin. Based on Siok and Fletcher's findings, it is possible that if Zhu-Yin-Fu-Hao knowledge would have been examined in the present study, it may have accounted for a significant amount of grade 2 Character Recognition variance.

In sum, the major difference in predicting character recognition across the grades involves the skill of orthographic processing, whereas the only difference in terms of predicting word reading fluency was in the role of Tone Sensitivity. It is possible that, developmentally, orthographic processing influences Chinese character recognition accuracy later than phonological awareness and rapid naming. For grade 2 children, with a limited number of characters acquired, there may be less pressure to attend to and to make use of orthographic information. However, as the number of characters learned accumulates rapidly, Chinese readers are forced to attend to the orthographic information provided by characters to ensure reading success. Thus, in the present study, the skill of orthographic processing began to manifest its effects in grade 4 reading.

The Developmental Differences Between Grades

The results of correlation and regression analyses show that the strongest correlates of grade 2 reading variables were phonological awareness and rapid naming, whereas for grade 4, phonological awareness, rapid naming, and orthographic processing all correlated significantly with reading variables. Notably, Figure Memory significantly correlated with Chinese character recognition and predicted character reading across grades after age and IQ were statistically controlled.

The pattern of differences between grades is in partial agreement with the work of Siok and Fletcher (2001) regarding the developmental trend in Chinese reading. Siok and Fletcher reported that visual skills predict reading in the lower grades (grade 1 and grade 2) and that orthographic and phonological skills predict reading in the higher grades (grade 2, grade 3 and grade 5). Unfortunately, rapid naming speed was not assessed in their study. Siok and Fletcher concluded that the developmental stages of Chinese reading acquisition are similar to that of alphabetic scripts (Ehri, 1996).

In the present study, however, visual skills contributed to both grade 2 and grade 4 character reading suggesting that the importance of visual processing, as measured by the Figure Memory task, may stay relatively constant. It is generally believed that reading Chinese requires some kind of visual skills owing to the complexity of the character configuration (McBride-Chang & Kail, 2002; McBride-Chang, Chow et al., 2005). Figure Memory, a test that requires children to identify a visually presented geometric figure embedded in a more complex geometric pattern, involves processing of wholes to parts and recognition of the initially presented simpler figure among these parts. The positive association of Figure Memory with character recognition suggests that the processes required by Figure Memory and character recognition are at least partially overlapping. It is well documented in previous studies that Chinese readers use an analytical approach that parses characters into functional orthographic units to gain faster access to sound and meaning (e.g., Chan & Wang, 2003; Feldman & Siok, 1999a; Leck, Weekes, & Chen, 1995). In other words, these functional orthographic units are coded as patterns during the process of character recognition. Therefore, the significant association of Figure Memory with character reading would be expected as both tasks involve recognizing parts of the wholes. Yet, the findings regarding visual skills in Chinese reading are inconsistent. Some studies have reported positive associations between visual skills and Chinese reading (Ho & Bryant, 1999; Huang & Hanley 1995; Siok & Fletcher, 2001), while other studies did not find an association (Hu & Catts, 1998; Lu, 2003). Therefore, further investigation of the role of visual skills in Chinese reading acquisition is required.

Moreover, present results suggest that in the development of phonological awareness in Chinese, the skill of attending to differences in tones is more prominent in grade 2, whereas the skill of analyzing onsets and rimes is more important in grade 4. In alphabetic languages, children's performance in phonological awareness tasks depends on the complexity of the sound units involved. Researchers believe that young children start to develop awareness of bigger sound segments and progress to smaller ones later (Adams, 1990; Treiman & Zukowski, 1996; Torgesen & Mathes, 2000). For example, Adams (1990, p. 296) stated, "their [children's] awareness of spoken phonemes, syllables, and words are consistent with the evidence that each is more difficult and attained later in development than the next." In Chinese, the syllable usually consists of two segmental units, initial sounds (onsets) and final sounds (rimes), and one suprasegmental unit, the tone. Specifically, in Zhu-Yin-Fu-Hao system, there are 21 initial sound symbols, 16 final sound symbols, and 4 tone symbols. If taking the number of each component into account, the 4 tones should be encountered more frequently than any other sound segments during reading, speaking, and listening. Also, notably, there are no Chinese syllables that can be pronounced without a tone. Therefore, with the non-dissectible feature and the small number of tones, it is not surprising that the skill of detecting tones develops fairly early.

Finally, the distinct role of orthographic processing in grade 4 indicates that in the later stage of reading development, Chinese readers apply other strategies to facilitate fluent reading. Recall the fact that a limited number of syllables (about 400) are used on 4,000 regularly used characters (or morphemes). Due to the large number of homophones in Chinese, readers frequently encounter situations where a familiar syllable maps on a large number of distinct graphic units in Chinese. Therefore, skilled Chinese readers need to be able to utilize orthographic properties of the characters to avoid the ambiguity of phonology (Shen & Bear, 2000). Accordingly, the ability to read Chinese script by applying an analytical approach that parses characters into functional units will be more important for skilled readers who have already learned a large number of characters (Chan & Wang, 2003; Feldman & Siok, 1999a; Leck et al., 1995).

In conclusion, the present results suggest that phonological awareness, rapid naming and visual skills are important in Chinese reading acquisition across grades, whereas orthographic processing is more important for grade 4 readers who are in the later stage of reading development.

Implications for Educational Practice

The findings of the present study have several possible implications for Chinese reading instruction and for identifying children who are at-risk for reading difficulties.

First of all, this study lends support for classroom instruction on the sound segments of Chinese syllables and orthographic components. Phonological awareness emerged as a good predictor of reading abilities, indicating that being sensitive to sounds may facilitate reading acquisition in Chinese. In Taiwan, the only formal instruction in sounds takes place during the first few weeks of Zhu-Yin-Fu-Hao lessons. After that, instruction in character recognition mainly focuses on understanding the meaning of characters, forming characters into multi-character words, and the correct writing of characters (Ministry of Education, Taiwan, 2006). Thus, sounds and Zhu-Yin-Fu-Hao symbols that represent them mainly serve as an auxiliary tool during character learning. While the traditional method of teaching Chinese does result in learning, it would be worth examining whether increasing the instruction of sounds would make character learning more effective.

Similarly, knowledge of orthographic structure and semantic radicals appeared to be very important for grade 4 children in the present study. These two aspects of orthographic knowledge are seldom taught explicitly in Chinese classes (Ho, Ng, & Ng, 2003; Tsai & Nunes, 2003). As the number of characters learned increases, children eventually develop an implicit understanding of character configuration and the role of semantic radicals. However, instead of having children figure out the orthographic information themselves, direct instruction on the rules of character formation and the function of semantic radicals in Chinese would likely be beneficial for children.

Identifying precursors of reading difficulties is an important goal for reading research for the purpose of prevention and early remediation. In the current study, tone sensitivity and rapid naming predicted significantly grade 2 reading variance, suggesting that these two skills may be good early indicators for initial screening of reading difficulties. These two constructs are neither difficult nor time-consuming to assess, making them valuable tools for distinguishing children who are having trouble in reading from those who are not.

Limitations of the Current Study

This study had several limitations that should be kept in mind when generalizing the findings. First, the results of this study are restricted for the developmental span and population examined, and therefore the findings may not apply to other grades or to Chinese speaking children in other parts of the world whose reading instruction is different from that of Taiwanese children in this sample.

Second, there are other skills that may be related to character recognition in grades 2 and 4 that were not examined in the present study. For example, recent research has demonstrated the importance of morphological awareness in Chinese reading (e.g., McBride-Chang et al., 2003; McBride-Chang et al., 2005). The limited amount of variance predicted in grade 2 character recognition could be the result of not including measures of morphological awareness.

Third, the grade 2 sample may not have been as representative of the sampling population as the grade 4 sample. During the sampling procedure, almost every (54 out of 59) grade 4 student approached was given permission to participate whereas only about two-thirds (63 out of 96) of grade 2 students approached were given permission to participate. The possibility that the grade 2 sample was from the higher end of the population was indicated by their superior performance on the Character Recognition and the Matrices tests.

Fourth, sound isolation tasks used in the present study were too easy for the participants. The ceiling effects on the two tasks in grade 2 and grade 4 indicate that these tasks were not effective for assessing children's phonological awareness skills. More appropriate sound isolation tasks need to be developed in future studies.

Fifth, categorization of Figure Memory as a short-term memory measure may be misguided. Word Series, a phonological short-term memory task, and Figure Memory were initially selected to assess short-term memory in this study because both phonological memory (Hu & Catts, 1998) and visual memory (Siok & Fletcher, 2001) appear to be associated with Chinese character recognition. However, the results of the present study showed that the correlations between the Word Series and Figure Memory were low in both grade 2 and grade 4 (*r*s = .13 and .07, respectively). Therefore, it is evident that these two tasks actually tapped on quite distinct primary cognitive processes. Word Series is a test that requires children to repeat auditory stimuli in the presented order. Therefore, it seems clear that Word Series primarily assesses verbal short-term memory skills. On the other hand, Figure Memory requires children to form a mental representation of an abstract figure presented briefly and then recognize that figure within a larger, more complex figure. While Figure Memory certainly requires some memory skills, the low correlation between Figure Memory and Word Series suggests that either the required memory skills are very different in the two tasks, or that memory skills may not be the primary process that is assessed by Figure Memory.

Sixth, reading abilities in the present study focused on character reading and word reading. Reading comprehension at sentence or paragraph level was not assessed. While studies in alphabetic languages indicate that word reading is highly predictive of general reading comprehension (e.g., Parrila et al., 2004), future studies should include reading comprehension measures to examine the full range of reading proficiency.

Finally, this is a cross-sectional and correlational study; therefore, we cannot establish casual associations between the dependent and independent variables.

Future Directions

The results of this study suggest several directions for future research. First, tone sensitivity emerged as a strong predictor for grade 2 reading, indicating that it could be an appropriate measure of phonological awareness for beginning readers. The scarcity of data regarding tone sensitivity makes any conclusions based on the current data tentative. However, it seems clear that when phonological awareness is assessed in future studies, tone sensitivity should be included. In addition, more tone sensitivity tasks should be developed to allow more reliable assessment of this skill.

Second, rapid naming skills were strong predictors of Chinese reading in grade 2 and grade 4 in this study, clearly indicating the significance of these skills in Chinese literacy development. In addition, rapid naming tasks correlated stronger with phonological awareness measures in grade 2 and with orthographic processing measures in grade 4. Similarly, more empirical data on rapid naming is needed before we know how generalizable the present results are and what implications they have for educational practice.

Finally, investigations of morphological awareness and Zhu-Yin-Fu-Hao (or Pinyin) knowledge should be pursued in future studies, together with phonological awareness, rapid naming, and orthographic processing. The weak predictive model of reading measures in grade 2 indicates the need for including other reading-related cognitive processes in the study. Based on previous research, morphological awareness and Zhu-Yin-Fu-Hao/Pinyin knowledge may explain additional variance in reading acquisition. Moreover, reading comprehension should be tested when reading abilities are assessed.

Conclusion

The results of the present study indicate that phonological awareness is important for Chinese reading acquisition. Specifically, tone sensitivity played an important role for grade 2 Chinese readers, whereas onset and rime awareness was more important for grade 4 children. These findings are, in general, similar to previous studies suggesting that phonological awareness skills are associated with Chinese character recognition (Ho, 1997; Ho & Bryant, 1997a, 1997b; Ho et al., 1999; Huang & Hanley, 1997; Hu & Catts, 1998; Siok & Fletcher, 2001; So & Siegel, 1997; Wang, 2005), but differ from the previous studies with regards to the importance of tone sensitivity.

The present finding that rapid naming predicts Chinese reading is in agreement with previous studies (Chow et al., 2005; Hu & Catts, 1998; McBride-Chang et al., 2003; McBride-Chang & Ho, 2005; Tan et al., 2005; Wang, 2005) that have examined character recognition. However, the present study also found that the rapid naming tasks are much more important predictors of word reading fluency than of character recognition, something that the previous studies did not examine. In terms of the relationship between rapid naming and other reading-related cognitive processes, the present results indicated that the rapid naming tasks have stronger correlations with phonological awareness skills in grade 2 and with orthographic processing skills in grade 4. This implies that the underlying processes reflected by rapid naming changed as reading proficiency progressed.

Finally, the present study showed that orthographic processing skills were more important for grade 4 readers than for grade 2 readers. Knowledge of orthographic structure and awareness of semantic radicals were significant predictors of grade 4 Character Recognition but not of grade 2 Character Recognition. These findings support previous studies that have suggested that the significance of orthographic processing to Chinese character recognition increases as children advance in grades (Chan & Nunes, 2001; Chan & Wang, 2003; Ho, Ng, & Ng, 2003).

In conclusion, phonological awareness, rapid naming, and orthographic processing skills are important for Chinese reading acquisition. These skills may manifest differently in reading in different grade levels; however, at some point they all are significantly associated with reading acquisition of Chinese children.

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