Chinese children’s character recognition: Visuo-orthographic, phonological processing and morphological skills

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Tasks tapping visual skills, orthographic knowledge, phonological awareness, speeded naming, morphological awareness and Chinese character recognition were administered to 184 kindergarteners and 273 primary school students from Beijing. Regression analyses indicated that only syllable deletion, morphological construction and speeded number naming were unique correlates of Chinese character recognition in kindergarteners. Among primary school children, the independent correlates of character recognition were rime detection, homophone judgement, morpheme production, orthographic knowledge and speeded number naming. Results underscore the importance of some dimensions of both phonological processing and morphological awareness for both very early and intermediate Chinese reading acquisition. Although significantly correlated with character recognition in younger (but not older) children, visual skills were not uniquely associated with Chinese character reading at any grade level. However, orthographic skills were strongly associated with reading in primary school but not kindergarten, suggesting that orthographic skills are more important for literacy development as reading experience increases.
What are the unique metalinguistic and cognitive correlates of word reading in Chinese children’s developing word reading skills? In the present study, we tried to answer this question by testing core skills in relation to Chinese character recognition for Mainland (Beijing) Chinese children in kindergarten and early primary school. The correlates included measures of visual skills, orthographic knowledge, phonological awareness, speeded naming and morphological awareness, all of which have been examined in some previous studies of Chinese reading acquisition (Ho & Bryant, 1997; Huang & Hanley, 1995, 1997; McBride-Chang, Chow, Zhong, Burgess & Hayward, 2005; McBride-Chang & Ho, 2000; McBride-Chang, Shu, Zhou, Wat & Wagner, 2003; Shu, McBride-Chang, Wu & Liu, 2006; Shu, Peng & McBride-Chang, 2008; Tong, McBride-Chang, Shu & Wong, 2009). The present study included perhaps the most comprehensive battery of cognitive skills in relation to Chinese children’s early reading development thus far. This focus, in a large sample, was intended to distinguish the apparently more and less central cognitive skills associated with reading development in Chinese.

Moreover, the study focused on Mainland Chinese children, whose development of reading-related skills may differ from those in other Chinese societies, that is, Hong Kong and Taiwan, in ways relevant to this comprehensive battery. To begin with, Chinese children from Beijing tend to demonstrate reduced phonological sensitivity relative to Cantonese speakers (e.g. Chen et al., 2004) in certain aspects, perhaps influencing the associations of phonological awareness to word reading with age. Moreover, their use of Pinyin to learn to read likely also influences their sensitivity to phonological skills (e.g. Shu et al., 2008). Finally, although children in Hong Kong and Taiwan use traditional script, Mainland Chinese children use a simplified script to read. This script use may sensitise them to heightened visual skills relative to those reading traditional script very early (e.g. McBride-Chang, Chow et al., 2005). Moreover, because simplified script may affect print learning in a variety of ways (e.g. Chen & Yuen, 1991), the role of orthographic processing in relation to learning to read words is important to explore. Although the present study focused on the core constructs important for learning to read across orthographies (e.g. Seidenberg & McClelland, 1989), it is important to consider cognitive skills contributing to reading development both within a given Chinese society, as outlined above, and also in relation to Chinese literacy development overall.

Chinese is a language used by the largest population in the world, and it is believed to be the oldest extant writing system, having appeared 3,200 years ago. There are important linguistic differences between Chinese and European languages that are directly relevant to understanding the acquisition of literacy in Chinese. Chinese is a morphosyllabic writing system, where the basic graphic unit, the Chinese character, represents a morpheme as well as a syllable, and characters can be segmented using orthographic, morphological and syllabic information (Shu & Anderson, 1997). Compared with alphabetic languages, which use a relatively limited number of symbols (typically 22–30 or so letters of the alphabet) to produce all of the words in the language, learning to read Chinese presents a much greater challenge, with full literacy in Chinese requiring knowledge of between 3,000 and 4,000 different characters. Given these overarching differences between Chinese and alphabetic scripts, we turn now to different cognitive skills that might be useful for understanding reading development in Chinese. These include visual skills, orthographic knowledge, phonological awareness, speeded naming and morphological awareness.
Visual skills

Chinese writing is perhaps best known for its visual complexity. Indeed, Chinese characters contain much more visual information than do English words (e.g. Chen & Kao, 2002). In particular, in contrast to the linear structure of English where word length is a visual cue, the space a character occupies is constant and each character is a salient perceptual unit that differs from thousands of others in terms of individual strokes and the overall spatial configuration. As a result, it is reasonable to assume that visual skills, defined here as the ability to process two-dimensional visual representations such as shapes, dots, lines, etc., visually, play a role in Chinese reading acquisition, at least among early readers. Our definition of visual skills encompasses both visual discrimination and visual memory ability, and ideally, such skills should be culture-free. Such skills are distinguished here from orthographic skills, which imply some knowledge of a given script. Prominent and distinct visual cues seem to be a hallmark of Chinese, particularly for beginning readers or those with no knowledge of Chinese. However, evidence for the importance of visual skills for Chinese character recognition is mixed. Some have argued that visual skills are essential for early learning of Chinese because of its complexity (McBride-Chang, Chow et al., 2005). For example, Huang and Hanley (1995) found that visual skills predicted Chinese reading ability among Hong Kong and Taiwanese children, and Ho and Bryant (1999) found evidence for visual skills being associated with Chinese character reading in Hong Kong. Visual perceptual and visual memory skills also distinguished a subset of children with and without developmental dyslexia in Chinese (Ho, Chan, Lee, Tsang & Luan, 2004), suggesting that they may be important for certain aspects of Chinese reading acquisition. Note that across all of these studies reviewed, visual skills were examined in relation to children learning to read the traditional script. Traditional Chinese characters contain more visual features (or strokes) than simplified characters, and not all orthographic information originally contained in traditional characters is found in their simplified versions (e.g. McBride-Chang, Chow et al., 2005). Indeed, one rather simplistic conclusion one might make based on existing data is that, because of this difference in visual features, simplified characters are easier to learn to write but more difficult to learn to read because the visual features of such characters are relatively few, making them difficult to distinguish in print.

Variability in visual skills is crucial in recognising an association between visual skills and word reading. One goal of the present study was to determine the extent to which visual skills distinguish children by age in order to chart the development of visual skills in Chinese children in early kindergarten through third grade. Variability is also important for examining associations of visual skills, in comparison to other metacognitive skills, for word reading. For example, in one study focused on phonological awareness, speeded naming and visual skills, visual skills failed to distinguish across readers once other reading-related abilities were included as predictors of early Chinese word reading (e.g. McBride-Chang, Chow, et al., 2005). However, that study focused only on kindergarten children with limited word reading ability, and, to our knowledge, no other such studies have examined this issue. In the present study, we examined the associations of two tasks of visual processing, visual memory and visual spatial relations, to Chinese character reading across ages, with a variety of other cognitive skills included.
Orthographic knowledge

Beyond basic visual complexity, a much less controversial aspect of learning to read Chinese is the fact that characters have internal structures that are fairly predictable. About 82% of modern Chinese characters are compound characters that can be segmented into subcharacter components based on orthographic rules. Written Chinese contains about 190 semantic radicals, which carry information about meaning, and 1,100 phonetic radicals, which provide information about pronunciation. They may be further divided into about 648 subcomponents (e.g. ⤧, ⤨). Thousands of compound characters are formed from combinations of these components or subcomponents (Fu, 1989). Semantic and phonetic radicals are the two basic components of compound characters. Some semantic or phonetic radicals consistently appear in the same position within characters, whereas other radicals may appear in two or more positions. For example, the radical ⤧ always appears on the left side of characters, while the radical ⤨ appears only on the right. If the radicals within a Chinese character are in their legal positions, that character may be conceptualised either as a real character or as a pseudo-character. However, if the radicals are in illegal positions or components or subcomponents are not real components in Chinese, the result is a noncharacter. The internal structures and positions of components within characters are important for recognition of Chinese characters (Shu, Chen, Anderson, Wu & Xuan, 2003). However, the complex rules of positional and functional regularities are seldom taught in schools or addressed in textbooks explicitly. It normally takes Chinese children considerable effort and several years of education to acquire comprehensive orthographic knowledge, the insight of inter-structure knowledge of characters, in Chinese (Cheng & Huang, 1995; Ho et al., 2004).

Research conducted with English-speaking children demonstrates that orthographic knowledge, conceptualised as children’s ability to detect acceptable and unacceptable letter sequences and also their relations to letter positions in words, facilitates reading acquisition in English (e.g. Cassar & Treiman, 1997). Similarly, a few studies of reading development in Chinese also showed that children’s understanding of the conventions used in the Chinese writing system was important in learning to read Chinese characters (e.g. Huang & Hanley, 1995; Li, Fu & Lin, 2000). Orthographic awareness has been reported to be important for Chinese character reading and writing acquisition (Li, Peng & Shu, 2006; Peng & Li, 1995; Shu & Anderson, 1998) and impairment (e.g. Ho et al., 2004). However, the extent to which orthographic skills are uniquely associated with Chinese character reading development even when other metalinguistic skills are also taken into account remains unclear. Thus, in the present study, we examined orthographic skill in relation to other linguistic abilities, including phonological awareness and morphological awareness, to get a comprehensive picture of the relative importance of orthographic awareness for early Chinese reading.

Phonological awareness

Several studies have demonstrated a strong link between phonological awareness and character recognition in Chinese children (Ho & Bryant, 1997; Hu & Catts, 1998; Huang & Hanley, 1997; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002; Shu et al., 2008; Siok & Fletcher, 2001). However, different languages in the world differ in terms of subsyllabic unit preference (Wang & Cheng, 2008), and the ways in which
phonological awareness has been measured in children has varied across studies and ages. For most alphabetic scripts such as English, tasks of phonemic awareness, used to measure children’s ability to distinguish the phonemes in spoken language, tend to yield the largest variability across readers and are most highly associated with word reading (e.g. Høien, Lundberg, Stanovich & Bjaalid, 1995; Hulme et al., 2002). In contrast to English, Chinese has a relatively simple syllable structure. All syllables can be divided into an onset, which is always a single phoneme, and a rime, while consonant clusters are rare. Interestingly, some research conducted with preschool Chinese children has suggested that phonological awareness at the level of the syllable, but not phoneme onset awareness, is particularly related to early Chinese reading (Chow, McBride-Chang & Burgess, 2005; McBride-Chang, Bialystok, Chong & Li, 2004; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002). However, other studies of Chinese children in preschool and primary school have most commonly measured rime awareness (e.g. Ho & Bryant, 1997; Hu & Catts, 1998; Siok & Fletcher, 2001; So & Siegel, 1997) as a core of phonological sensitivity. A recent study exploring the nature of phonological awareness in Chinese showed that syllable and rime awareness increased gradually and steadily across preschool years without instruction while phoneme awareness did not (Shu et al., 2008). Different levels of phonological awareness may develop at varying rates and explain reading ability in Chinese differently with age.

Different results across studies may be accounted for by differences in instruction. In Mainland China, kindergarten represents an institution that is independent from primary school. Almost all children attend kindergartens for 3 years, roughly from ages 3 to 6 years. The majority of kindergartens do not teach children to read Chinese. In primary school, children learn Pinyin in the first 8 weeks of school and then pair this script with characters that are linked to orthographic units. Pinyin is a phonological coding system that roughly corresponds in appearance to the Western alphabet. It represents single phonemes as in alphabetic scripts, but it is taught in a syllabic way, divided into onset and rime. Following initial instruction, Pinyin is written above characters during reading for young children. Thus, beginning in primary school, children tend to be familiar with how to represent phonemes in Chinese despite the fact that these phonemes are not represented in actual Chinese text.

Several studies have shown that awareness of phonemes increases rapidly when children receive Pinyin instruction (Shu et al., 2008). Moreover, children who have had experiences with Pinyin outperform their counterparts who have not received instruction in Pinyin, on onset and coda analyses (Cheung, Chen, Lai, Wong & Hills, 2001). Shu et al. (2006) found that phonemic awareness was particularly important in explaining reading impairment among fifth- and sixth-grade Beijing students, perhaps because phoneme size unit representation is important for older readers for learning new characters.

In the present study, we included three tasks of phonological awareness representing different grain size units (Ziegler & Goswami, 2005). A task of syllable awareness, which directly conforms to the speech unit represented by a given Chinese character, was administered. This task has been demonstrated to have strong associations with Chinese character recognition in several studies (Chow et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002); therefore, we expected that it would be linked to Chinese reading. However, by the time children reach primary school, their performance on tasks of syllable awareness tends to reach ceiling (Shu et al., 2008; Treiman & Zukowski, 1991), and hence, we did not include this particular task for the older children.
The second measure of phonological awareness administered to all children was rime awareness, an important aspect of phonological awareness in Chinese children and adults because of the traditional organisation of dictionaries into onsets and rimes (Siok & Fletcher, 2001). Our rime measures tapped basic sensitivity to the rime unit and also sensitivity to the lexical tone, the pitch contour for a syllable that can distinguish lexical meaning, another important component of phonological sensitivity in Chinese children (e.g. Chen et al., 2004; Fu & Huang, 2000; Leong, Cheng & Tan, 2005; Siok & Fletcher, 2001; So & Siegel, 1997).

Third, we tapped phoneme awareness given the previous findings from Shu et al. (2006) that it distinguished disabled from nondisabled readers in older children. In previous work (e.g. Shu et al., 2008), this task was too difficult for younger children, and so it was included only for this older age group. Thus, every child was given two phonological tasks: one a receptive task (rime detection task) and the other a production task (syllable deletion task or phoneme deletion task). One goal of the present study was to examine the extent to which these different dimensions of phonological awareness might be variously associated with Chinese character recognition in children with and without instruction.

**Speeded naming**

Another construct included in the present study was speeded naming. There is increasing evidence for the importance of naming speed (known as rapid automatised naming [RAN]) in reading acquisition and for its causal role in reading disability in alphabetic languages (e.g. Wimmer, Mayringer & Landerl, 2000; Wolf et al., 2002). A substantial body of evidence has established that RAN is related to Chinese reading acquisition and reading impairment (e.g. Chow et al., 2005; Ho & Lai, 1999; Hu & Catts, 1998; Shu, Meng & Lai, 2003; Tong et al., 2009). The existing interpretations of the relationship between RAN and reading in Chinese have focused on the speed of lexical access. Because the orthography-to-phonology mapping is more arbitrary in Chinese than it is in alphabetic languages, it is reasonable to conjecture that the relationship between RAN and reading performance should be particularly strong in Chinese reading. However, whether the RAN–reading relationship follows the same developmental pattern in Chinese as that observed in English, in which RAN is often strongly associated with word reading across ages, is not clear. In the present study, we examined the unique associations of this measure to Chinese character recognition across kindergarteners and primary school children with other reading-related measures statistically controlled. This measure was identical across all participants.

**Morphological awareness**

The final broad construct included in the present study was morphological awareness, including sensitivity to homophones/homographs and lexical compounding. Both of these appear to be particularly salient in Chinese (e.g. Li, Anderson, Nagy & Zhang, 2002; McBride-Chang et al., 2003; Shu & Anderson, 1997, 1998; Shu et al., 2006). Versions of tasks tapping these constructs have been found to be associated with children’s Chinese character recognition (e.g. McBride-Chang et al., 2003; McBride-Chang, Cho et al., 2005; Shu et al., 2006) in previous studies. In the present study, all children were asked to
determine whether homophones/homographs had the same meaning in different words. Because the items were orally administered, homophones and homographs were not distinguished in this task. An example of this problem in English might be as follows: is the be in because the same as the bee in beehive? Children simply answered yes or no for each item in this task.

To look more in depth at morphological awareness, for younger children only, a measure of lexical compounding skill was also administered. This task tends to be relatively easy for older children, for whom a different task was designed. For older children only, another morphological awareness task involved generating words that contained the targeted morpheme (e.g. given the target morpheme of pain, one answer might be painful) as well as those that contained a morpheme pronounced the same as but with a different meaning from the target (e.g. given the morpheme pain, one answer might be windowpane).

Summary

In the present study, we were particularly interested in establishing the strengths of associations of each of these different constructs to Chinese word recognition with grade level in children. Although there are few data on the developmental trajectories of each construct to character recognition, we generated some basic hypotheses regarding age differences based on previous studies.

In particular, we anticipated that visual skills should be more strongly related to early Chinese character recognition and that orthographic skills should be more strongly associated with later Chinese character recognition. The majority of studies that have found a link between visual skills and Chinese reading acquisition have focused on beginning readers (Ho & Bryant, 1999; McBride-Chang, Chow et al., 2005). In terms of overall development, it seems reasonable to expect that very young children likely learn to identify some characters based on salient features of their shapes, similar to observations of how English-speaking children first learn to recognise some printed words (Ehri & Wilce, 1985). However, with experience, orthographic knowledge likely supersedes any visual skills so that older children are unlikely to rely on pure visual strategies for word recognition. From a developmental perspective, orthographic knowledge develops gradually and becomes more refined and comprehensive with reading experience. Therefore, older children were hypothesised to rely less on visual strategies but more on orthographic knowledge for character recognition relative to their younger counterparts in the present study.

Correspondingly, we hypothesised that phonological awareness would be relatively more important for early Chinese reading acquisition and less strongly associated with reading in primary school children. Although phonological skills have been linked to Chinese character recognition fairly consistently as reviewed above, compared with any other orthography, Chinese characters have relatively few reliable phonological cues (e.g. Shu, Chen et al., 2003). Thus, the importance of phonological awareness for reading Chinese is likely to diminish as other strategies that are more analytic and reliable, such as making reference to morphological cues from language or orthographic strategies learned in literacy acquisition, mature.

We were less clear about development in relation to RAN and morphological awareness for Chinese character recognition. Aspects of morphological awareness have been demonstrated to be associated with reading across varied grade levels in Chinese
(e.g. Shu et al., 2006). Naming speed has been similarly associated with word recognition in Chinese. Thus, we anticipated those two skills should be significantly correlated with Chinese character recognition but did not make explicit predictions about these changes in relation to age in the present study.

To summarise, relatively few studies have included a comprehensive battery of constructs of metalinguistic and cognitive skills together as correlates of word reading in Chinese. Moreover, even fewer studies have done so over a relatively wide range of ages and grade levels. The present study had two broad aims: (1) to investigate visuo-orthographic, phonological processing and morphological skills as unique correlates of character recognition in Chinese-speaking children from Beijing; and (2) to explore whether such correlates are different for children prior to, and following the onset of, formal reading instruction.

Method

Participants

Four hundred and fifty-seven Chinese children from Beijing participated in the present study. These included 184 children from two kindergartens and 273 children from three primary schools. Because age information was missing for 87 children (2 second-year kindergarten [K2] children, 43 first graders, 17 second graders and 25 third graders), means of ages were calculated only for the remaining 370 children. There were 85 K2 (second year of kindergarten) and 99 K3 (third year of kindergarten) children. Their mean ages were 4.84 years ($SD = .33$) and 5.76 years ($SD = .33$), respectively. In Grade 1, there were 97 students with a mean age of 6.91 years ($SD = .48$). The Grade 2 sample consisted of 87 children with a mean age of 7.94 years ($SD = .32$). Finally, there were 89 Grade 3 students, with a mean age of 8.90 years ($SD = .49$). More information on these children by gender and age is presented in Table 1. All of the children were native Mandarin speakers.

Measures

Chinese character recognition task. As no standardised Chinese character reading test is available in Mainland China, a task was constructed for the present study and consisted of 150 single characters. The first 40 items were taken from a Chinese character recognition list for kindergarten, which has been used successfully (Shu et al., 2008). These characters were judged by two kindergarten teachers to be orally familiar to the kindergarteners and are formally introduced in Grade 1. The other 110 characters were judged by two primary school teachers to be orally familiar to primary school children. One hundred of the characters were taken from Chinese language textbooks; there were 20 items from each grade level from Grades 2 to 6 (Shu, Chen et al., 2003). The last 10 characters had not been introduced in textbooks. We included 150 characters in different levels to make this task sufficiently broad so that all children could be given the same list. All characters were listed in order of increasing difficulty level based on the results of a pilot study, which included five kindergarten and 27 children in Grades 1–3. Children were asked to read from the beginning and stopped when they failed to read 15 consecutive items.

Visual skills. The Visual–Spatial Relationships and Visual Memory subtests from Gardner’s (1996) Test of Visual–Perceptual Skills (nonmotor) Revised were administered
Table 1. Means, standard deviations and ranges of all measures for K2, K3, Grade 1, Grade 2 and Grade 3.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Reliability</th>
<th>K2 (43M, 42F)</th>
<th>K3 (51M, 48F)</th>
<th>Grade 1 (49M, 48F)</th>
<th>Grade 2 (57M, 30F)</th>
<th>Grade 3 (48M, 41F)</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (SD) (Range)</td>
<td>Mean (SD) (Range)</td>
<td>Mean (SD) (Range)</td>
<td>Mean (SD) (Range)</td>
<td>Mean (SD) (Range)</td>
<td></td>
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<tr>
<td>Agea</td>
<td>.99</td>
<td>4.84 (0.33) (4.17–6.01)</td>
<td>5.76 (0.33) (4.92–6.42)</td>
<td>6.91 (0.48) (5.92–8.17)</td>
<td>7.94 (0.32) (7.33–8.67)</td>
<td>8.90 (0.49) (8.08–10.92)</td>
<td>1,359.38***</td>
</tr>
<tr>
<td>Character Recognition (150)</td>
<td>.85</td>
<td>13.45 (17.64) (0–90)</td>
<td>17.82 (18.01) (2–16)</td>
<td>42.99 (15.77) (16–101)</td>
<td>71.26 (15.29) (47–113)</td>
<td>93.63 (19.56) (50–139)</td>
<td>(K2 &lt; K3 &lt; G1 &lt; G2 &lt; G3)</td>
</tr>
<tr>
<td>Visual Memory (16)</td>
<td>.96</td>
<td>7.93 (2.82) (6–30)</td>
<td>10.29 (2.21) (5–14)</td>
<td>10.52 (2.61) (5–15)</td>
<td>10.89 (2.71) (5–15)</td>
<td>11.03 (2.87) (5–15)</td>
<td>(K2 &lt; K3 = G1 = G2 = G3)</td>
</tr>
<tr>
<td>Orthographic Judgement (40)</td>
<td>.70</td>
<td>12.49 (5.05) (6–14)</td>
<td>11.99 (4.41) (4–14)</td>
<td>23.23 (9.72) (4–14)</td>
<td>30.66 (6.49) (4–14)</td>
<td>33.42 (4.61) (4–14)</td>
<td>217.70***</td>
</tr>
<tr>
<td>Rime Detection (16)</td>
<td>.70</td>
<td>10.11 (2.44) (4–14)</td>
<td>10.60 (2.13) (5–16)</td>
<td>12.72 (2.50) (6–16)</td>
<td>13.87 (2.27) (7–16)</td>
<td>14.70 (1.68) (8–16)</td>
<td>(K2 = K3 &lt; G1 &lt; G2 &lt; G3)</td>
</tr>
<tr>
<td>Syllable Deletion (20)</td>
<td>.89</td>
<td>10.96 (4.93) (0–19)</td>
<td>14.84 (3.73) (5–20)</td>
<td>–                   (–)</td>
<td>–                   (–)</td>
<td>–                   (–)</td>
<td>36.71***</td>
</tr>
<tr>
<td>Phoneme Deletion (18)</td>
<td>.86</td>
<td>–               (–)</td>
<td>9.37 (4.73) (0–18)</td>
<td>12.05 (4.21) (2–18)</td>
<td>14.37 (2.68) (5–18)</td>
<td>36.51***</td>
<td></td>
</tr>
<tr>
<td>Homophone Judgement (16)</td>
<td>.84</td>
<td>9.76 (4.36) (0–16)</td>
<td>10.66 (3.96) (1–16)</td>
<td>11.80 (3.01) (1–16)</td>
<td>13.24 (2.31) (4–16)</td>
<td>14.46 (1.80) (8–16)</td>
<td>(K2 &lt; K3 &lt; G1 &lt; G2 &lt; G3)</td>
</tr>
<tr>
<td>Morphological Construction (18)</td>
<td>.70</td>
<td>10.26 (3.05) (0–18)</td>
<td>11.22 (2.72) (3–18)</td>
<td>–                   (–)</td>
<td>–                   (–)</td>
<td>–                   (–)</td>
<td>5.13*</td>
</tr>
<tr>
<td>Morpheme Production (30)</td>
<td>.84</td>
<td>–               (–)</td>
<td>11.61 (4.49) (1–21)</td>
<td>16.41 (4.75) (1–23)</td>
<td>18.79 (4.35) (6–28)</td>
<td>61.05***</td>
<td></td>
</tr>
</tbody>
</table>

Note: Numbers in parentheses represent the maximum score for each measure. All reliabilities represent internal consistency reliabilities (Cronbach’s α), except that for the rapid number naming task, which represents test–retest reliability.

aIn years.

bIn seconds.

*p < .05, ***p < .001.
to all children to test their visual-processing skills. Both tasks consisted of one practice item and 16 test items. In the Visual Spatial Relationships task, each trial consisted of five black-and-white line drawings. Children were asked to distinguish which of these drawings was oriented differently from the other four. For the Visual Memory task, children were asked to recognise an abstract black-and-white line drawing from among five alternatives, after having seen the target shape alone. Children responded by pointing to the picture they selected, and the experimenters recorded children’s responses.

**Orthographic judgement.** The orthographic judgement task was created to measure orthographic awareness of Chinese children (Shu & Anderson, 1998) and has been used successfully in previous research (Li et al., 2006). For this task, children were shown a total of 70 items and asked to decide whether each one could be a real character or not. Of a total of 40 test items, 10 items were black-and-white line drawings that contained no conventional stroke patterns (e.g. \[\text{\textcircled{A}}\]). Twenty additional items were compound noncharacters of one of two types: 10 items of an ill-formed structure that contained real components, but with radicals in the illegal positions (e.g. \[\text{\textcircled{B}}\]) and 10 items that were ill-formed components and that looked like standard compound characters, but for which the components or subcomponents were not real ones in the Chinese writing system (e.g. \[\text{\textcircled{C}}\]). In addition, there were 10 well-formed structure pseudo-character items, which consisted of real components of Chinese with components in their legal positions (e.g. \[\text{\textcircled{D}}\]). We also included 30 real Chinese characters as fillers.

**Phonological awareness**

**Rime detection.** This task consisted of two practice trials and 16 experimental trials. Children were asked to carefully listen to one monosyllabic target (e.g. /wan3/ [meaning bowl]) and two response choice ones (e.g. /san3/ [meaning umbrella] and /hu3/ [meaning tiger]) in each trial and identify which one of the two choices sounded more similar to the target. The two choices used were names of common objects. One of them shared the same rime as the target (e.g. /san3/) and the other (e.g. /hu3/) was an unrelated distracter. While the children heard each of the two choices, they were given a simple line drawing representing each word to ease the memory load. All words were semantically unrelated and familiar to the children. To maximise task difficulty level, in the first eight trials, the lexical tone (indicated by number across examples) was kept constant across all three syllables (e.g. /wan3/, /san3/ and /hu3/), and in the final eight trials, the tones of the three syllables were different (e.g. /gu3/, /ku4/ and /xia1/).

**Syllable deletion.** This task consisted of four practice trials and 20 experimental trials and required that children delete one syllable from two- or three-syllable phrases. For example, /qi4 che1 zhan4/ (meaning bus station) without /zhan4/ would be /qi4 che1/ (meaning bus). To maximise task difficulty, both two-syllable phrases (eight items) and three-syllable phrases (12 items), real syllables (15 items) and nonsyllables (five items, which conform to the phonological constraints of Chinese but do not exist in modern Mandarin), word (eight items) and nonword (12 items) were included. Half of the two-syllable items required taking away the first syllable and half of them involved deleting the last syllable, while in the three-syllable phrases, one-third of the items required taking away the first, middle and last syllables, respectively.

**Phoneme deletion.** Children were asked to produce a new syllable by taking away the target phoneme from a monosyllabic Chinese word. For example, given the syllable /mei4/, children were asked to delete the /m/ sound. The answer, in this case, is /ei4/.
There were three practice trials before the 18 experimental trials, of which six required deletion of the initial, middle and last phonemes, respectively.

**Rapid number naming.** The rapid number naming task was used to measure the RAN ability. In this task, five numbers, 1, 3, 4, 5 and 8, were repeated five times on a single sheet of paper. The child was asked to name the numbers as accurately and rapidly as possible. Each child named the list twice, and the mean score was based on the average naming time across the two trials. Because it was anticipated that most children would be accurate in naming each stimulus virtually all of the time (McBride-Chang et al., 2003), accuracy scores were not recorded for these tasks.

**Morphological awareness**

**Homophone judgement.** In this task, the experimenter orally presented the children with paired two-morpheme Chinese words (e.g. /song1 shu4/ [meaning pine] and /song1 ruan3/ [meaning soft]). In each of the paired words, there was a morpheme (e.g. /song1/) that shared the same sound (homophone/homograph). Children were asked to judge whether the target morpheme in the two words had the same meaning or not. The correct answer in this case is no. To maximise task difficulty level, although the target morpheme was identical in sound, in eight trials, the written form (orthography) of the target morpheme was kept constant across the paired words (homograph, e.g., a target morpheme /song1/in /song1 shu4/, and in /song1 ruan3/), and in the other eight trials, the written forms (orthography) of the target morpheme were different (homophone, e.g., a target morpheme /gao1/ in /dan4 gao1/[meaning cake], and in /tiao4 gao1/[meaning jump]). We also included 16 yes trials (e.g. a target morpheme /xin1/ in /xin1 wen2/[meaning new news] and in /xin1 nian2/[meaning new year] as fillers.

**Morphological construction.** This task consisted of two practice trials and 18 experimental trials. It has been used successfully in previous studies of morphological awareness (e.g. McBride-Chang et al., 2003; McBride-Chang, Chow et al., 2005). In each trial, a scenario was presented orally in three-sentence stories. Children were asked to construct a new compound word to represent the described objects or concepts based on previously acquired morphemes. For example, the trained experimenter said ‘If a big flower that is red in colour is called a big red flower (/da4 hong2 hua1/), what should we call the big flower that is blue?’ The correct answer, in this case, is ‘big blue flower (/da4 lan2 hua1/)’.

**Morpheme production.** This task has been used successfully in previous research on upper primary-level Chinese students (e.g. Shu et al., 2006). In this task, the experimenter initially orally presented a two-character Chinese word (e.g. /ming2 tian1/[meaning tomorrow]), and one of the two morphemes (e.g. /ming2/) was identified for the child. The child was then asked to produce two words containing the target morpheme. One of the morphemes was supposed to have the same meaning as the target morpheme (e.g. /ming2 nian2/[meaning next year]). The other morpheme was supposed to have a meaning different from its original meaning (e.g. /ming2 liang4/[meaning brightness]). This task consisted of two practice trials and 15 experimental trials, and the maximum score was 30 (two points per trial).

**Procedure.** Once permission from the schools and individual parents was obtained to include the children in the present study, children were tested on nine different tasks to measure six different cognitive skills. All tasks were administered to the children
individually by trained psychology majors in the children’s own school. Each child participated in two separate testing sessions, each lasting about 40–50 minutes on two separate days to avoid fatigue. All tasks were carefully ordered so that those measuring the same cognitive skills were separated by other tasks.

Results

Reliability estimates, means, standard deviations and ranges for all tasks are displayed separately for five school levels (K2, K3, Grades 1–3) in Table 1. All measures are presented as raw scores, with the exception of rapid number naming, which was calculated in seconds. Generally, skills on all measures improved gradually across grade levels. Kindergarteners across the two grade levels did not differ in Chinese character recognition, however, perhaps because neither grade had experienced formal instruction in reading yet. The two grade levels were also not different on the rime detection, homophone judgement and orthographic judgement tasks. In contrast, K3 children outperformed K2 children on measures of morphological construction, syllable awareness, rapid naming, visual memory and visual–spatial skill. Across primary school children, neither the visual memory nor the visual–spatial relationship task distinguished grade levels. However, most of the other tasks distinguished across some of these grade levels, with those in the higher grades tending to perform better. Compared with kindergarten children, primary school children were quicker on the RAN task and had higher total scores on all other measures. Moreover, there was no floor or ceiling effect and variability across tasks was generally adequate. Because the homophone judgement and orthographic judgement task were yes/no response tasks and including fillers trials, we corrected for guessing by using $d'$, following correlation and regression analyses.

Tables 2 and 3 show inter-correlations among all measures included in the study, controlling for children’s grade, for kindergarten and primary school children, respectively. Our hypotheses about visual and orthographic skills across development were upheld by the simple correlational analyses. As anticipated, neither measure of visual skill was associated with Chinese character recognition among the primary school students. However, both were significantly and positively associated with word

<table>
<thead>
<tr>
<th>Table 2.</th>
<th>Inter-correlations among different measurers of kindergarten children partialling for children’s grade.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1. Chinese Character Recognition</td>
<td>–</td>
</tr>
<tr>
<td>2. Visual Spatial Relationship</td>
<td></td>
</tr>
<tr>
<td>3. Visual Memory</td>
<td></td>
</tr>
<tr>
<td>4. Orthographic Judgement</td>
<td></td>
</tr>
<tr>
<td>5. Rime Detection</td>
<td></td>
</tr>
<tr>
<td>6. Syllable Deletion</td>
<td></td>
</tr>
<tr>
<td>8. Homophone Judgement</td>
<td></td>
</tr>
<tr>
<td>9. Morphological Construction</td>
<td></td>
</tr>
</tbody>
</table>

*Note: $N = 184$ for kindergarteners.*

$p < .05$, $**p < .01$, $***p < .001$. Copyright © 2010 UKLA
recognition in kindergarteners. In contrast, the orthographic judgement task was not associated with Chinese character recognition in kindergarteners, but had a moderate association with reading for primary school children.

Of the phonological awareness tasks, rime detection was not associated with Chinese character recognition for kindergarteners, but it was moderately associated with this measure for primary school students. However, the syllable deletion task was significantly associated with word recognition in kindergarteners. Among primary school students, phoneme deletion was also significantly associated with Chinese character recognition, though the magnitude of this association was low.

Across grade levels, the task of rapid number naming was significantly and negatively correlated with Chinese word recognition, indicating that those who were faster on the task tended to be better readers. The magnitude of this association was at least moderate in both groups.

Finally, both morphological awareness tasks were significantly and positively associated with Chinese word recognition in primary school students, but only one of these was significantly associated with reading for kindergarteners. Although homophone judgement was moderately associated with reading for primary school children, it had no association with reading for the younger students. However, both the morpheme production task administered only to primary school children and the morphological construction task administered only to kindergarteners were significant correlates of word recognition in this study.

To test for the unique contributions of different cognitive abilities to Chinese character recognition across these two groups of children, we performed two regression analyses for each group. In the first models, only those tasks common to both groups were included. Then, all available measures, including those that were administered only to a single group, were included in the second models. Across analyses, children’s grade level was statistically controlled. To simplify these analyses, we indicated only final standardised β weights for all tasks.

All predictor variables were entered into the first models in one step to evaluate the unique contribution of all common measures to both groups. Results for kindergartener and primary school children are summarised in Table 4. In this table, for the kindergarteners, only rapid number naming was uniquely associated with Chinese character recognition,
with all other variables statistically controlled. All other variables, including measures of rime detection, homophone judgement, visual skills and orthographic knowledge were nonsignificantly associated with reading. In contrast, for the primary school children, all experimental variables, with the exception of visual skills, were uniquely associated with Chinese character recognition. The total \( R^2 \) from these variables for the kindergarten group was .22, \( F(1,182) = 49.82, p < .001 \), relatively small, though it was .72, \( F(5,267) = 134.69, p < .001 \), fairly substantial, in the primary school group.

We then analysed the data similarly with the inclusion of the syllable deletion and morphological construction tasks for the kindergarten group only and the phoneme deletion and morpheme production tasks only for the primary school group to test whether the inclusion of these would improve the variance explained in either group. The inclusion of these new variables resulted in an increase of .06 to .28, \( F(3,180) = 23.83, p < .001 \) for the kindergarten group, but only a .01 increase in the primary school group, \( F(6,266) = 120.61, p < .001 \). Final standardised \( \beta \)s for all variables, as shown in Table 5, were significant for both newly introduced variables for the kindergarten group. That is,

Table 4. Standardised \( \beta \)s for regression equations predicting Chinese character recognition from common predictor variables for both groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Kindergarten</th>
<th>Primary school</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta )</td>
<td>( t )-value</td>
</tr>
<tr>
<td>Grade</td>
<td>-.07</td>
<td>-1.03</td>
</tr>
<tr>
<td>Visual Spatial Relationship</td>
<td>.12</td>
<td>1.65</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>.08</td>
<td>1.15</td>
</tr>
<tr>
<td>Orthographic Judgement</td>
<td>.02</td>
<td>0.22</td>
</tr>
<tr>
<td>Rime Detection</td>
<td>.02</td>
<td>0.37</td>
</tr>
<tr>
<td>Rapid Number Naming</td>
<td>-.46</td>
<td>-7.06***</td>
</tr>
<tr>
<td>Homophone Judgement</td>
<td>.07</td>
<td>1.08</td>
</tr>
</tbody>
</table>

**\( p < .01 \), ***\( p < .001 \).

Table 5. Standardised \( \beta \)s for regression equations predicting Chinese character recognition from all predictor variables for both groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Kindergarten</th>
<th>Primary school</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta )</td>
<td>( t )-value</td>
</tr>
<tr>
<td>Grade</td>
<td>-.13</td>
<td>-1.87</td>
</tr>
<tr>
<td>Visual Spatial Relationship</td>
<td>-.01</td>
<td>-0.08</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>-.01</td>
<td>-0.09</td>
</tr>
<tr>
<td>Orthographic Judgement</td>
<td>.04</td>
<td>-0.62</td>
</tr>
<tr>
<td>Rime Detection</td>
<td>-.02</td>
<td>-0.23</td>
</tr>
<tr>
<td>Syllable Deletion</td>
<td>.21</td>
<td>2.47*</td>
</tr>
<tr>
<td>Phoneme Deletion</td>
<td>.29</td>
<td>-3.71***</td>
</tr>
<tr>
<td>Rapid Number Naming</td>
<td>.05</td>
<td>0.84</td>
</tr>
<tr>
<td>Homophone Judgement</td>
<td>.15</td>
<td>2.10*</td>
</tr>
</tbody>
</table>

*\( p < .05 \), **\( p < .01 \), ***\( p < .001 \).
in addition to the significant association of rapid number naming, both syllable deletion and morphological construction tasks were uniquely associated with Chinese word recognition in this group. For the primary school group, although the morpheme production task was uniquely associated with Chinese character recognition in the final equation, the phoneme deletion task was not; all other variables had roughly the same associations with reading in this regression equation as in the previous one without the new variables included.

Discussion

With data from 457 children on a relatively comprehensive battery of reading-related skills, our basic conclusions about possible courses of reading acquisition in Chinese include the following: there are clear developmental differences in visual and orthographic skills with age. Visual skills are significantly associated with very early Chinese character recognition, while orthographic processing is not, at least in the present study. In contrast, we found no association of visual skills to Chinese character recognition in primary school children, but there was a unique and relatively strong association of orthographic knowledge to reading in the primary school children. At the same time, both phonological and morphological awareness appear to be somewhat important for reading throughout the very beginning and intermediate periods of character acquisition; the prediction that phonological awareness would be less important for older children was not upheld in the present data set. RAN can also stably and independently explain variability in Chinese character recognition for both kindergarten and primary school children. We elaborate on these results below.

Our tasks of visual and orthographic skills yielded some clear developmental differences. Both tasks of visual processing were significantly associated with Chinese word recognition in correlational analyses for the kindergarteners; yet neither visual task was associated with Chinese word recognition among the primary school children. These results suggest that if visual skills are important for reading acquisition in Chinese, their impact is likely to be the strongest at the initial stages of word recognition. Such associations were not attributable merely to ceiling effects in the older children, given that the Visual Memory task mean remained fairly stable from late kindergarten through third grade. It appears that in early kindergarten only, children may adopt a somewhat logographic strategy such that they recognise Chinese characters by overall shape. Although our data demonstrate some association of visual skills to Chinese character recognition, this association was not unique when other reading-related skills were included in the analyses. Thus, although visual skills may have some role to play in early Chinese character recognition, it is likely a relatively minor one. Moreover, with time, children quickly acquire some orthographic knowledge, such as the legal positions of Chinese radicals and common and uncommon stroke patterns. When this occurs, it seems that Chinese children no longer make use of a basic visual strategy but go on to more sophisticated orthographic analyses. Our data clearly demonstrate a relatively strong association of orthographic knowledge to Chinese character recognition for the older children but no such link for the younger ones, even in regression analyses, confirming the idea that orthographic knowledge becomes more important for Chinese character recognition with age and reading experience. Again, these findings cannot be explained only by a floor effect in the younger children, because the kindergarteners’ mean scores
and variations were reasonable (correct responses are approximately 12 out of 40 and standard deviations are about 5), though they did not differ across levels of kindergarten. It seems that children’s orthographic knowledge had a bidirectional association with word reading, particularly in primary school.

Phonological awareness was consistently associated with Chinese character reading across samples, though the tasks of phonological awareness that were uniquely associated with character recognition varied across age levels. To begin with, the syllable awareness task was uniquely associated with Chinese character recognition in the younger children. This finding has been well established in Hong Kong Chinese children (e.g. Chow et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002). The present study extends these findings to Mainland Chinese children and again highlights the fact that awareness of the unit of the syllable is crucial for reading Chinese because each Chinese character has a one-to-one correspondence with a single Chinese syllable. Moreover, apart from its salience in print, the syllable is a strongly salient unit in spoken Chinese, perhaps even ‘transferring’ across languages. For example, in one study (McBride-Chang & Kail, 2002) of kindergarteners in America and Hong Kong, the Hong Kong Chinese children outperformed their American counterparts on a test of syllable deletion in English, underscoring Chinese children’s linguistic sensitivity to the syllable unit. Apart from this syllable measure, our rime awareness measure was not associated with Chinese character recognition in younger children, but was a unique correlate of reading in primary school children. The results conform to some previous findings. For example, Wang and Cheng (2008) reported that young Chinese children prefer body over rime unit in processing spoken Chinese syllables. Although this study did not focus on children’s skill in recognising rime units per se, it suggests that young Chinese children may be less focused on this unit in general in their earliest years of literacy acquisition. Siok and Fletcher (2001) also demonstrated that rime awareness was uniquely associated with reading in Mainland Chinese students in Grades 2 and 5 (though not in Grade 1 or 3) in primary school. Perhaps this finding reflects the fact that rime awareness may not be strongly linked to reading initially because a large number of syllables in Chinese are open syllables and rimes are not explicitly represented in Chinese print. However, some important phonological units such as tones and rimes, both of which were tapped by this task, are sometimes represented in the phonetics across characters, and this linkage may become increasingly clear to older Chinese readers (e.g. Shu, Chen et al., 2003).

Additionally, the phoneme deletion measure was not uniquely associated with Chinese character recognition in the primary school students of the first 3 years in the present study. This finding is in line with previous studies (e.g. McBride-Chang et al., 2004) demonstrating that phoneme awareness by itself is relatively unimportant for reading Chinese because the phoneme is not explicitly represented in the Chinese orthography. These findings are also in line with previous studies of Korean (Cho & McBride-Chang, 2005) and Greek (Aidinis & Nunes, 2001) that suggest that larger grain size units may be more strongly integrated with the reading process in some orthographies that represent print in relatively large units (Ziegler & Goswami, 2005). Thus, unlike most alphabetic orthographies, where phoneme size units tend to be most strongly linked to the reading process (e.g. Hoien et al., 1995; Hulme et al., 2002), larger units such as syllables and rimes may be better predictors of reading development in Chinese.

Along with this variability in relation to phonological awareness, the results of previous studies on the importance of RAN for Chinese character recognition were upheld across age groups in the present study. Several studies have established this relation previously (e.g. Ho
& Lai, 1999; Shu et al., 2003). However, ours may be among the first studies to demonstrate this association across such a wide age range. Establishing fluency in reading, involving automatic sequencing of Chinese characters, is essential for success in the reading process. The rapid naming task tapped this ability across age levels such that those who were faster and more efficient at accessing graphological symbols in one domain, that is, numbers, also tended to be better readers in the domain of character recognition.

Finally, morphological awareness was also positively associated with Chinese character recognition, though the associations of individual tasks of morphological awareness differed with grade level. Specifically, both morphological awareness tasks administered were relatively strongly and uniquely associated with Chinese character recognition in the older group. Both tasks tapped children’s knowledge of homophones and abilities to recognise and incorporate such homophones into real words. This ability to distinguish homophones is clearly essential for advanced reading development in Chinese, given the very large number of homophones that must be distinguished in Chinese print. For younger children, the homophone task was not significantly associated with Chinese character recognition even in correlational analyses. However, the morphological construction task, previously used in other studies to explain variance in Chinese character recognition both in Hong Kong (e.g. McBride-Chang et al., 2003) and in Beijing (e.g. McBride-Chang, Cho et al., 2005) was independently associated with Chinese word recognition in this group, even with other reading-related skills statistically controlled. Because lexical compounding is highly prevalent in Chinese and because learning to read Chinese even at the beginning levels usually involves recognising characters comprised of two or more morphemes, knowing how the morphemes of the Chinese language fit together linguistically may give children an edge in early reading. If Chinese children can generalise how morphemes can be combined in oral language, they may be able to transfer this knowledge to print such that knowing some of the morphemes in print can enable them to guess at words comprised of both familiar and unfamiliar morphemes via bootstrapping.

There were some limitations to the present study. First, although we included a fairly wide range of tasks in our battery across ages, it might have been better to have included more tasks representing each domain for both groups. However, some of the measures that best captured some developmental challenges in the reading process were subject to floor or ceiling effects depending on age group (e.g. Shu et al., 2008) and tasks common to such a wide range of ages and grade levels were not optimal for each grade. For example, the amount of variance in Chinese word recognition explained from tasks common to both groups for the kindergarten sample was only 22%. In future, we might try to refine such tasks to extend the age range in which they can be administered. Secondly, these data patterns were correlational and the study was a cross-sectional design. With this study, in addition to several previous studies of Chinese reading acquisition, we are beginning to get a broader picture of those reading-related skills that might be most important for reading development in Chinese children. However, more experimental manipulations and longitudinal studies, examining these skills over time in the same children relative to their literacy skill, will be essential for the future. Moreover, in future studies, literacy skill should be considered to include not only Chinese character recognition but also spelling (to dictation) and reading comprehension abilities.

Despite these limitations, the current results suggest some basic conclusions about reading development. First, mastery of a writing system, involving converting speech into a visual code, depends largely on acquiring an adequate awareness of phonological processing. This appears to be universal across different languages, though the unit of
phonological awareness may differ across orthographies (e.g. Ziegler & Goswami, 2005). Second, sensitivity to the morphemic structure of words may be particularly important for reading acquisition, given some special properties of the Chinese writing system. Third, orthographic knowledge is another unique, essential element for successful reading in Chinese, at least beginning in primary school. Finally, RAN, for all of its theoretical controversies, is an important correlate of Chinese reading skills, at least for the relatively wide age range of kindergarten and primary school.

These results also suggest that reading instruction and explicit teaching may be essential for the development of some cognitive skills related to reading, such as phonological awareness, morphological awareness and orthographic skills. While syllable awareness, compound word awareness and visual skills appear to develop naturally and contribute to emergent character recognition, rime awareness, homophone/homograph awareness and orthographic awareness may rely more on reading instruction and experience for development and, ultimately, children’s reading success.

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