Understanding Chinese Developmental Dyslexia: Morphological Awareness as a Core Cognitive Construct

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Tasks representing 9 cognitive constructs of potential importance to understanding Chinese reading development and impairment were administered to 75 children with dyslexia and 77 age-matched children without reading difficulties in 5th and 6th grade. Logistic regression analyses revealed that dyslexic readers were best distinguished from age-matched controls with tasks of morphological awareness, speeded number naming, and vocabulary skill; performance on tasks of visual skills or phonological awareness failed to distinguish the groups. Path analyses further revealed that a construct of morphological awareness was the strongest consistent predictor of a variety of literacy-related skills across both groups. Findings suggest that morphological awareness may be a core theoretical construct necessary for explaining variability in reading Chinese.

Keywords: phonological awareness, visual skills, spelling, reading

Studies on reading development and impairment from alphabetic scripts have strongly influenced the agenda for later research and evidence-based intervention strategies on developmental dyslexia (e.g., Report of the National Reading Panel, 2000). What is particularly important about this alphabetic script perspective is its clear emphasis on phonological skills in relation to reading. Indeed, according to a 2003 definition of dyslexia, reading problems in dyslexic children, "typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction" (Lyon, Shaywitz, & Shaywitz, 2003, p. 2). One purpose of the present study was to examine the extent to which phonological skills distinguish Chinese-reading children who are adequate readers from those with reading difficulties.

Compared with the research conducted on alphabetic reading, Chinese reading development and impairment have been researched relatively rarely. Therefore, there are few models for explaining how reading develops in Chinese. Indeed, defining dyslexia in Chinese is difficult because of a paucity of studies on children's reading. However, early research (Stevenson & Stigler, 1982) demonstrated that the percentage of children labeled as reading disabled did not differ significantly between the United States and Taiwan. Estimates similar to those (from 4.5% to 8.0%) were found in children in Mainland China (C. Zhang, Zhang, Yin, Zhou, & Chang, 1996). Chinese children with dyslexia consistently demonstrate particular difficulties in reading and writing Chinese words and characters (Ho, Chan, Lee, Tsang & Luan, 2004; Shu, Meng & Lai, 2003). Thus the nature of reading disability in Chinese children, both in terms of prevalence and manifestation of difficulties, is similar to that found in children learning alphabetic scripts.

However, what seems increasingly clear from recent research on Chinese developmental dyslexia (Ho, Chan, Tsang, & Lee, 2002; Ho et al., 2004) is that learning to read Chinese likely requires abilities separate from phonological processing. Across cognitive profiling studies, Ho and colleagues (Ho et al., 2002, 2004) found that problems with orthographic knowledge and rapid automatized naming were particularly evident in Chinese dyslexic readers, leading the researchers to conclude that "orthographic-related difficulties may be the crux of the problem in Chinese developmental dyslexia" (Ho et al., 2004, p. 70). Perhaps equally interesting in these studies was the fact that phonological awareness was a relatively minimal problem in poor readers from Hong Kong. Although this careful research included a variety of cognitive skills—including phonological memory, visual memory, visual perception, rapid naming, and orthographic processing—to distinguish dyslexic readers in Hong Kong, one cognitive construct relevant for Chinese character recognition, morphological awareness, was untapped in these studies.

Morphological awareness, defined here as awareness of and access to morphemes in words, is key for Chinese word recognition in at least three ways. First, Chinese compound characters typically comprise two distinct parts, a phonetic radical and a semantic radical (Shu & Anderson, 1997). The phonetic radical gives some indication of the sound of the character. However, this information is unreliable relative to the phonological cues provided by alphabetic orthographies. In contrast, the semantic radical indicates a character's meaning but not sound, distinguishing morphological from phonological information in a way that does not usually occur in alphabetic languages. Second, Chinese is a relatively semantically transparent language, so that learning given morphemes may be helpful in learning to read new words that contain these morphemes. Third, because Chinese has many homophones, learning to distinguish them orally may be bidirectionally associated with character recognition (e.g., McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003). Given these features of Chinese, elaborated on below, a second purpose of the present study was to test the extent to which morphological awareness, among many other cognitive abilities tested in relation to developmental dyslexia in Chinese, might distinguish children with reading impairments from those without such difficulties.

Because there are still so few studies on reading skills in Chinese children, we administered a large number of tasks, testing nine cognitive constructs, to determine those that would best distinguish children with normal reading ability from children with dyslexia in our sample of Chinese fifth and sixth graders from Beijing. We tested a variety of cognitive skills tapped in previous studies of reading disability in both alphabetic and Chinese scripts, including verbal and visual memory, visual skills, general speed, and articulation (e.g., Elbro, Borstrøm, & Petersen, 1998; Ho et al., 2002, 2004; Morris et al., 1998). The importance of these constructs for reading of Chinese has been reviewed elsewhere (Ho et al., 2002, 2004). Our own theoretical perspective drew on the growing literatures on both development and impairment in Chinese character acquisition, including morphological awareness (e.g., McBride-Chang et al., 2003; Shu & Anderson, 1997), phonological awareness (e.g., Ho & Bryant, 1997; Hu & Catts, 1998; McBride-Chang & Ho, 2000), and rapid automatized naming (e.g., Ho & Lai, 1999; McBride-Chang & Ho, 2000). Below, we highlight these three cognitive skills in relation to word recognition in Chinese.

As mentioned above, there are good theoretical reasons to focus on morphological awareness as a critical component of Chinese reading acquisition. One of the clearest examples of the importance of morphological skills for reading Chinese comes from a study of the structure of Chinese characters. In 80% of characters, the semantic radical is directly linked to meaning (Shu, Chen, Anderson, Wu, & Xuan, 2003). Thus, in contrast to alphabetic scripts, such as English, in which morphemes and phonological units might be confounded, in Chinese, morphological and phonological print information can be more clearly distinguished. For example, in English, the morphemes [ed], [s], or [bee] (respectively, indicating past tense, plural, and an insect that makes honey) can be easily recognized as letter units. However, such letter patterns do not always communicate this morphological information, as demonstrated by the words *sediment* or *seed* (both of which contain the letter patterns *ed* and *s*) or *been* or *beep* (containing the letter pattern *bee*). Furthermore, in these examples,

sometimes the pronunciation of the letter patterns as morphemes is preserved, though the meaning is different (as in *sediment* or *beep*) and sometimes it is not (as in the *ed* in *seed* or the *bee* in *been*). Such confounds of phonological and morphological information in print are uncommon in Chinese. This observation in part motivated Shu and Anderson's (1997) study, which looked at the importance of morphological information for learning to read Chinese in primary schoolchildren. Indeed, they demonstrated that awareness of semantic radicals increased with reading skills across development. Children capitalize on morphological information as they learn to read, making good use of semantic radicals to distinguish characters by meaning as early as kindergarten and first grade (Chan & Wang, 2003; Ho, Yau, & Au, 2003) in different Chinese societies. Thus, this aspect of morphological awareness in relation to reading is clearly a function of the structure of Chinese characters themselves, rather than language per se.

A second aspect of Chinese that highlights the importance of morphological awareness for reading comes from the language structure. Chinese is semantically relatively transparent, so that complex vocabulary can often be built by combining morphemes via compounding. There are certainly similar examples of semantic transparency in English. The morpheme [work], for instance, occurs in the words *workplace*, *homework*, *workforce*, and *overworked*. The presence of the morpheme [work] in all of these words may be helpful in indicating both semantic relations across them and also in transferring our abilities to read and write *work* across words. Although such examples occur in English, they are infrequent relative to Chinese. Thus, compared with English language, the Chinese language is much more systematic in combining morphemes logically to form new words in language and print.

A third characteristic of Chinese that has been widely recognized and studied, particularly in research on adults (P. Li & Yip, 1998; Tan & Perfetti, 1997; Zhou, Zhuang, & Yu, 2002), is the large number of homophones in Chinese. It has been estimated that each Chinese syllable has approximately five homophones in Mandarin, for example (Packard, 2000). This unique aspect of Chinese may be fundamentally important for word recognition. To become a good reader of Chinese, one needs to be able to distinguish the meanings of words that sound identical. Although this ability can be tested in English (e.g., *rows* vs. *rose*), English has relatively few homophones. The many homophones in Chinese likely means that, as children learn to read, they become better able to understand how morphemes are related to one another. Carlisle (1995) pointed out that learning to read clarifies for children how certain morphemes are related in English (e.g., the /t/ sound in *walked* and *tapped* differs in meaning from the /t/ in *rapt*). Similarly, children may come to realize which homophones are the same and different in meaning as they occur across different Chinese words.

Given the several aspects of morphological awareness that are theoretically important for learning to read Chinese, we measured children's skills in morphological production in the present study. The morphological production task taps morphological awareness in the absence of print. Thus, as with measures of phonological awareness, morphological awareness involves language manipulation only; reading is not confounded with language in the task. The morphological production task included in the present study made use of children's knowledge of both homophones and morpheme construction skills, both of which have been demonstrated to

predict unique variance in character recognition among Hong Kong Chinese children (McBride-Chang et al., 2003).

Along with morphological awareness, we also included measures of phonological awareness in the present study. Although we agree with Ho and colleagues (Ho et al., 2002, 2004) that phonological awareness may be less important in learning to read Chinese than in learning to read English, this idea must be qualified by considering method of measurement and relevance of phonological awareness to reading in a given Chinese environment. Methodologically, phonological awareness tasks that require that children themselves produce an answer tend to discriminate good from poor readers better than do forced-choice tasks. The phonological awareness tasks administered by Ho et al. (2002, 2004) were all forced-choice tasks and possibly inflated risks of guessing among participants. In the present study, we included one task that required children to produce answers themselves, and thus possibly improved the ability of this task to discriminate good from poor readers. In addition, unlike Hong Kong children, who learn to read Chinese without any phonemic coding system as an aid, Beijing children routinely make use of Pinyin throughout their learning process. Pinyin is an alphabetic coding system used throughout Mainland China to teach pronunciations of newly introduced Chinese characters. Because Pinyin is an important aid to Beijing children in learning to read Chinese, phonemic awareness itself might be useful in discriminating children with dyslexia from nonimpaired readers in this sample. Finally, Chinese characters are often described as morphosyllabic, meaning that each character simultaneously represents both a syllable and a morpheme. Thus, as in alphabetic languages (Mann, 2000), there is a relatively close correspondence between speech sound representation and meaning representation, at least across multisyllable words, in Chinese. We, therefore, examined the associations of phonological and morphological awareness constructs in the present study.

The third construct we considered practically important in relation to reading variability among the Beijing children was rapid automatized naming (RAN). Although theory is lacking on the precise constructs measured by RAN tasks, it is clear that RAN has been shown consistently to discriminate good from poor readers (Ho & Lai, 1999) and to predict early Chinese character recognition across samples of children. One explanation for this has to do with the fact that Chinese character recognition is relatively "arbitrary," as defined by Manis, Seidenberg, and Doi (1999). In their conceptualization in Manis et al. (1999), RAN tasks in part tap the arbitrary links of symbols to spoken language. For this reason, RAN tasks tend to be better associated with irregular than with phonologically regular words in English. Because both Chinese character recognition and RAN tasks involve the automatic mapping of arbitrary language and print information and because Chinese is relatively phonologically unpredictable, Chinese may be a writing system that is particularly strongly associated with such tasks across cultures. In the present study, we therefore expected, on the basis of previous research (Ho et al., 2002, 2004), that RAN tasks would be useful in distinguishing children who were nonimpaired readers from children with reading impairments.

The methodology for this study involved a two-stage plan. First, because there is relatively little theory developed thus far to guide our exploration of Chinese word recognition in children, we examined a large battery of tasks tapping cognitive abilities that might be useful for learning to read Chinese. These were derived from studies of both alphabetic languages (Elbro et al., 1998; Morris et al., 1998) and Chinese (Ho et al., 2002, 2004). In this first step, we used the logistic regression technique and a wide variety of tasks to distinguish children with reading difficulties from children who were nonimpaired. Second, we tested a model explaining variance in different literacy measures from the three constructs of most theoretical interest to us. These included morphological awareness, because of its theoretically important links to Chinese character acquisition; phonological awareness, because of its central focus for word recognition in alphabetic languages; and speeded naming, because of its strong clinical utility in distinguishing poor from good readers in previous studies of Chinese readers.

Method

Participants

Of 751 Grade 5 and 6 Beijing Chinese children initially screened from two schools, our final sample consisted of 75 children who demonstrated clear reading difficulties and 77 children without reading difficulties. There were 57 boys and 18 girls among the impaired readers and 48 boys and 29 girls among the nonimpaired readers. These groups were formed on the basis of two tasks administered to all 751 children. The first of these tasks was the Character Recognition Measure and Assessment Scale for Primary School Children (Wang & Tao, 1993). This is a widely used test for screening Mandarin-speaking Chinese children for dyslexia (e.g., Meng, 2001; Ding et al., 2002; Shu, Meng, & Lai, 2003; Shu & Meng, 2000; Wu & Shu, 2004). On this standardized battery of Chinese character recognition skills, the children with dyslexia demonstrated reading achievement scores of at least 1.5 years below their corresponding age. The readers without reading difficulties came from the same schools and were no more than 1.5 year below on the same measure. The second task administered to all children was the standardized test of nonverbal intelligence, Raven's Standard Progressive Matrices (Raven, Court, & Raven, 1996), with local norms established by H. Zhang and Wang (1985). On this measure, there are five sets of 12 items. For each item, there is a target matrix with one missing part. The children are asked to select, from six to eight alternatives, the one that best completes the matrix. The two groups of children included in the present study were selected so that they did not differ on this measure because we wanted to include those who differed significantly on reading only and not on nonverbal reasoning skills.

Procedure

Following the initial screening at school for reading achievement, two trained psychology graduate students conducted subsequent testing in a quiet room in the children's school. Testing took place over two sessions. Session 1 was done with the children individually, and Session 2 was done in a group setting in the classroom. Each session lasted approximately 60 min. All tasks described below were administered in random order.

We administered the following tasks to the participating children (please see Table 1 for internal consistencies of experimental tasks):

Literacy Tasks

Chinese character naming. The Chinese character recognition task consisted of 56 single characters taken from Grade 5- and Grade 6-level reading texts (reading lists for fifth and sixth graders shared 57% of the characters in common). Children were asked to read aloud one character at a time. For each character that they could identify, they were then asked to use the character in a word or phrase. The purpose of doing this was to make sure the children could understand the meaning of each character.

Table 1

Reliabilities, Means, Standard Deviations, and Fs of All Tasks Administered to Children in the Dyslexic and Control Groups

Variable (N per task)	Reliability coefficient	Dyslexia (n = 75)		Control (n = 77)		F(1, 150)
		M	SD	M	SD	
Age, years, months		11,11		11,6		11.57**
Character recognition score (2,834)		2,189	282.48	2,821	239.51	221.65***
Raven's Standard Progressive Matrices score		47%	31.21	53%	36.54	1.07
Literacy tasks						
Chinese character naming	.93	21	7.61	39	7.71	227.07***
Chinese character dictation	.94	38	10.1	53	8.09	102.16***
Comprehension	.80	10	4.85	15	3.31	61.85***
Morphological awareness						
Morpheme production, raw data (30)	.75	16.05	3.32	21.08	4.56	69.7**
Morpheme judgment, raw data (30)	.98	18.51	2.74	19.7	2.50	7.89**
Rapid naming						
No. naming in s	.82	16.15	3.44	13.48	3.25	24.32***
Picture naming in s	.77	22.45	4.14	20.04	3.73	14.21***
Phonological awareness						
Phoneme deletion, raw data (16)	.81	6.73	3.68	9.69	3.49	25.77***
Onset/rime/tone judgment, raw data (36)	.86	26.28	6.70	28.68	6.69	4.86*
Verbal short-term memory						
Syllable repetition, raw data (18)	.76	7.93	1.45	8.88	2.27	9.44**
No. repetition score (30)		6.51	2.45	16.73	3.15	18.78***
Lexical vocabulary						
Vocabulary score		6.56	2.77	9.06	2.31	36.75***
Similarity score		6.99	2.31	8.65	2.71	16.54***
Visual spatial test						
WISC–R Block Design score		32.27	10.29	31.99	12.19	0.09
Embedded Figures, raw data		12.39	4.64	12.64	5.02	0.15
Articulatory rate						
Syllable Articulation Rate in s		7.89	1.65	7.28	1.22	1.82
Nonsense Syllable Articulation Rate in s		6.38	1.71	5.69	1.44	2.10
Visual attention						
Nonsense letter 1, raw data		41.88	20.07	31.95	11.18	0.07
Figures 2, raw data		44.67	14.83	35.51	8.59	0.11
Nonverbal short-term memory						
Corsi Blocks 1 (ordered), raw data		8.09	1.49	8.18	1.82	0.27
Corsi Blocks 2 (total), raw data		9.99	2.02	10.09	2.04	0.31

Note. Test–retest reliability was computed for the rapid naming tasks, and Spearman–Brown split-half reliability was computed for morpheme production, morpheme judgment, phoneme deletion, onset/rime/tone judgment, and syllable repetition, which were constructed by the authors. WISC–R = Wechsler Intelligence Scale for Children—Revised.

* $p < .05$. ** $p < .01$. *** $p < .001$.

There are many homophones in Chinese, and the majority of Chinese words comprise two or more morphemes. Moreover, in Chinese, distinctions among words versus phrases are not always clear (e.g., Packard, 2000). Thus, scoring was flexible and based on common usage. An example of an item from this task is presenting the child with a character that should be read aloud as *lan2* (meaning *blue*). The child was then asked to use *lan2* in a word or phrase. One correct answer would be *lan2tian1* (meaning *blue sky*). Children only received a point for each item if they could both identify the character and use it in a word or word phrase. This task was individually administered to each child.

Chinese character dictation. For this task, done in a group setting, children were orally presented with 64 target morphemes in different two-morpheme characters individually and asked to write the target morpheme on paper. Given the large number of homophones in Chinese, the target morpheme was presented in a two-morpheme character. Every item was dictated twice by a well-trained graduate student. As an example, the experimenter orally presented the children with the target morpheme [歌](*song*) in [唱歌](*sing a song*), and the children were required to write down the morpheme [歌]. Across grades, 67% of the characters were the same. The average frequency of these characters was 150(/1,000,000) for Grade 5 and 151(/1,000,000) for Grade 6, respectively.

Comprehension. In this cloze test, consisting of a short story of about 300 characters with 20 blanks in it, participants were asked to read the story and fill in the blanks with the appropriate characters. The words included in the stories were familiar vocabulary appearing in Grade 5 textbooks. Thus, the total possible score on this task was 20. This task was done in a group.

Morphological Awareness

To measure children's understanding of the meaning structure of words, we administered two tasks of morphological skills.

Morpheme production. In this task, administered individually to each child, the experimenter orally presented a two-syllable Chinese word. Within that two-morpheme word, one morpheme was identified. The child was then asked to produce two words with the target morpheme. One of the morphemes was supposed to have the same meaning as the target morpheme. The other morpheme was supposed to have a meaning different from its original meaning. However, both morphemes were identical in pronunciation. For example, when the experimenter gave the word *cao3di4* (meaning *lawn*), the child was asked to produce a new word with the morpheme [cao3] in which the [cao3] had the same meaning as it did in

cao3di4. One acceptable answer would be xiao3cao3 (meaning grass). The child was also asked to say a word that included the morpheme [cao3] in which its meaning was different from that in cao3di4. An example is cao3shuai4 (meaning cursory). All items consisted of real words. There were 30 items.

Morpheme judgment. In this task, administered to the children in a group, the experimenter orally presented the child with 2 two-morpheme read Chinese words. In each of the two words, there was a syllable that shared the same sound (e.g., a shared syllable sheng1 in mo4sheng1 (meaning new man) and sheng1zi4 (meaning new Chinese character)). In each example, although the target syllable was identical in sound and written form (Chinese character), in half of the words it had the same and half the time a different meaning. For each pair of words, the child's task was to judge whether the syllable common across both words had a similar or different meaning. There were 30 items in total.

Rapid Naming

Two measures of speeded naming, which measured graphological and nongraphological naming, respectively, were administered individually to the children. Because most children were accurate in naming each stimulus virtually all of the time, accuracy scores were not recorded for these tasks.

Number naming. In this task, five numbers, 7, 4, 6, 9, and 2, were repeated six times on a single sheet of paper. The numbers were arranged in different orders from top to bottom on the sheet. The child was then asked to say the number names in order on the sheet from beginning to end as accurately and quickly as possible. Each child named each list twice, and the score was the average naming latency across the two trials. Naming latencies were recorded with a stopwatch to the nearest millisecond.

Picture naming. Pictures of five objects, apple, plane, watermelon, sun, and butterfly, were repeated six times in random orders, on a single sheet of paper, as described above for the number-naming task. As with the number-naming task, children named each list from beginning to end twice, and the average of these two times was used for subsequent analyses.

Phonological Awareness

We measured phonological awareness at the phoneme and phoneme onset and rime levels.

Phoneme deletion. This 16-item task was individually administered. In this task, the experimenter first orally presented a one-syllable real word and then asked the child to say the word with a given phoneme deleted. For example, mei4 without the /m/ sound is pronounced ei4. The task included deletion of both initial and final phonemes.

Onset/rime/tone judgment. This judgment test was administered to the children in groups and consisted of three subtests measuring onset, rime, and tone, respectively. The experimenter pronounced single-syllable real words two times, and the children were then asked to write down the one syllable that was different from the other two. Every subtest comprised 12 items, for a total of 36 items altogether.

Verbal Short-Term Memory

To tap short-term memory processes, we administered two memory measures individually to the children.

Number repetition. All children were given the Chinese version of the Digit Span subtest (Wechsler, 1974), which requires repetition of digits in forward and backward conditions. Longer strings of digits are presented to the children as the task progresses. Scoring procedures were based on the local norm established by Lin and Zhang (1986).

Syllable repetition. This task requires that Chinese syllables, orally presented by the experimenter (one-syllable real words), be repeated back by each child in the order in which the experimenter presented them. The syllables were read aloud by a trained graduate student at the speed of one syllable per second. The length of word strings ranged from 2 to 10 syllables. There were two word strings of each length. The total possible score was 18, because 1 point was given for each word string correctly recalled.

Lexical Vocabulary

To measure vocabulary knowledge of the children, we individually administered Chinese versions of both the Similarities and Vocabulary subtests of the revised Wechsler Intelligence Scale for Children (WISC–R; Wechsler, 1974). Scoring procedures of these tasks were based on the local norm established by Lin and Zhang (1986).

Visual Spatial Test

Children were each tested on visual spatial skills with the following measures.

WISC–R Block Design. The Block Design subtest of WISC–R, which requires construction of block arrays, was individually administered to each child. Scoring procedures were based on the local norm established by Lin and Zhang (1986).

Embedded figures. In this group-administered test (C. Zhang, 1998), each target figure is presented to the children on a separate page. Below each figure is a complex figure in which the target is embedded. Children were asked to draw the profile of different target figures from each of the 25 items. Each child was given 10 min to complete this task; 1 point was given for each item correctly drawn.

Articulatory Rate

To test articulation rate, we administered the following two tasks individually to each child.

Syllable Articulation Rate. In this task, the experimenter orally presented the child with either a pair of single syllables (e.g., guang1–yan2, meaning light–language), or a pair of two syllables (e.g., huang2he2–qiu1qian1, meaning yellow river–swing). Children were asked simply to repeat these syllable nonsense phrases 10 times as quickly as possible. Two of the articulation pairs were two-syllable items, and two of the articulation pairs were four-syllable items. Times articulating each phrase were measured with a stopwatch. The total score on this measure consisted of the average latencies across all four items.

Nonsense Syllable Articulation Rate. This task was similar in method and measurement to the syllable articulation task. However, the materials included for this task were phonetic syllables that were nonsense syllables in Chinese.

Visual Attention

In order to measure children's visual attention, children were administered the following two tasks in group settings.

Nonsense letter. Following the task created by Doehring (1968), we gave children a piece of paper with 540 nonsense letters on it. On a measure based on a subtest from the Students and Pupils Attention Test (Jin, 1995), children were asked to delete a reverse z with a pencil each time it appeared in random sequence among all of the letters. Children were given 1 min to delete the letter-like targets, and their score consisted of the number of reverse zs correctly deleted minus the total of letters that were incorrectly deleted.

Figures. We used the same technique of visual search to measure children's skills in detecting a trapezoid figure. From among 540 figures, children were asked to cross out only the trapezoid figures. Total score after 1 min spent on the task was again the total number of figures correctly crossed out minus those that were incorrectly crossed out.

Nonverbal Short-Term Memory

The Corsi Block 1 test is a nonverbal memory task. There are nine blocks (Milner, 1971). The blocks are numbered on the examiner's side for ease in recording performance, but the numbers are not visible to the children. On any trial, the examiner taps some of the blocks in a particular sequence and the child is required to tap out exactly the same pattern immediately afterward. The two scores obtained from this task are (a) whether on a given trial all the blocks were recalled in correct sequence (ordered) and (b) whether the total number of blocks were correctly recalled irrespective of sequence (total).

Results

Preliminary Analyses

Table 1 presents means, standard deviations, and separate F tests for all measures administered to the children in the dyslexic and control groups, respectively. Significant mean differences were found in all three literacy tasks and in morphological awareness, phonological awareness, rapid naming, lexical–vocabulary, and verbal short-term memory tasks. The control group attained higher scores than the dyslexic group across all of these tasks except for the rapid naming tasks, on which the dyslexic group was faster (i.e., taking fewer seconds to complete the task). In contrast, there were no group differences on the visual spatial tasks, articulatory rate measures, visual attention tasks, or test of nonverbal short-term memory. Pairwise Pearson's correlation coefficients for all linguistic variables included in the present study are presented in Table 2. The correlations between the two measures selected to measure each construct were significant (change by group). Table 3 shows the correlations of the three individual measures of literacy with all of the cognitive tasks administered for the children in the dyslexic and control groups separately.

Distinguishing Children With Dyslexia From Children Without Reading Difficulties

The first goal of this research was to use a large battery of tasks to distinguish readers with dyslexia from those without reading

problems using logistic regression analyses. Logistic regression analyses were carried out with variables from each of nine cognitive abilities, taking one cognitive ability at a time. This first step was taken to find the best predictors of reading deficit across each cognitive ability. This analysis used a backward stepwise selection following Elbro et al. (1998). At the second step of the analysis, the remaining statistically significant predictors from each cognitive ability were entered together in a final regression analysis. All results are reported below.

The first analysis assessed the predictive values of the morphological measures. These measures were morpheme production and morpheme judgment. When entered simultaneously into a logistic regression analysis, only morpheme production remained statistically significant, $\chi^2(1, N = 152) = 49.95, p < .001$. Hence, morpheme production was the only predictor that was carried over to the second step of the analysis.

Next, the predictive value of the phonological awareness measures, including both phoneme deletion and onset/rime/tone judgment, was analyzed. The only significant variable representing this construct for subsequent analysis was phoneme deletion, $\chi^2(1, N = 152) = 23.53, p < .001$. Across RAN tasks, the selected predictor was rapid naming of numbers, $\chi^2(1, N = 152) = 23.97, p < .001$, and of the lexical–vocabulary measures, only vocabulary was significant, $\chi^2(1, N = 152) = 27.99, p < .001$. Finally, short-term memory of numbers was the only significant predictor of the short-term memory measures, $\chi^2(1, N = 152) = 18.04, p < .001$. Of the other cognitive abilities, no significant variables emerged as predictors from the tasks representing visual skills, articulatory rate, or nonverbal short-term memory. Thus, altogether only five significant variables emerged from among the nine cognitive abilities tested in the first stage of the analysis (see Table 4).

At the second step of the analysis, we performed a new logistic regression that included all five significant variables from the first step. Once the five predictors had been entered into the equation together, the final model after backward stepwise selection contained three significant predictors. The three final significant predictors were morpheme production, $\chi^2(1, N = 152) = 20.10, p <$

Table 2
Correlations Among Individual Linguistic Tasks

Variable	1	2	3	4	5	6	7	8	9	10
Morphological awareness										
1. Morpheme production	—	.28*	−.00	−.02	.24*	.2	.13	.2	.38*	.35*
2. Morpheme judgment	.28	—	−.18	.00	.36*	.35*	.17	.26*	.39*	.40*
Rapid naming										
3. Picture	−.20	−.11	—	.60*	−.14	−.31*	−.24*	−.21	−.09	−.16
4. No.	−.28*	−.16	.58*	—	.04	−.13	−.17	−.27*	−.10	−.03
Phonological awareness										
5. Phoneme deletion	.47*	.26*	−.32*	−.33*	—	.42*	.10	.43*	.32*	.41*
6. Onset/rime/tone judgment	.51*	.27*	−.44*	−.50*	.63*	—	.25	.32*	.31*	.34*
Verbal short term memory										
7. Syllable repetition	.49*	.28*	−.11	−.34*	.30*	.29*	—	.35*	.19	.02
8. Number repetition	.57*	.36*	−.23*	−.40*	.49*	.47*	.69*	—	.24*	.14
Lexical vocabulary										
9. Vocabulary	.42*	.16	−.25*	−.17	.35*	.28*	.44*	.42*	—	.69*
10. Similarity	.39*	.16	−.06	−.05	.26*	.33*	.29*	.37*	.28*	—

Note. Correlations above the diagonal are for the children with dyslexia; those below the diagonal are for the nonimpaired readers.
* $p < .05$.

Table 3
Correlations Among Individual Measures for the Children With and Without Reading Difficulties

	Dyslexia			Control		
Variable	Word recognition	Comprehension	Dictation	Word recognition	Comprehension	Dictation
Morphological awareness						
Morpheme production, raw data	.39*	.20	.32*	.64*	.50*	.53*
Morpheme judgment, raw data	.25*	.25*	.19	.27*	.04	.12
Rapid naming						
No. naming in s	−.10	−.23*	−.02	−.23*	−.25*	−.22
Picture naming in s	−.07	−.20	−.10	−.30*	−.27*	−.38*
Phonological awareness						
Phoneme deletion, raw data	.24*	.24*	.32*	.46*	.39*	.33*
Onset/rime/tone judgment, raw data	.34*	.39*	.30*	.47*	.54*	.42*
Verbal short term memory						
Syllable repetition, raw data	.05	.22	−.03	.47*	.25*	.32*
No. repetition score	.23*	.48*	.27*	.57*	.28*	.41*
Lexical vocabulary						
Vocabulary score	.46*	.43*	.27*	.48*	.30*	.42*
Similarity score	.37*	.33*	.32*	.38*	.33*	.36*
Visual spatial test						
WISC–R Block Design score	.25*	.05	.09	.37*	−.04	−.07
Embedded Figures, raw data	.35*	.15	.22	.50*	.01	−.10
Articulatory rate						
Syllable Articulation Rate, raw data	−.11	−.09	−.06	−.43*	−.10	−.21
Nonsense Syllable Articulation Rate, raw data	−.03	.04	−.03	−.37*	−.09	−.19
Visual attention						
Nonsense letter, raw data	−.03	.001	−.14	.13	.07	.04
Figures, raw data	−.09	.12	.03	.06	.13	.04
Nonverbal short-term memory						
Corsi Block 1 (ordered), raw data	−.10	.20	−.14	.24*	.15	−.13
Corsi Block 2 (total), raw data	.11	.12	−.02	.11	.003	−.18

Note. WISC–R = Wechsler Intelligence Scale for Children—Revised.
* $p < .05$.

.001; rapid naming of numbers, $\chi^2(1, N = 152) = 8.60$, $p < .001$, and vocabulary, $\chi^2(1, N = 152) = 5.30$, $p < .05$.

The best test of the power of a set of predictors is to examine the extent to which a small group of predictors predicts individual reading difficulties (Elbro et al., 1998). The overall hit rate was 77.7%, with accuracy rates of both the dyslexic and control groups being very similar to one another.

To summarize, logistic regression analyses showed that only three variables significantly distinguished Chinese children identified as dyslexic and nonimpaired readers. The first two, morphological production and rapid naming of numbers, were ones that had been of particular interest to us a priori. The third was

vocabulary knowledge, which was not surprising given that dyslexic readers are often relatively poor in vocabulary skills (e.g., Stanovich, 1986).

Models of Literacy

The second part of our analyses focused on modeling literacy skills based on the constructs of greatest theoretical and practical importance in Chinese. The path analyses were conducted using Lisrel 8.53, a structural equation-modeling program, and *t* tests were used to examine the effects of predictors on reading. Our path analysis model included morphological awareness, speeded naming, vocabulary, and phonological awareness as our four primary constructs (see Figure 1). Although the phonological awareness

Table 4
Significant Variables in First Step Logistic Regression

Variable	$\chi^2(1, N = 152)$
Morpheme production	49.95
Phoneme deletion	23.53
No. naming	23.97
Vocabulary	27.99
No. repetition	18.04

Note. Chi-square is the change in −2 log-likelihood if the predictor is removed from the model.
All $ps < .001$.

Table 5
Prediction of Dyslexia

	Predicted (*n*)		
Observed	Dyslexic	Control	Prediction rate
Dyslexic	59	16	78.7%
Control	18	59	76.7%
Prediction rate	76.7%	78.7%	

Note. Cutoff value $p < .5$.

tasks were not among the final tasks predictive of reading in our logistic regression analyses, we had a priori planned to examine the strength of this construct, so central for understanding reading development and impairment in alphabetic orthographies, for Chinese reading. In addition, we sought to examine the associations across constructs. Because vocabulary knowledge had differed significantly across dyslexic and unimpaired reading groups, we included it in the modeling. Given that semantic and phonological information are consistently conveyed in speech and print, we were interested in the strengths of association among vocabulary, morphological awareness, and phonological awareness.

The reading measures focused on three relatively distinct aspects of literacy development. These were Chinese character reading, Chinese character dictation, and reading comprehension. Because the extent to which correlates of reading, spelling, and reading comprehension might differ in fifth- and sixth-grade Chinese students was unclear, we tested three separate path analyses models to reflect these different aspects of literacy. The results are shown separately for each literacy task, respectively, in Figures 2, 3, and 4.

It is interesting that in the model for Chinese character reading (see Figure 2), after we controlled the effects of vocabulary and speed naming, both morphological structure awareness, $\beta = .509$, $t(135) = 8.068$, and phonological awareness, $\beta = .192$, $t(135) = 3.267$, significantly explained variance in Chinese character reading. However, the association of morphological awareness to character recognition was stronger than that of phonological awareness as demonstrated by their respective beta weights. Similar results were obtained in explaining Chinese character dictation (see Figure 3) and reading comprehension (see Figure 4). The effects of morphological structure awareness on Chinese character dictation, $\beta = .509$, $t(135) = 5.588$, and comprehension, $\beta = .320$, $t(135) = 3.926$, were statistically significant at the .001 probability level, whereas phonological awareness measures contributed significantly to Chinese character dictation, $\beta = .193$, $t(135) = 2.752$, and comprehension, $\beta = .176$, $t(135) = 2.317$, at the .01 and .05 probability levels, respectively. In addition, as shown in Figures

2–4, speeded naming was a significant correlate of all three reading tasks; vocabulary significantly explained variance in Chinese character reading and comprehension but not Chinese character dictation. As expected, the morphological and phonological tasks were significantly and relatively highly associated as well ($r = .49$).

Potential Group Differences

A statistical invariance test was conducted to test potential reading differences across children with and without reading problems in each model. Across models, our strategy was to compare two parameter-nested models. One model allowed parameters to be freely estimated within each group (this model was saturated and fit the data perfectly). The other model constrained relevant estimates to be equal across the two reading groups. Results of the overall model comparison yielded nonsignificant differences involving Chinese character reading, $\Delta\chi^2(4, N = 152) = 1.662$, $p = .798$, root-mean-square error of approximation (RMSEA) = 0.000, normed fit index (NFI) = 0.990, nonnormed fit index (NNFI) = 1.075, comparative fit index (CFI) = 1.000, Incremental Fit Index (IFI) = 1.014, standardized root-mean-square residual (SRMR) = .021; Chinese character dictation, $\Delta\chi^2(4, N = 152) = 4.681$, $p = .322$, RMSEA = 0.048, NFI = 0.964, NNFI = 0.966, CFI = 0.993, IFI = 0.994, SRMR = .032; and comprehension, $\Delta\chi^2(4, N = 152) = 3.977$, $p = .409$, RMSEA = 0.000, NFI = 0.966, NNFI = 0.998, CFI = 1.000, IFI = 1.000, SRMR = .032. Separate tests of specific effects also revealed that none of these differences was statistically significant.

Discussion

Results of the present study highlighted the potential importance of morphological awareness for understanding literacy development and impairment in Chinese children. Logistic regression analyses demonstrated that our morphological production task most accurately discriminated adequate from nonimpaired readers
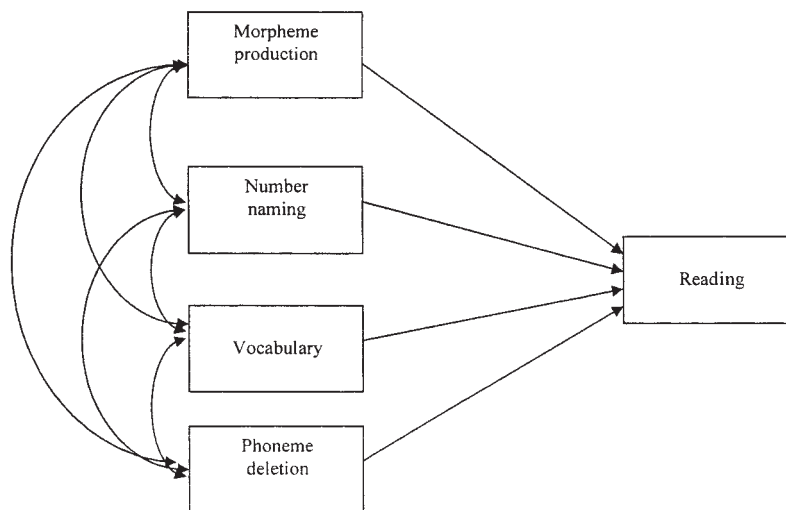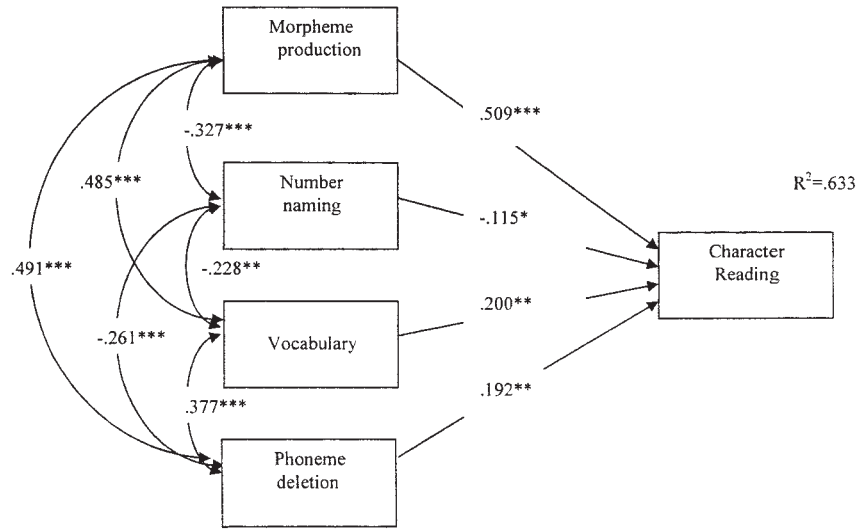

Figure 1. Complete model.

Figure 2. Model of Chinese character recognition. *p < .05. **p < .01. ***p < .001.

in this sample. Speeded naming of numbers also strongly distinguished the groups, though tasks of memory, visuospatial skills, and phonological awareness, among others, did not. Using path analyses, we further demonstrated that the morphological awareness task was the strongest cognitive correlate of character recognition, dictation, and reading comprehension and that these associations did not differ across reading groups. Measures of phonological awareness and speeded naming were also uniquely associated with all three measures of literacy skills. Below, we highlight morphological awareness in relation to literacy development and reading impairment among Chinese children.

The importance of our research is in its theoretical linking of morphological characteristics of Chinese (e.g., Packard, 2000) to practical aspects of reading impairment and development in Chinese. The clear compounding morphological structure, along with the large number of homophones of Chinese, together suggest

strategies and difficulties that may be somewhat striking in Chinese relative to other (at least alphabetic) orthographies. As children learn to read Chinese, they look for systematic associations and regularities in their spoken and written language to exploit to maximize learning. Children are naturally analytical in their approach to script. What may be particularly obvious to the young Chinese learner is the regularity of the morphemic structure of the language (McBride-Chang, et al., 2003; Shu & Anderson, 1997).

Thus, for example, in the context of reading a Chinese passage, if a child comes to unknown characters, she or he may be better able to get a general meaning of the text with morphological knowledge. Knowing that there is a morpheme [che1], meaning, roughly, a wheeled vehicle, for instance, may help children to get the approximate meaning of a passage that includes a word such as *zi4xing2che1* (*bicycle*), *qi4che1* (*car*), or *huo3che1* (*train*) when encountering such words in print. Location of the character *che1*
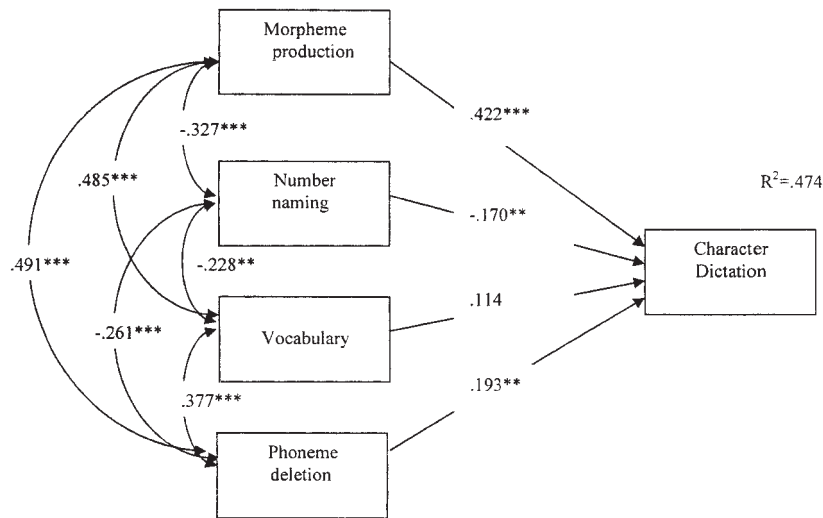

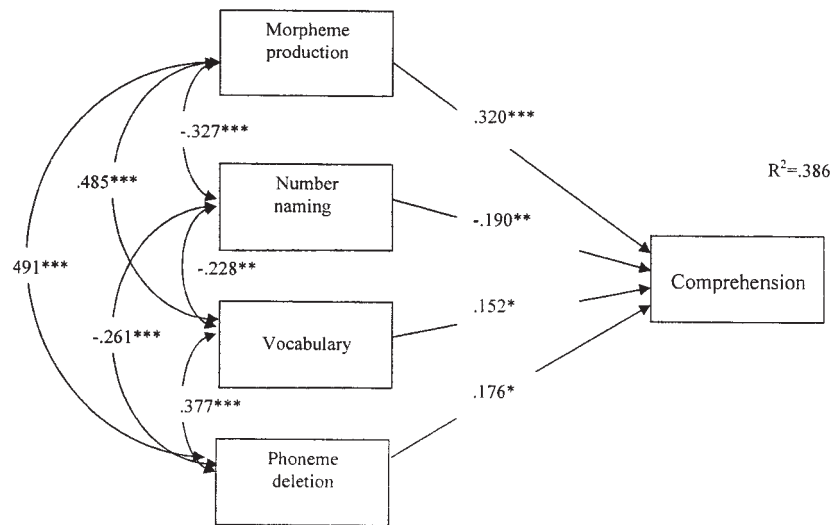*Figure 3.* Model of Chinese character dictation. **p < .01. ***p < .001.

Figure 4. Model of reading comprehension. **$p < .01$. ***$p < .001$.

and an unknown character preceding it might prompt an alert child to think about what type of *che1* is being discussed. Based on context or by process of elimination (e.g., the Chinese character *huo3* is already known to the child, so the character in question cannot be *huo3*, but the character *qi4* is unknown and is plausible in the context of the passage), a child may make an educated guess as to the meaning of the passage if skills in morphological awareness are well developed. Although it is clear that word reading in English may involve relatively little utilization of context (e.g., Adams, 1990), it is unclear whether this is also true for Chinese. Because Chinese is relatively unreliable phonologically, when a child encounters an unfamiliar word in Chinese, she or he has no way to know its meaning without help from others or by using morphological knowledge and context for educated guessing. Learning to read Chinese clearly requires more extended adult supervision and support than does learning to read an alphabetic orthography (e.g., H. Li & Rao, 2000). Thus, it is plausible that the clear morphemic structure of Chinese may help children in learning to read both at the word and passage levels. Similarly, inability to internalize this characteristic of one's native language clearly may impair reading development by slowing the process of character recognition and reading comprehension.

Distinguishing meanings across homophones is also helpful in learning to recognize and understand text (McBride-Chang, et al., 2003; Shu, Meng & Lai, 2003). With the vast number of homophones in Chinese, good readers must rely on different characters discriminating meanings in homophones to derive meaning from text. To perform successfully on the morphological production task, children have to be able to identify a given morpheme in another word. Mistakes in confusing homophone meanings in this task yield language errors crucial for reading text. A parallel example in English might be confusion in a child's interpretation of the word *before* as meaning *be four* or interpreting the word *grandson* to mean *grand sun*. Although such confusions are likely relatively rare in English, which has few homophones to begin with, one can imagine that routine confusions such as these in Chinese could potentially lead to both word recognition and reading comprehension problems over time.

As is the case for all languages and scripts, morphological and phonological information are clearly linked in Chinese. Thus, our constructs of morphological and phonological awareness were strongly associated with one another. In addition, the phonological awareness and RAN constructs were significantly associated, indicating that RAN tasks likely tap phonological skills as well as many other abilities, including visual skills (e.g., Ho et al., 2002, 2004). Of interest, phonological awareness, RAN, and morphological awareness were all significantly associated with all three measures of literacy administered to the children. Thus, apart from morphological awareness, phonological processing skills remain important for reading in Chinese, even among upper primary schoolchildren. We therefore do not wish to argue simplistically that morphological skills are important for Chinese and phonological skills are not. Both morphological and phonological skills are intrinsic to language and must coexist. Our analyses also demonstrate that morphological and phonological awareness uniquely explain literacy performance. What is new in these data, however, is the fact that one measure of morphological awareness was a particularly strong correlate of literacy across groups and reading-related tasks.

This study had at least four limitations. First, our sample was limited to children from Beijing. Other previous explorations of reading disabilities in relation to various cognitive constructs have been carried out primarily with Hong Kong children (Ho et al., 2002, 2004). Hong Kong children differ from Beijing children in the age at which literacy instruction begins, literacy instruction itself, language(s) spoken, and even script (simplified characters in Beijing, traditional characters in Hong Kong; Cheung & Ng, 2003). Thus, the extent to which our results are generalizable across Chinese societies remains unclear.

Second, we did not include the orthographic measures included in studies by Ho et al. (2002, 2004). Although our choices of tasks were motivated by the desire to measure relatively "pure" cognitive skills, in the absence of print, future studies of Chinese reading impairment should also include such orthographic measures to determine the relative weightings of morphological and phonological awareness in relation to orthographic skills.

Third, our two measures of morphological awareness were rather weakly associated with one another. Because these measures are relatively new and unexplored, we can only speculate on this association. It is likely that the forced-choice format for the judgment task reduced variability of this task. In addition, the judgment task was group administered, whereas the production task was individually administered. Still, further studies are needed to better understand differences across these two tasks. A higher association across tasks conceptualized to measure the same underlying construct would be useful in confirming the core cognitive skill tapped by each.

Finally, we cannot establish causal associations between literacy skills and morphological production in the present study. It is clear that morphological awareness and literacy skills are likely bidirectionally associated. It may, in fact, be the case that morphological awareness is a consequence rather than a cause of reading difficulties. For example, although magnitudes of association of each task with literacy measures tended to be higher in the children without reading difficulties compared with those with reading problems, the associations of the morphological awareness task with all literacy measures among the nonimpaired readers were strikingly high (all at or above .5). Having established a strong relation between morphological awareness and literacy skills, we must turn to the causal nature of this association in future studies.

Thus, despite these limitations, we believe that these results give a clear direction to future research in this area. These findings, in addition to others on younger developing readers (McBride-Chang et al., 2003) and on older Chinese readers (Shu & Anderson, 1997) clearly demonstrate that the concept of morphological awareness should be thoroughly explored in understanding reading development and impairment in Chinese children. The outstanding linguistic and script features of Chinese that suggest the theoretical importance of morphological awareness for reading this script are largely absent in English. Thus, an exploration of morphological awareness in Chinese requires not a replication or extension of findings from other alphabetic languages but rather an extensive exploration of features of Chinese, and perhaps other Asian languages (e.g., Korean, Japanese), that highlight the unique features of semantic relationships communicated through these languages. Although there has been extensive research on morphological skills in relation to expert adult reading of Chinese, research on Chinese children's reading acquisition and impairment is relatively limited. Developmental approaches to tapping both explicit and implicit morphological awareness among developing readers offer exciting new directions for the field.

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