Learning to read in Chinese: Evidence for reciprocal relationships between word
reading and oral language skills

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Research Highlights

- Early levels of Chinese word reading were predicted by vocabulary, phonological awareness and visual discrimination in a large sample of 7-year old children living in mainland China
- These findings demonstrate that the cognitive processes involved in learning to read in Chinese differ from those in alphabetic orthographies
- We present the first evidence that learning to read in Chinese has reciprocal effects on oral language and facilitates growth in vocabulary and morphological awareness

Abstract

This study investigates the longitudinal predictors of the development of Chinese word reading skills and potential bidirectional relationships between Chinese word reading and oral language skills. We examine, in a 2-year longitudinal study, a wide range of theoretically important predictors (phonological awareness, tone awareness, morphological awareness, visual skills, rapid automatized naming (RAN), Pinyin knowledge, and vocabulary knowledge) of reading in 143 primary-school children living in mainland China. Initial levels of reading were predicted by vocabulary knowledge, phonological awareness and visual discrimination skills. Only initial reading levels predicted growth in reading. Initial reading also predicted growth in vocabulary knowledge and morphological construction. This pattern demonstrates that the early stages of learning to read in Chinese places demands on semantic (vocabulary) and visual skills in addition to phonological skills. Furthermore, early levels of word reading predict the later growth of vocabulary knowledge and morphological awareness suggesting that the development of these oral language skills is facilitated by learning to read.

Learning to read in Chinese: Evidence for reciprocal relationships between word reading and oral language skills

In the present paper we focus on the cognitive mechanisms involved in learning to read words in Chinese, and on possible reciprocal relationships between learning to read and the development of key language skills, particularly vocabulary knowledge and morphological skills. The logographic and morphosyllabic Chinese orthography represents sound and meaning differently to alphabetic orthographies, and learning to read in Chinese is likely to depend upon different cognitive-linguistic skills. There are few longitudinal studies of the development of Chinese word reading, and existing studies typically focus on a limited range of possible cognitive skills which may influence reading development. Furthermore, most of these studies have been conducted in Hong Kong where children learn both the traditional Chinese script and English in parallel. Relatively little is known about reading development in mainland China where children are monolingual and learn the simplified Chinese script. In this paper, we present the results of a comprehensive longitudinal study of reading development in 7-year old children learning to read in mainland China.

Learning to read in an alphabetic orthography depends critically on phonological skills: Variations in word reading are predicted by phoneme awareness, letter knowledge and rapid automatized naming (RAN) (Caravolas, Lervåg, Defior, Malkova & Hulme, 2012; Furnes & Samuelsson, 2011; Hulme & Snowling, 2013; Parrila, Kirby, & McQuarrie, 2004). These predictors can all be thought of as tapping into different aspects of children's phonological skills. In contrast, semantic skills (i.e. vocabulary knowledge) play a much weaker role in word reading in alphabetic orthographies (Ziegler et al., 2010).

In Chinese, the basic orthographic unit is a character. Most characters are semantic-phonetic compounds comprising a semantic radical (clue to meaning) and a phonetic radical (clue to sound; Yin & Rohsenow, 1994). Because of the morphosyllabic nature of Chinese

characters, morphological and semantic skills are likely to play a much larger role in learning to read words in Chinese than in alphabetic orthographies. Spoken Mandarin contains many homophones and written Chinese contains many lexical compounds comprising two or more characters, each of which represents a morpheme. Children's ability to recognise morphemes and understand how they operate is therefore likely to be important for learning to read. Strong support for this idea comes from a large-scale longitudinal study (Yeung, Ho, Wong, Chan, Chung, & Lo, 2013) in which morphological awareness at 6 years explained variance in word reading measured 3 years later after controlling for autoregressive effects. This relationship between morphological awareness and Chinese word reading has been found in studies of both kindergarten (Li, Shu, McBride-Chang, Liu & Peng, 2012; McBride-Chang, Shu, Zhou, Wat & Wagner, 2003; Tong, McBride-Chang, Wong, Shu, Reitsma & Rispen, 2011; Tong, McBride-Chang, Shu & Wong, 2009; Wang, McBride-Chang, & Chan, 2014) and primary school children (Li et al., 2012; Pan et al., 2015; Yeung et al., 2011).

Vocabulary skills have often been included in studies of Chinese word reading, but typically only as a control variable which makes it difficult to clarify specific relationships. Correlations between vocabulary and word reading are small and non-significant in some studies (e.g. r 's .02-.04; Yeung et al., 2013) but moderate in others (e.g. r 's .39-.40; Tong et al., 2009). A 5-year longitudinal study (Pan, McBride-Chang, Shu, Liu, Zhang, & Li, 2011) demonstrated that vocabulary knowledge at age 5 years uniquely predicted Chinese character reading measured at age 8 to 10 years. Evidence from a training study showing that teaching the meanings of words in Mandarin improved children's ability to learn to read them (Zhou, Duff, & Hulme, 2015) further suggests that knowledge of word meanings is important for the development of word reading in Chinese.

There is good evidence from studies of alphabetic orthographies that learning to read confers benefits on children's oral language development, including the development of

phonological skills (e.g. Peterson, Arnett, Pennington, Byrne, Samuelsson, & Olson, 2017), vocabulary knowledge (e.g. Cunningham & Stanovich, 1997) and morphological awareness (e.g. Deacon, Benere, & Pasquarella, 2012). Given the nature of the Chinese orthography, it seems reasonable to predict that the process of learning to read in Chinese may highlight semantic information (morphemes and vocabulary) which may lead to subsequent growth in these skills. Whilst there is evidence that learning to read in Chinese boosts phonological awareness (Chow, McBride-Chang, & Burgess, 2005), we do not know of any previous studies that have assessed the influence of learning to read on vocabulary and morphological skills. A central aim of the current study was therefore to examine bidirectional relationships between the growth of reading skills and the development of morphological awareness and vocabulary knowledge.

In contrast to alphabetic readers, readers of Chinese cannot rely heavily on mappings between orthography and sound because these mappings are unreliable (Tong & McBride, 2017). Consequently, though phonological awareness is a significant concurrent (McBride-Chang, Tong, Shu, Wong, Leung & Tardif, 2008; Shu, Peng & McBride-Chang, 2008; Tong et al., 2011) and longitudinal (Pan et al., 2015, 2011) predictor of reading in Chinese, this relationship is weaker ($r=.36$; Song, Georgiou, Su & Hua, 2016) than in alphabetic languages (e.g. $r=.57$; Melby-Lervag, Lyster & Hulme, 2012). Furthermore, this relationship is not always significant after controlling for other reading-related skills including rapid naming, orthographic skills and morphological awareness (Tong et al., 2009; Yeung et al., 2011, 2013).

The relationship between phonological awareness and Chinese word reading may vary depending on whether children have been taught Pinyin. Pinyin, an alphabetic system that uses the Roman alphabet, is typically taught to children in mainland China in Grade 1 and can be subsequently used to learn new characters. Pinyin supports the development of phonological awareness (McBride-Chang, Bialystok, Chong, & Li, 2004; Shu, Peng & McBride-Chang,

2008) and is related to reading (Lin et al., 2010; Siok & Fletcher, 2001; Wang et al., 2014). It is plausible therefore that phonological skills may play a greater role in learning to read in Chinese among children who have been taught Pinyin (i.e. those living in mainland China) than those who have not (i.e. children living in Hong Kong).

Pinyin instruction also highlights tonal information, an essential phonological feature of the Chinese language that conveys meaning. For example, the Mandarin monosyllable /ma/ can represent four different meanings (/mā/ (mother), /má/ (hemp), /mǎ/ (horse), /mà/ (to scold)) when pronounced with four different tones. Awareness of tones has rarely been included in longitudinal studies but there is increasing evidence that it is related to learning to read in Chinese (for typically developing children: see McBride-Chang et al., 2008; Shu et al., 2008; Siok & Fletcher, 2001; for developmental dyslexia: Tong, Tong, & Yiu, 2017), although one recent study in mainland China found no significant relationship between tone awareness and reading (Xue, Shu, Li, Li & Tian, 2013). It seems plausible that the teaching of Pinyin to children in mainland China may lead to improvements in tone awareness, which in turn may reduce the importance of tone awareness as a predictor of reading development.

Another cognitive skill that appears critical for learning to read is rapid automatic naming (RAN). RAN appears to tap the integrity of a left-hemisphere object naming circuit that is recruited to the task of learning to read (Lervag & Hulme, 2009). The process of memorizing the pronunciation of a visual cue is inherent to character reading and to learning letter sound correspondences in an alphabetic orthography. RAN is a unique predictor of word reading in alphabetic languages (Caravolas et al., 2012; 2013) and in Chinese (Song et al., 2016; Tong et al., 2009; Yeung et al., 2011; 2013); presumably because RAN taps the efficiency of a mechanism for translating visual inputs into speech-based representations.

The visual complexity of the Chinese character orthography suggests that visual perceptual and memory skills may be critical for learning to read in Chinese. Although tests of visual skills have rarely been included in longitudinal studies there is some evidence that they are related to early word reading development (Li et al., 2012; Siok & Fletcher, 2001; Tong et al., 2011). A 2-year longitudinal study of 187 kindergarten children (average age: 4 years, 4 months; Tong et al., 2011) found that performance on a visual spatial test (which asked children to select which of five target line drawings differed from the others) was a significant longitudinal predictor of reading in Chinese (explaining an additional 4% of the variance) after controlling for age, IQ, vocabulary, morphological awareness, and phonological awareness (r 's .35 -.43; although the effects of visual-spatial skills were no longer significant after controlling for autoregressive effects). Visual skills are also unique concurrent correlates of Chinese word reading in both grades 2 and 5 (Tong & McBride-Chang, 2010).

In summary, the nature of the orthography suggests that learning to read in Chinese is likely to place greater demands on semantic skills than phonological skills. The process of learning to read the Chinese script may also contribute to growth in vocabulary and morphological skills because the orthography explicitly represents morphemes. Here we present findings from a large-scale 2-year longitudinal study of word reading in 7-year-old children living in mainland China. We examine a wide range of cognitive skills (phonological awareness, tone awareness, morphological awareness, visual skills, RAN, Pinyin knowledge, and vocabulary knowledge) as predictors of the growth of word reading. We also examine potential bidirectional relationships between Chinese word reading and oral language skills (morphological awareness and vocabulary). We predict that reading will be predicted by morphological awareness, vocabulary knowledge, phonological awareness and RAN, and that in turn, word reading will predict growth in oral language skills (morphological skills and vocabulary knowledge).

Method

Participants

We report data from a longitudinal study conducted in mainland China. The sample was unselected for ability and all children whose parents gave consent participated (N=143; 79 boys and 64 girls; mean age 85.23 months at the beginning of the study). Children were assessed 5 times over the 2-year study at approximately 6 month intervals (in the second semester of Grade 1 (April Year 1), the first semester of Grade 2 (September Year 1), the second semester of Grade 2 (March Year 2), the first semester of Grade 3 (September Year 2) and the second semester of Grade 3 (March Year 3). All children were native Mandarin speakers and none had any diagnosed learning difficulties.

Ethical approval for the study was provided by the Research Ethics Committee at University College London.

Tests and Procedures

Time 1

A wide range of cognitive, language, and literacy tests were administered at Time 1. Here we report only the measures used in the present analyses. For each test, unless stated otherwise, the child received a raw score based on the number of items correct.

Phonological awareness was measured using a test of syllable-deletion and phoneme (onset) deletion based on McBride-Chang et al. (2003). The syllable deletion subtest consisted of 19 three syllable items; 5 words and 14 non words. Children repeated each item and were then asked to delete the initial, middle or final syllable. Onset deletion was assessed with 7 one-syllable nonwords. Children were required to repeat the syllable, and then delete the initial phoneme.

Tone discrimination was measured using a test modelled after Tong and McBride-Chang (2010). On each trial the child heard a sequence of four single syllable words. Each sequence was spoken to the child twice. Three of the words in each sequence shared the same tone and one differed in tone. The child was required to select the syllable that differed in tone.

Pinyin Tasks: Test items for all Pinyin tasks were randomly selected from the Xinhua Chinese dictionary (2011).

Pinyin word reading. Children were given 30 seconds to read as many words as possible from a list of 100 Pinyin words. Each correct Pinyin word was awarded 1 point. Examples of items used in this task include jù, chuān, huā, qíng, shì, jiē and tián.

Pinyin letter reading. Children were presented with 100 Pinyin letters and asked to name as many letters as possible within 30 seconds. Each correct Pinyin letter was awarded 1 point.

Pinyin spelling was tested in whole-classes (approximately 30 children). Children heard the spoken form of Pinyin words and were asked to write them down. Each correct word spelled correctly was awarded 1 point. Any error on onset, rime, or tone was penalized. Examples of items used in this task include nǚ, chuō, wèi, dài, fèi, jǐng and shī.

Morphological construction was assessed using a task from McBride-Chang et al. (2003). On each trial children listened to 2 spoken sentences. The first sentence described a familiar word as a morphological cue. The second sentence described a novel object or concept for which children were required to construct a compound word based on the morphological cue. For example, ‘If a ball played with a foot is called football, what should we call a ball which is played with the mouth?’ (Answer: mouthball).

Visual discrimination was assessed in a task where a target shape was presented alongside five alternative choices on a computer screen. Children were given 6 seconds to point to the shape (out of 5) that matched the target. An example of one trial from this task is as follows:

Visual memory was assessed using a task that had the same format as the visual discrimination task except that the target stimulus was shown first and removed before the response alternatives were presented. The target shape was presented on the computer screen for 2 seconds, followed on the next screen by the 5 alternative shapes presented for 6 seconds; the child was required to point to the shape which matched the target.

Rapid Automatized Naming (RAN) was assessed using a digit naming task in which children were presented with a 5*5 matrix containing the Arabic digits 1, 2, 5, 6, and 8 (Denckla & Rudel, 1976). Children were asked to name the digits as rapidly and accurately as possible. The time taken to name all 25 stimuli and the number of errors made were recorded. RAN rate was calculated as the number of digits named correctly (maximum 25) divided by the time taken (in seconds).

Vocabulary was assessed using a test from McBride-Chang et al. (2003) in which children were asked to give a definition for spoken words. Responses were given a score of 0, 1, or 2 according to the accuracy of the definition (following criteria from McBride-Chang et al., 2003).

Chinese Word Reading was assessed by asking children to read aloud a list of two-character words (Ho, Chan, Tsang, & Lee, 2000). Testing was discontinued after 15 consecutive errors.

Times 2-5

On each subsequent test occasion (times 2, 3, 4, & 5) children were retested on the Chinese word reading, vocabulary and morphological construction tasks. The number of items administered at later time points was increased to avoid ceiling effects (see Table 1 for maximum scores).

Results

To analyse the patterns of change over time in reading and key language skills we use individual growth curve models. Growth curve models provide a rich description of longitudinal data by estimating the initial levels of a skill and the subsequent rate of growth in that skill over time. Below we present two sets of growth curve models. The first set of models assess variations in initial levels of reading skill in grade 1, rates of growth in reading, and the predictors of both initial level and growth. The second set of models focus on the growth of vocabulary and morphological awareness and possible bidirectional relationships between these skills and word reading skills.

The means, standard deviations and reliabilities for each variable at all time points are shown in Table 1. The estimated correlations between all variables are shown in the online

appendix S1. Reading shows very high stability across the different times of measurement. Structural equation models (SEM) were estimated in Mplus 8.0 (Muthén & Muthén, 1998-2017) using full information maximum likelihood (FIML) estimators. In all models, the observed predictor variables were given an error variance estimated from their reliabilities in order to control for measurement error (Cole & Preacher, 2014). For three variables (RAN, Pinyin letter and Pinyin reading) without alpha scores we included a conservative measurement error of 10%.

INSERT TABLE 1 HERE

Predicting Reading Skills

A latent growth curve model was estimated to capture the development of Chinese word reading skills. This model has an intercept factor describing initial levels of reading skill and a slope factor describing the growth of reading. The middle time points (2-4) of the slope factor were freely estimated in order to accommodate the slightly nonlinear growth pattern. This model had an excellent fit to the data, $\chi^2(6) = 5.024, p = .541$, RMSEA = .000 (10% CI = .000-.098), CFI = 1.00, TLI = 1.00, SRMR = .014. On average, the children read 63.31 (SD = 35.05) words correctly at the beginning at the study and the average rate of growth from the first to the last time point was 4.09 words per month (SD = 0.81). There was a negative correlation between initial status (starting value) and the growth of reading ($r = -0.72$) which reflects the fact that children with weaker reading skills at the beginning of the study showed the steepest growth (i.e. tended to catch up with their peers).

Next, we examined if our cognitive and linguistic measures (phonological awareness, vocabulary, morphological construction, Pinyin letter knowledge, reading and spelling, Rapid Automatized Naming (RAN), visual memory and visual discrimination) were predictors of the development of reading. Initial status and growth were regressed on these predictors. In

addition, the growth factor was also regressed on initial status to ensure that any association between the predictors and growth were not confounded with their association with initial status. This initial model (with all predictors regressed on both initial reading levels and reading slope) showed that vocabulary was the only unique predictor of variations in initial reading skills. None of the cognitive/linguistic variables predicted variations in slope (rate of growth). This model explained 40% of the variance in initial status and 59% of the variance in slope and has an excellent fit, $\chi^2(33) = 45.872$, $p = .067$, RMSEA = .052 (10% CI = .000-.086), CFI = .989, TLI = .970, SRMR = .018. Estimated bivariate correlations between the latent variables in this model are shown in Table 2.

As is clear from Table 2 all the predictors have significant bivariate correlations with initial reading skills although vocabulary was the only significant unique predictor in the multivariate analysis. Because vocabulary was the only unique predictor and given the strong theoretical reasons for believing that vocabulary is a key influence on learning to read in Chinese we proceeded to examine if any of the other measures predicted initial reading skills after controlling for vocabulary. We began by estimating an equivalent model where all paths predicting initial reading except vocabulary were deleted from the model. This model had a significantly worse fit, $\Delta\chi^2(8) = 31.141$, $p < .001$, and accounted for substantially less variance in initial reading skills (21%) than the full model, confirming that predictors other than vocabulary predict additional shared variance in initial reading skills. We added each of the other predictors one at a time to see if they explained additional variance beyond vocabulary. All of them (with the exception of Pinyin letter knowledge) made a contribution to predicting initial reading level. The variable that contributed most variance after vocabulary was phonological awareness. After including phonological awareness and vocabulary, we then added the other predictors individually to see if they explained additional variance; this showed that only visual discrimination was an additional unique predictor. The

final model in which vocabulary, phonological awareness and visual discrimination are all significant unique predictors of initial levels of reading skills is shown in Figure 1 and has an excellent fit, $\chi^2(39) = 49.567$, $p = .120$, RMSEA = .044 (10% CI = .000-.077), CFI = .991, TLI = .979, SRMR = .025.

For the growth of reading skills, deleting the paths from all predictors with the exception of initial reading skills did not lead to a significantly worse fit, $\Delta\chi^2(9) = 11.197$, $p = .263$ confirming that none of our measures were important predictors of the growth of reading skills after controlling for the relationship between intercept and slope. This pattern appears to reflect the substantial negative correlation between intercept and slope ($r = -.72$) coupled with the fact that the predictors that did show significant bivariate correlations with slope (vocabulary, morphological awareness, RAN and visual discrimination) showed stronger relationships with the intercept. In other words, any effects of these predictors on growth can be more parsimoniously explained in terms of their effects on the intercept.

INSERT FIGURE 1 HERE

Bidirectional Relationships between Reading Skills and Oral Language (Vocabulary and Morphological Skills)

We also wanted to assess possible bidirectional relationships between reading and the development of morphological and vocabulary knowledge. More specifically, we wanted to assess if initial levels of reading skill predicted the growth of morphological construction and vocabulary knowledge after controlling for initial skills in these two processes and if the initial status of these two processes predicted growth in reading after controlling for initial levels of reading skill. To avoid potential confounding effect of phonological awareness, we also controlled for this construct measured at the first time point. In order to capture the nonlinear growth of morphological construction and vocabulary knowledge piecewise growth

models with an intercept (initial status) and two slope factors (early growth and later growth) were used. To capture nonlinearities in growth, one factor loading on the first and later growth factors for morphological construction and vocabulary respectively were freely estimated.

In these parallel growth models, the growth of reading, morphological construction and vocabulary were regressed on all the four constructs at t1 in addition to earlier growth (only the significant paths are shown in the Figures). As shown in Figure 2 initial reading skills predicted both the early and later growth of morphological construction after controlling for earlier rates of growth in this measure. In contrast, the morphological growth constructs did not predict any of the reading growth constructs: in other words having good word reading skills appears to facilitate the growth of morphological skills, but not vice versa. The vocabulary model (Figure 3) shows that initial reading skill predicted both early and later vocabulary growth. However, vocabulary did not predict the growth of reading. In short, as with morphological construction, good reading skills facilitate vocabulary development but not vice versa. Both models provide good fits to the data (morphological construction model, $\chi^2(40) = 55.240, p = .055$, RMSEA = .052 (10% CI = .000-.082), CFI = .987, TLI = .979, SRMR = .048; vocabulary model, $\chi^2(42) = 48.467, p = .228$, RMSEA = .033 (10% CI = .000-.068), CFI = .996, TLI = .994, SRMR = .034).

INSERT FIGURES 2 AND 3 HERE

Discussion

We explored a wide range of theoretically important cognitive-linguistic skills as potential predictors of the development of Chinese word reading in primary-school children. There were high levels of common variance between variables and a high degree of longitudinal stability in word reading across the 2 years of the study. Children's initial levels of reading were predicted by vocabulary, phonological awareness and visual discrimination

skills. Initial reading status was the only significant predictor of the growth of reading with children who started with poorer reading skills making faster progress. Initial reading levels also predicted subsequent growth in morphological awareness and vocabulary knowledge.

Chinese characters are heavily meaning-based, and our results add to a number of recent studies that show that vocabulary knowledge is a predictor of reading ability in Chinese (e.g. Pan et al., 2011; Wang et al., 2015; Zhou et al., 2015). In the current study, vocabulary knowledge predicted initial levels of reading skill, but not the subsequent rate of growth in reading. This pattern suggests that vocabulary knowledge may be particularly important as an influence on early reading skills, but less important as a constraint on the rate growth in word reading skills once some basic level of reading skill has been attained. Surprisingly, in this study, morphological skills (here measured by a morphological construction task) were not a unique predictor of reading growth after controlling for autoregressive effects and the other predictors. It should be noted however, that morphological construction was a significant correlate of initial reading status and it was also moderately correlated with other important predictors (including vocabulary knowledge and visual discrimination). Previous research has consistently shown strong longitudinal relationships between morphological awareness and reading in Chinese (e.g. Yeung et al., 2013; as well as being a predictor in alphabetic orthographies e.g. Deacon & Kirby, 2004; Kirby et al., 2012). Children's ability to recognise and manipulate morphemes is likely to reflect (at least partly) general semantic knowledge, which is also captured by our measure of vocabulary. It has also been suggested that strong oral vocabulary skills are a prerequisite for morphological skills to facilitate reading (McBride, 2016). The fact that morphological construction shared substantial common variance with vocabulary, along with a number of other variables (including phonological awareness and visual discrimination) in this study appears to provide an explanation for why it was not a unique predictor in the current study.

Phonological awareness was also a significant predictor of initial word reading. One essential process underlying learning to read in Chinese is the ability to create links in memory between printed characters and their pronunciations. Creating such links is an example of visual-verbal paired-associate learning and measures of children's phonological awareness are predictive of such learning (Hulme, Goetz, Gooch, Adams & Snowling, 2007; Warmington & Hulme, 2011). For example, Warmington and Hulme (2011) reported quite a strong correlation ($r = .50$) between phoneme deletion and visual-verbal paired associate learning. In this view, effective visual-verbal paired-associate learning depends in part upon the efficient representation of phonological information in memory, and measures of phonological awareness may be one way of tapping the quality of underlying phonological representations which in turn are related to learning to read.

Our results concerning phonological awareness are in line with earlier work which demonstrates the role of phonology in learning to read simplified Chinese scripts (e.g. Shu et al., 2008; Siok & Fletcher, 2001). The children in the current study were living in mainland China and had been taught Pinyin, an alphabetic coding system that highlights phonological cues. Our results confirmed that Pinyin spelling shows a strong relationship with initial reading skill ($r = .44$) and shares substantial variance with phonological awareness ($r = .68$). An issue for future studies is to explore more directly the role of learning Pinyin as an influence on the relationship between phonological awareness and learning to read. It appears that learning Pinyin (as in mainland China, but not in Hong Kong) improves children's phonemic awareness (McBride-Chang et al., 2004). It would be interesting to explore experimentally the effects of teaching Pinyin to groups of children living in Hong Kong. Based on our findings and previous research it would be predicted that this would increase these children's phonological awareness skills, and possibly lead to a stronger relationship between phonological skills and word reading, compared to children who did not receive such training.

It is striking that visual discrimination skills were an additional predictor of initial reading levels in our study. Visual memory skills were also a significant correlate of initial reading levels, but not a unique predictor due to shared variance with a range of other predictors in the model including both visual discrimination and phonological awareness. Chinese characters are visually complex and some are visually similar such as 己 (*self*) versus 已 (*already*), 由 (*cause*) versus 田 (*field*), 未 (*have/has not*) versus 末 (*end*). These characters are usually learned at the beginning of reading. Thus, the ability to discriminate between visual cues that are highly similar plays an important role in reading Chinese characters. This parallels previous studies which have found correlations between measures of visual spatial skills and reading in young Chinese children (Li et al., 2012; McBride-Chang et al., 2005; McBride-Chang et al., 2011; Siok & Fletcher, 2001; Tong et al., 2011). Previous research suggests the relationship between visual skills and reading are no longer significant beyond the age of 6 years (e.g. Siok & Fletcher, 2001); one suggestion is that, as children become more skilled readers, they rely on more sophisticated orthographic skills which displace basic visual strategies (Li et al., 2012). Our findings suggest that visual skills (particularly visual discrimination) are predictive of word reading at 7 years; however, a limitation of the current study is that we did not include a measure of orthographic processing and are therefore not able to speak to the relative importance of these skills.

Our study is the first to assess the influence of learning to read Chinese on vocabulary and morphological skills. Vocabulary and reading shared a reciprocal relationship: vocabulary predicted initial reading and initial reading predicted growth in vocabulary. Although morphological skills did not predict reading in the current study, initial reading status predicted both early and later growth in morphological construction. This provides clear evidence that early Chinese reading skills are predictive of subsequent growth in oral language (semantic) skills. This is in line with findings from alphabetic orthographies that learning to read may

support vocabulary acquisition (Cunningham & Stanovich, 1997) and morphological awareness (Deacon et al., 2012). It appears that reading draws attention to semantic information and facilitates growth in children's lexical knowledge and understanding of the morphological structure of the spoken language.

In summary, our findings show that semantic skills (vocabulary knowledge) are one critical influence on the development of word reading skills in Chinese. Visual discrimination skills and phonological skills are additional influences. These findings, considered alongside evidence from studies of reading in alphabetic orthographies, have clear implications for a universal developmental model of reading in demonstrating unique features of learning to read the Chinese orthography. They also have clear implications for instruction: Phonological awareness training does not appear to support reading in Chinese (Zhou et al., 2012); our results suggest that supporting oral language skills, particularly vocabulary knowledge, alongside teaching strategies which support the ability to discriminate between visual cues (e.g. visual-orthographic copying), may support early reading acquisition. Our findings also show that reading the Chinese script highlights semantic information and leads to growth in morphological awareness and lexical knowledge. Whilst previous work has shown that teaching the meaning of a word facilitates learning to read that word in Chinese (Zhou et al., 2015), our findings further suggest that print-based interventions may be effective in supporting oral language development in Chinese children.

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Table 1. Descriptives and reliabilities for each variable

	Max. Score*	Means	Standard Deviations	Reliabilities
Phonological awareness (T1)	26	22.27	4.61	.882
Tone discrimination (T1)	24	17.20	5.95	.905
Pinyin word reading (T1)	100	10.65	4.89	--
Pinyin letter reading (T1)	100	22.55	7.09	--
Pinyin spelling (T1)	20	16.06	3.41	.807
Morphological construction (T1)	27	17.81	6.99	.934
Morphological construction (T2)	27	23.41	3.25	.802
Morphological construction (T3)	27	24.65	2.25	.837
Morphological construction (T4)	32	28.22	2.79	--

Morphological construction (T5)	37	32.40	4.32	--
Visual discrimination (T1)	20	14.14	3.01	.652
Visual memory (T1)	20	11.12	2.86	.515
RAN (T1)	-	15.46	4.23	--
Vocabulary (T1)	106	33.21	14.7	.918
Vocabulary (T2)	106	44.43	17.26	.938
Vocabulary (T3)	106	62.18	19.73	.939
Vocabulary (T4)	106	74.01	20.63	--
Vocabulary (T5)	126	83.43	19.64	--
Chinese Word Reading (T1)	150	63.27	37.12	.990
Chinese Word Reading (T2)	170	89.08	32.14	.989
Chinese Word Reading (T3)	170	122.48	30.18	.984
Chinese Word Reading (T4)	190	145.10	27.28	--

Chinese Word Reading (T5)	210	165.48	29.01	--
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Note. Measures are recorded in raw scores. RAN is the time to complete the task (in seconds). *The maximum score for all measures is equal to the number of items in each test, with the exception of Vocabulary where the maximum score is twice the number of items in the tests

Table 2

Estimated correlations between the latent variables in Figure 1.

	1	2	3	4	5	6	7	8	9	10	11
1 Phonological Awareness	1.00	.246**	.514**	.346**	.315**	.677**	-.397**	.349**	.454**	.451**	-.173
2 Vocabulary		1.00	.287**	.138	.141	.224*	-.240**	.213*	.265*	.449**	-.304**
3 Morphological construction			1.00	.106	.235**	.316**	-.234**	.454**	.493**	.344**	-.260**
4 Pinyin Letter				1.00	.263**	.286**	-.205*	.135	.139	.173*	-.161
5 Pinyin reading					1.00	.518**	-.362**	.109	.141	.219*	-.130
6 Pinyin spelling						1.00	-.309**	.448**	.512**	.442**	-.146
7 RAN							1.00	-.165	-.291*	-.335**	.283**
8 Visual discrimination								1.00	.463**	.392**	-.265*
9 Visual memory									1.00	.295**	-.155
10 Reading initial status										1.00	-.717**
11 Reading growth											1.00

Note. * = $p < .05$; ** = $p < .01$.

Chi-Square Test of Model Fit

Value	60.787
Degrees of Freedom	48
P-Value	0.1018

RMSEA (Root Mean Square Error Of Approximation)

Estimate	0.043
90 Percent C.I.	0.000 0.073
Probability RMSEA <= .05	0.612

CFI/TLI

CFI	0.989
TLI	0.980

SRMR (Standardized Root Mean Square Residual)

Value	0.032
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Figure 1. A latent growth curve model showing the predictors of Chinese word reading. Only significant regression paths are shown. The growth was coded in months from the start of the study and the factor loadings of the middle time points was freely estimated to accommodate the slight non-linear growth pattern

Figure 2. A latent growth curve model assessing bidirectional relationships between Chinese word reading and morphological construction. Only significant paths are shown.

Figure 3. A latent growth curve model assessing bidirectional relationships between Chinese word reading and vocabulary. Only significant paths are shown.