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The dynamic relationship between phonological awareness, morphological awareness and character reading in chinese early readers: a three-year longitudinal study

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Abstract

In this study, we examined the relationship between phonological awareness (PA), morphological awareness (MA), and character reading in Chinese kindergarten children. One hundred and twenty children were assessed in each of their three years at the kindergarten, with 12-month intervals in between. Using cross-lagged panel modeling, we found that: (1) from Time 1 to Time 2, character reading predicted PA and MA, and PA negatively predicted illiteracy; (2) from Time 2 to Time 3, MA predicted PA and character reading; (3) significant autoregressive effects were found in all three main variables at the two time intervals. The results indicated the benefits of reading experience to the development of oral language skills and the pivotal role of MA in both reading and oral language skills in Chinese early readers.

Keywords Phonological awareness · Morphological awareness · Character reading · Preschool children · Cross-lagged panel model

Previous studies have found consistently that phonological and morphological awareness contribute to reading development in Chinese children (e.g., Li et al., 2012; McBride-Chang et al., 2003; Pan et al., 2016). Most of these studies have focused on the contribution of morphological awareness (MA) or phonological

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awareness (PA), or their relative importance, to reading outcomes, whereas few have examined how the skills themselves develop and interact, or how reading abilities affect these skills longitudinally, especially in Chinese early readers. However, recognition of these relationships is important in updating the current theories on reading development (Cain Barnes, 2017). In this study, we investigated the bidirectional relationships between phonological awareness, morphological awareness, and character reading in Chinese kindergarten children using a three-year longitudinal design.

Phonological awareness and reading development in chinese children

PA, defined as the ability to operate phonological parts (e.g., syllables) of spoken words (Oakhill Kyle, 2000), is an important predictor of reading outcomes in Chinese children, particularly in early readers such as kindergarteners (e.g., Pan et al., 2016; Shu et al., 2008). Ho Bryant (1997) suggested that PA helps children to recognize the association between phonetic radicals and pronunciations in Chinese characters. Better PA also means that they can attain well-specified phonological representations of morphemes (i.e., the smallest meaning unit in a language), which support the mapping of sound and meaning to orthographic form (Perfetti, 2017).

PA has been found to contribute to character reading during the early stage of reading development. Despite the phonological structure of Chinese being regular and transparent (e.g., the Chinese syllables can be coded by about 22 onsets and 37 rimes directly, with larger grain size than phoneme) (Ziegler Goswami, 2005), young children still need to grasp the awareness of it to facilitate their learning to read. For example, Shu et al., (2008) found that PA in the form of syllable awareness and tone awareness significantly predicted character reading with age, vocabulary, and rapid naming controlled in kindergarteners from Beijing. Similarly, Tong et al., (2011) found that syllable awareness predicted character reading in kindergarten children from Hong Kong after controlling age, vocabulary, and nonverbal intelligence. In the 9-month longitudinal study by Chow et al., (2005), PA (in the form of syllable awareness) was the only significant predictor (among vocabulary, verbal memory, rapid naming, and visual skills) of character reading both concurrently and longitudinally in kindergarteners from Hong Kong.

Morphological awareness and reading development in chinese children

MA is the explicit awareness of word structure and the ability to manipulate the structure (Carlisle, 1995). It is a major predictor of reading ability in Chinese children (e.g., McBride-Chang et al., 2003, 2005). Based on the characteristics of the language (i.e., numerous homophones/homographs and the productive compounding morphology), two levels of MA in Chinese have been proposed (e.g., Liu et al., 2013). Specifically, at the morpheme level, MA represents the ability to differentiate

the morpheme from its homophones and homographs; at the morphological structural level, it refers to the knowledge about the word structure. Both levels are believed to support Chinese children learning new words (Liu et al., 2013).

Many researchers have considered MA particularly important to Chinese children's reading development (e.g., Chen et al., 2009). This prominent role is related to the characteristics of the Chinese language. Specifically, the almost one-to-one-to-one correspondence between morpheme, character and syllable, the great number of homophones and homographs, and the productive compounding morphology of the language all highlight morphological awareness in learning to read Chinese (e.g., McBride 2016).

The utility of MA in Chinese children's literacy development is increased further because of the transparency of Chinese morphology. Specifically, the forms and the sounds of morphemes remain largely unchanged when a word is composed in Chinese (Kuo Anderson, 2006). Moreover, researchers have suggested that Chinese morphology is generally more transparent and analytical than that of English, as the compounding words were often built upon simpler words (Ho, 2014; McBride-Chang et al., 2003). For example, the word *mask* in English is opaque, in contrast, in Chinese, the word is comprised of two morphemes which separately, mean *mouth* and *cover*. This straightforward morphology facilitates the deduction of word meaning through its morphemes and structure. As a result, MA was found to predict reading uniquely in kindergarten, the stage in which children are mostly learning simple and transparent words (e.g., Li et al., 2012; Lin et al., 2019).

The developmental relationship between PA and MA in Chinese early readers

PA may provide the foundation for the development of MA in Chinese children. A longitudinal study by Pan et al., (2016) found that preliterate syllable awareness contributed indirectly to character reading in primary school via post-literate MA in Chinese children. Their findings suggested that syllable awareness lays the foundation for the development of MA in the early stages of reading development and contributes indirectly to character reading via MA in the later stages. Specifically, the ability to segment spoken language into syllables is a prerequisite for recognizing morphemes, which is the first step to developing MA. However, this prediction of MA (measured in primary school) by early PA (measured in kindergarten) was conducted over a large time scale in Pan et al.'s (2016) study, it is still unknown how PA and MA interact with each other in the beginning learning phase.

In addition, after children have acquired certain levels of MA, the relationship between PA and MA may become bidirectional. Because of the productive and transparent compounding morphology of the language, MA is a powerful device in facilitating language and reading development in Chinese children (e.g., McBride-Chang et al., 2005). Owing to the correspondence between morpheme and syllable, MA as the ability to delineate and manipulate morphemes during word learning may entail the ability to delineate and manipulate syllables (i.e., syllable awareness). For example, when children realizing the word 红花 (/hong2 hua1/, red-flower, red

flower) is a two-morpheme word with the subordinate morpheme 红 (red) modifies the head morpheme 花 (flower) (i.e., subordinate word structure), they are also identifying the corresponding two syllables /hong2/ and /hua1/. Moreover, when they see a yellow flower and use lexical compounding awareness to name it as 黄花 (/huang2 hua1/, yellow-flower, yellow flower), they are not only manipulating the morphemes but also the syllables. Therefore, MA may also contribute to PA during language and reading development.

Kuo Anderson (2006) specified MA as the "knowledge about pairings of sound and meaning in a language and the word formation rules" (p. 161), whereas PA is the ability to manipulate phonological parts of words. Because of the added semantic component, it is believed that MA calls for a more general maneuvering of the language-related knowledge (Kuo Anderson, 2006). Similarly, Carlisle (1995) believed that MA is a more general indicator of metalinguistic ability compares to PA.

The relationship between PA and MA has been investigated in alphabetic languages with the experimental training design. For example, Casalis Colé (2009) trained two groups of French-speaking kindergarteners in MA (with a focus on derivational morphology) and PA (with a focus on phoneme manipulation). Reciprocal training effect were found between MA and phonological ability, specifically, the MA training group has improvement in phonological sensitivity (but not the manipulation of phonemes), and the PA training improved their ability to segment morphemes.

A stronger reciprocal training effect was found in the study conducted in a group of Norwegian-speaking kindergarteners by Lyster (2002), in which the PA training group had improvement in morphological knowledge and awareness, and the MA training group had improvement in identifying and manipulating phonemic structures in words. In Lyster's (2002) study, the manipulation of compounding morphology was the focus of the MA training. Additionally, both PA and MA training involved print exposure (Lyster, 2002; Casalis Colé, 2009) suspected the two differences (i.e., a focus on compounding morphology for the MA training and print exposure) in the training design may explain the larger reciprocal training effects found in Lyster (2002) compared to the results in their study.

Because the productive compounding morphology and the almost one-to-one-to-one correspondence between syllable, morpheme, and character in Chinese, a reciprocal relationship between PA and MA could be emerged in Chinese children, especially when the PA task is at the syllable level. However, as the print exposure for the early readers is limited, it is still unknown how the three factors (i.e., PA, MA, character reading) interact in this developmental phase.

The bidirectional relationships between the two metalinguistic awareness and character reading

In addition to the effects of the two metalinguistic awareness (PA, MA) on reading ability, some researchers have also examined the effect of reading on metalinguistic awareness, as well as their bidirectional relationships in Chinese early readers. For

instance, in a longitudinal study, Chow et al., (2005) found a reciprocal relationship between PA and word reading in Chinese kindergarten children. These researchers have suggested that, because of the correspondence between character and syllable, print experience may sensitize children's syllable awareness (Chow et al., 2005). In contrast, a study by Liu Chung (2021) found that early word reading predicted later PA, but not vice versa, in Chinese kindergarten children. The different result may be due to the difference in the statistical method used in the two studies. Specifically, the regression method was used by Chow et al., (2005), while cross-lagged path modeling was used by Liu Chung (2021), which was a more stringent control method.

Since character and morpheme are also almost in correspondence by unit (like character and syllable) in Chinese, the print experience may also improve MA. Moreover, in explaining the observed path from reading to MA, Deacon et al., (2013) suggested that learning to read in English advances knowledge about morphemes, especially for the words that have more recognizable morphemes in print (e.g., breakfast). In Chinese, the large number of homophones (i.e., different morphemes with the same pronunciation) increases the difficulty of morpheme recognition in oral language. However, when in print, homophones are represented by different characters that differentiate the morphemes clearly. Moreover, the visualized characters may facilitate the understanding of the relationships between morphemes.

Indeed, Hulme et al., (2019) found that the initial level of word reading predicted the growth of morphological awareness in Chinese lower graders. Reciprocal relationships between reading and MA were also found in Chinese children (e.g., Cheng et al., 2016). For example, Cheng et al., (2016) have found the bidirectional relationship between MA and reading comprehension in lower grade students, though the bidirectional relationships between MA and word reading were not investigated. Instead, Cheng et al., (2016) only considered the cross-lagged path from MA to word reading in examining its longitudinal indirect effect on reading comprehension. Their result showed that early MA did not predict later word reading across the three timepoints in their study.

In the study by Wu et al., (2009), the bidirectional relationship between word reading and MA was found in grade 3 students, while the unidirectional relationship from MA to word reading was found in grade 2 students. However, both relationships described by Wu et al., (2009) were fitted with concurrent MA and word reading in structural equation models, so the longitudinal relationship between the two constructs was not clear. Dulay et al., (2021) examined the bidirectional relationships between MA, vocabulary, and word reading using a two time-point (approximately 1 year in between) cross-lagged model in Chinese first grade students, which found the prediction of time 1 MA on time 2 word reading and the prediction of time 1 word reading on time 2 vocabulary but not the bidirectional relationship between MA and word reading (Dulay et al., 2021).

In sum, evidence for both directions of the relationship between MA and word reading was observed in previous studies. However, due to the differences in the methodology and the participants, the results were not consistent. In addition, the participants in the above-mentioned studies were mostly primary school children; to our knowledge, there have not been any studies examining the bidirectional

relationships between PA, MA, and word reading during the kindergarten period in Chinese children.

Previous studies assumed children have possessed some levels of reading ability and examined the relationships between metalinguistic awareness and reading ability. However, we still do not know how metalinguistic awareness influence the emergence of reading ability (i.e., from illiteracy to literacy) and how the limited reading ability affect metalinguistic awareness in Chinese early readers. In addition, the relationships between metalinguistic awareness and reading ability at this phase reflect the primary developmental relationships between these abilities, whereas the relationships became secondary after the children received formal literacy education at school. In other words, the relationships are affected by the formal literacy instruction once the children entered primary school.

For example, *Pinyin*, a phonological coding system for Chinese character, was introduced in the first grade in primary school in mainland China. Its introduction was accompanied with a sharp improvement of PA in Chinese children, which in turn promote their Chinese word reading (Lin et al., 2010; Shu et al., 2008). In sum, the early literacy phase in kindergarten allows researchers to examine the primary developmental relationships between metalinguistic awareness and reading ability, and how metalinguistic awareness influence the emergence of reading ability and vice versa.

One of the reasons for the lack of research in this phase may be that the early reader's ability is rudimentary. As a result, many of the children are illiterate (i.e., score zero in reading tasks), which can skew the distribution of reading scores and in turn cause difficulties for statistical analysis. Recently, some researchers have used the zero-inflated negative binomial (ZINB) model to deal with data that contain a high number of zero values (e.g., Chan et al., 2019). When this method is utilized to investigate the relationship between metalinguistic awareness and word reading, the prediction of the metalinguistic awareness on literacy (or not), in addition to the reading score, can be examined.

The present study

This study focused on the reciprocal relationships between PA, MA, and character reading in the early stage of reading development. We followed a group of Chinese kindergarten children from K1 to K3 (i.e., from the first to the third year in kindergarten) and examined the reciprocal relationships between the three variables using the cross-lagged panel modeling. Syllable awareness was chosen to represent PA in this study. Because of its correspondence with morpheme and character in Chinese, syllable is a particularly salient phonological unit for Chinese children (Shu et al., 2008). Moreover, compared to other types of phonological awareness (e.g., phoneme awareness), syllable awareness develops early, which made it suitable for the young children who were our participants (Shu et al., 2008). The syllable awareness task used in this study has been used successfully in children from mainland China in previous studies (Lin et al., 2010; Shu et al., 2008). Age appropriateness was also considered in selecting the MA task in this study. Between the two levels of

MA in Chinese, morphological structural awareness emerged in children as young as 2 years old (e.g., child made up the word *plant-man* for *gardener*) (Clark, 1995), whereas the morpheme awareness (i.e., homophone and homograph awareness) is believed to be challenging for kindergarten children because their limited vocabulary (Liu et al., 2013).

Thus, a lexical compounding awareness task, which required the children to identify morphemes and construct new words according to the morphological rules, was adopted as the index of MA in this study. The Cantonese version of the task has been used successfully in children from Hong Kong (e.g., Lin et al., 2019; Liu et al., 2013). The task with similar format has also been used in children from mainland China in previous study (Liu McBride-Chang, 2010). Considering the limited reading ability of early readers, Chinese character reading was operationalized as the children's reading ability in this study, this operationalization was applied in previous studies on Chinese early readers (e.g., McBride-Chang et al., 2003; Shu et al., 2008; Yang et al., 2019). Due to the correspondence between morpheme and character, Chinese characters can be viewed as single-character words, and it has a correlation of around 0.90 with two-character word reading in previous studies (e.g., Pan et al., 2021; Yang et al., 2022). Due to the correspondence between syllable, morpheme, and character in Chinese, the PA, MA, and character reading tasks in this study are likely to correlate with each other. However, the three tasks examine different abilities, which reflect on the task designs. Both PA and MA tasks tap the skills in oral language while the reading task focuses on the ability to pronounce Chinese characters in print. Thus, PA and MA tasks are aurally presented with no print exposure, whereas the reading task is presented in print. Between the PA and MA tasks, the former taps the ability to manipulate syllable by asking the children to delete one syllable from a three-syllable string with no semantic processing in each item, while the latter taps the knowledge of Chinese word structure and manipulate morphemes accordingly by asking the children to create a novel word with a semantically weaved scenario in each item.

We proposed three research questions for this study:

1. Whether PA and MA are contributors to character reading across the three years in kindergarten,
2. Whether the basic reading ability in Chinese early readers could support the development of PA and MA,
3. Whether the reciprocal relationship between PA and MA could emerge reading across the three years in kindergarten.

Method

Participants

The original sample consisted of 120 (age: $M = 50$ months, $SD = 3.46$ months; 62 girls) K1 children from two public kindergartens in Beijing, China. Of these, 118 (age: $M = 62$ months, $SD = 3.49$ months; 60 girls) were tested in K2 and 99 (age:

$M = 74$ months, $SD = 3.50$ months; 50 girls) in K3. The attrition was due to children's absences during the data collection (e.g., sick leave) or kindergarten transfer. No significant differences were found between the children who stayed and those who dropped out in terms of the variables measured in the previous wave, $ts < 1.78$, $ps > 0.08$. As explained above, in mainland China, children do not receive formal literacy instruction in kindergarten (Li et al., 2008), so their literacy skills are only acquired through informal instruction by parents and teachers (McBride, 2016).

All participants in this study were native Chinese speakers. Written consent was obtained from the participants' legal guardians and assent was obtained from each child before participating in the study. This study was approved by the Human Research Ethics Committee of The Education University of Hong Kong and conformed to the Declaration of Helsinki.

Procedure

The children were tested individually by trained experimenters in a quiet room in the kindergarten. All three waves of data were collected near the end of the second semester each year. Nonverbal intelligence was measured only at K1, and the other tests were administered at all three times.

Measures

Nonverbal intelligence

The Raven's Standard Progressive Matrices (Raven et al., 1995) was used to measure nonverbal intelligence. Set A and B, which consist of 24 items, were used. One point was given for each correct answer.

Phonological awareness

A syllable deletion task was used to measure the children's ability to identify and manipulate syllables. In each item of the task, the experimenter orally presented a three-syllable word. The children were asked to repeat the word first, then to remove one syllable and respond with the remaining syllables according to the instruction. For example, experimenter asked children to repeat the word /xia4 wu3 cha2/, then asked them not to say the syllable /wu3/ and respond the remaining syllables, the correct answer is /xia4 cha2/. This task consisted of 16 items, including deletions of 6 initial, 6 medial, and 4 final syllables. One point was given for each correct answer. Similar tasks have been used successfully in previous studies with Chinese kindergarten children (e.g., Zhang et al., 2014).

Morphological awareness

The morphological construction task was used to measure the children's lexical compounding awareness. In each item of the task, the children were asked to produce a novel word to describe the scenario that had been presented orally by the experimenter. For example, the experimenter asked, "Here is a piece of paper. Since it is white, we call it white paper. Here is another piece of paper. It is red. What should we call it?" The correct answer was "red paper". This task consisted of 27 items. One point was given for each correct answer. This task has also been used in a previous study with Chinese kindergarten children (Lin et al., 2019).

Chinese character reading

This task consisted of 150 single characters, arranged from easy to difficult. The children were asked to read the characters one by one from the beginning. One point was given for each correct answer. The test stopped when a child failed to answer 15 consecutive items correctly. This task has been used in a previous study with Chinese kindergarten children (Li et al., 2012). The first 40 items were judged by two kindergarten teachers to be orally familiar to the kindergarten children, the other 110 items were judged by two primary school teachers to be orally familiar to primary school children, the first 40 characters have also been used successfully in kindergarten children as character reading task (Li et al., 2012; Shu et al., 2008).

Analytic plan

To examine the cross-lagged relationships among children's morphological awareness, phonological awareness, and Chinese character reading, the cross-lagged models were specified in M*plus* 8.3 (Muthén Muthén, 1998–2018). Missing data were handled with the full information maximum likelihood method, and the maximum likelihood robust (MLR) estimator was used to estimate the model parameters. The scores for PA, MA, and the control variables were transformed into *z*-scores before entering the model.

Because the scores for the character-reading task had high numbers of zeros, we used the ZINB model to capture the distributions of character reading scores. The ZINB model captured the scores for character reading in two parts: (1) *the negative binomial count part*, where a positive coefficient indicates higher reading ability; and (2) *the logistic part*, where a positive coefficient indicates a higher likelihood of scoring zero (i.e., illiterate in this study) over scoring at least one. To facilitate interpretation, standardized coefficients (β) were calculated for the linear part of the cross-lagged model. The unstandardized coefficients (*b*) of the logistic part were exponentiated as odds ratios (*OR*), and the unstandardized coefficients (*b*) of the count part were exponentiated as incidence rate ratios (*IRR*).

Our model included autoregressive and cross-lagged pathways across three variables, as well as control paths from age and nonverbal intelligence to three main

Table 1 Descriptive statistics for the variables in this study

	K1					K2				K3			
	age	NI	PA	MA	CCR	age	PA	MA	CCR	age	PA	MA	CCR
M	50.01	8.73	3.33	11.31	4.09	62.49	7.74	17.28	9.75	74.17	11.19	20.27	15.57
SD	3.46	3.38	3.82	6.22	10.80	3.49	5.08	5.08	20.83	3.50	4.78	4.61	24.51
Cronbach's α	–	–[†]	0.89	0.91	0.98	–	0.91	0.90	0.99	–	0.91	0.88	0.99
Min	41	2	0	0	0	54	0	0	0	66	0	0	0
Max	57	16	16	25	66	69	16	27	90	81	16	27	90
Skewness	−.0.002	−0.41	1.14	−0.12	3.91	−0.08	−0.12	−.0.59	2.55	0.06	−0.74	−1.16	1.92
Kurtosis	−1.00	−0.54	0.61	−0.78	18.02	−1.12	−1.08	0.59	6.01	−1.09	−0.49	2.98	2.83
N	120	120	120	120	120	118	118	116	118	99	99	99	99

K1 = kindergarten year one; K2 = kindergarten year two; K3 = kindergarten year three; NI = nonverbal intelligence; PA = phonological awareness; MA = morphological awareness; CCR = Chinese character reading. [†]The reliability of the nonverbal intelligence test was not calculated because this measure is from a standardized test

Table 2 Pearson correlation for the measures in this study

	1	2	3	4	5	6	7	8	9	10
1. NI_K1	–									
2. PA_K1	0.30**	–								
3. MA_K1	0.37**	0.51**	–							
4. CCR_K1	0.07	0.43**	0.27**	–						
5. PA_K2	0.26**	0.51**	0.40**	0.37**	–					
6. MA_K2	0.42**	0.42**	0.61**	0.29**	0.41**	–				
7. CCR_K2	0.11	0.50**	0.27**	0.82**	0.42**	0.34**	–			
8. PA_K3	0.36**	0.40**	0.48**	0.12	0.52**	0.45**	0.17	–		
9. MA_K3	0.33**	0.47**	0.49**	0.26*	0.34**	0.45**	0.34**	0.40**	–	
10. CCR_K3	0.18	0.53**	0.36**	0.74**	0.35**	0.41**	0.90**	0.20*	0.39**	–

NI = nonverbal intelligence; PA = phonological awareness; MA = morphological awareness; CCR = Chinese character reading; K1 = kindergarten year one; K2 = kindergarten year two; K3 = kindergarten year three

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

Table 3 Estimates and standard errors for the cross-lagged model

	K2 outcomes					
	MA	PA	CCR logistic portion (Illiteracy/Literacy)		CCR counts portion (Reading scores)	
K1 Predictors	β *(SE)*	β *(SE)*	*b (SE)*	*OR*	*b (SE)*	*IRR*
MA	0.45 (0.08)***	0.14 (0.11)	-0.20 (0.39)	0.82	0.10 (0.16)	1.10
PA	0.08 (0.10)	0.34 (0.09)***	-3.46 (2.04)†	0.03	0.12 (0.19)	1.12
CCR	0.18 (0.005)**	0.19 (0.03)***	/	/	0.13 (0.04)**	1.14**
	K3 outcomes					
	MA	PA	CCR logistic portion (Illiteracy/Literacy)		CCR counts portion (Reading scores)	
K2 Predictors	β *(SE)*	β *(SE)*	*b (SE)*	*OR*	*b (SE)*	*IRR*
MA	0.46 (0.08)***	0.33 (0.12)**	− 0.0.23 (0.59)	0.80	0.30 (0.12)*	1.31*
PA	0.13 (0.12)	0.43 (0.11)***	0.25 (0.60)	1.28	-0.02 (0.13)	0.98
CCR	0.01 (0.02)	− 0.37 (0.01)	/	/	0.04 (0.006)***	1.04***

K1 = kindergarten year one; K2 = kindergarten year two; K3 = kindergarten year three; PA = phonological awareness; MA = morphological awareness; CCR = Chinese character reading; SE = standard error; OR = odd ratio; IRR = incident rate ratio. Standardized coefficients (βs) were used for the linear part of the cross-lagged model, unstandardized coefficients (*b*s), odd ratio, and incident rate ratio were used for the nonlinear part of the model

†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$

variables. Residual variances of phonological awareness and morphological awareness at the same time point were set to correlate. For the baseline model, the autoregressive and cross-lagged paths were set to be time invariant. This baseline model

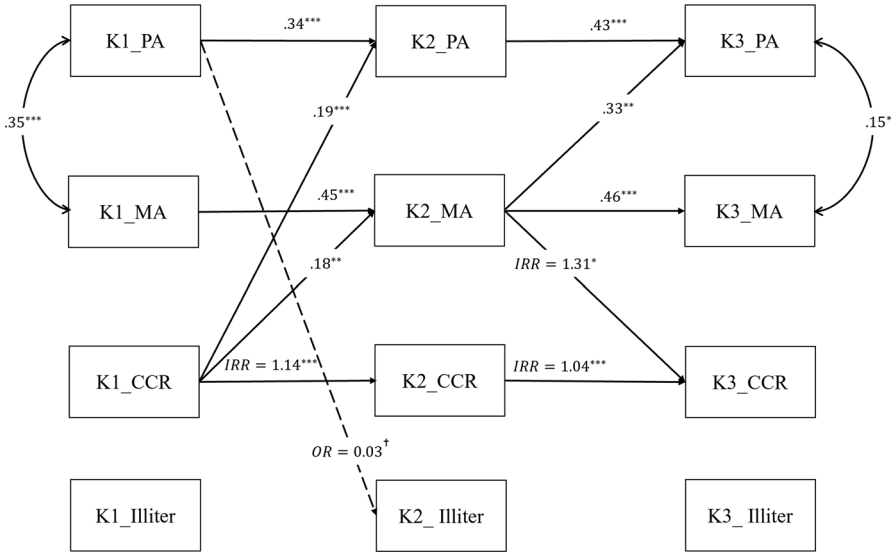

Fig. 1 Path estimates for the cross-lagged panel model in this study
Note. K1 = kindergarten year one; K2 = kindergarten year two; K3 = kindergarten year three; PA = phonological awareness; MA = morphological awareness; CCR = Chinese character reading; Illiter = illiteracy. Standardized coefficients were used for the linear part of the cross-lagged model, odd ratio (OR) and incident rate ratio (IRR) were used for the nonlinear part of the model. The nonsignificant paths and the control paths were removed for clarity
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

was compared to a more complex model which allows the autoregressive and cross-lagged paths to be estimated freely over time. Because the fit indices (e.g., root mean square error of approximation) were not available for the ZINB model, the final model was selected by comparing the relative fitness of the two models, which was based on sample-size adjusted (SSA) BIC and Satorra-Bentler scaled Chi-Square difference test.

Specifically, a smaller value of SSA BIC represents a better fit. A significant result of the Satorra-Bentler scaled Chi-Square difference test indicates that the more complex model has a significant improvement in model fit and thus the complex model should be retained, whereas a nonsignificant result indicates that the added complexity does not significantly improve the model fit, and thus the baseline model should be retained. It is noted that our sample size is relatively small. However, given that we are estimating path model composed of only single indicator for each construct and the measures were carefully chosen to be highly reliable and valid in previous studies, the model can be reasonably run with the current sample size (Wolf et al., 2013).

Results

The descriptive statistics for the variables in this study are presented in Table 1, and the correlations between measures are presented in Table 2. The results show that PA, MA, and character reading were correlated both concurrently and longitudinally, except for the PA at K3 that was not significantly correlated with character reading at K1 and K2. The Tolerance Index and variance inflation factor (VIF) were computed to estimate the degree of multicollinearity using PA, MA, and character reading at K1 and K2 as independent variables and PA, MA, and character reading at K2 and K3 as dependent variables, respectively. The results showed that the tolerance values were all larger than 0.64 (the value smaller than 0.2 would indicate multicollinearity) and VIF were all smaller than 1.58 (the value larger than 5.0 would indicate multicollinearity), indicating there was no issue of multicollinearity in the present analysis (Menard, 1995).

For the baseline model with the paths set to be time invariant, SSA BIC = 3248.95. For the more complex model with the paths set to be freely estimated across times, SSA BIC = 3242.44, which indicated that this model had a better fit. The Satorra-Bentler scaled Chi-Square difference test also showed that the more complex model had a significantly better fit compared to the baseline model, $\Delta x^2(11) = 22.94$, $p = .018$. Thus, we retained the more complex model as the final one.

In this model (see Fig. 1), with age and nonverbal intelligence controlled, the autoregressive paths at the two time intervals for PA (βs = 0.34 − 0.43, ps < 0.001), MA (βs = 0.45 − 0.46, ps < 0.001), and character reading (bs = 0.04–0.13, IRR = 1.04–1.14, ps < 0.01) were all significant. Specifically, the coefficients of the autoregressive paths for character reading indicated that, with each additional increase of one score in early character reading, the later character reading score is expected to multiply by a factor of 1.14 (K1 to K2) or 1.04 (K2 to K3). Moreover, the concurrent associations between PA and MA were significant at K1 (cov = 0.35, $p < .001$) and K3 (cov = 0.15, $p < .05$), but not K2 (cov = 0.08, $p = .21$).

For the cross-lagged paths from K1 to K2, PA at K1 negatively predicted illiteracy at K2 ($b = -3.46$, OR = 0.03, $p = .09$). That is, each additional increase of one z-score in PA at K1 predicted a 97% decrease in the odds of illiteracy at K2. Moreover, character reading at K1 predicted PA at K2 (β = 0.19, $p < .001$) and MA at K2 (β = 0.18, $p < .01$). For the cross-lagged paths from K2 to K3, MA at K2 predicted PA (β = 0.33, $p < .001$) and character reading (b = 0.30, IRR = 1.30, $p < .05$) at K3. The other cross-lagged paths were nonsignificant. The estimates and standard errors for the paths in the model are shown in Table 3.

Discussion

This study longitudinally tracked a group of children from K1 to K3 and examined the bidirectional relationships between PA, MA, and character reading. We found that: (1) from K1 to K2, character reading predicted PA and MA, and PA negatively predicted illiteracy; (2) from K2 to K3, MA predicted PA and character reading; (3)

significant autoregressive effects were found in all three main variables at the two time intervals.

From K1 to K2: character reading contributed to PA and MA

In this study, character reading at K1 contributed to PA and MA at K2. The contribution of character reading to PA is consistent with the study by Chow et al., (2005), which found word reading predicted PA in Chinese kindergarten children. A similar result was found in the study by Liu and Chung (2021), where character reading was found to predict PA, but not vice versa in kindergarten children from mainland China. This result suggested that learning characters is beneficial to the development of syllable awareness. Because one character corresponds to one syllable in Chinese, learning to read characters sensitizes the children's PA at the syllable level (Chow et al., 2005). In addition, learning to read Chinese may facilitate higher-order cognitive skills such as executive function, which in turn frees more cognitive resources for phonological processing (Liu Chung, 2021).

The contribution from character reading to MA suggests that even the nascent reading experience in kindergarten children is conducive to the development of MA. Learning characters can benefit the development of MA in multiple ways. First, the correspondence between character and morpheme can help children to recognize morpheme in oral language. Second, seeing morphemes in their orthographic forms may be conducive to understanding the relationships between them and thus supports the development of MA. Furthermore, reading experience may draw children's attention to the semantic information (e.g., word structure knowledge) in oral language, which is beneficial to the development of MA (Hulme et al., 2019). In this study, we used a lexical compounding task to measure children's MA, future studies could include an age-appropriate task that taps homophone/homograph awareness in investigating the extent of the contribution of character learning on homophone/homograph discrimination and vice versa.

The contribution of early character reading to later PA and MA became nonsignificant from K2 to K3. The nonsignificant prediction of character reading at K2 on MA at K3 may be due to the leptokurtic distribution of MA at K3 (kurtosis = 2.98), i.e., most of its values were close to the mean, which reduced the prediction of character reading, while the path from character reading to PA may be overshadowed by the newly emerged path from MA to PA during the same interval. In addition, PA was found to negatively predict illiteracy from K1 to K2. In this study, reading ability was delineated as occurrence (illiteracy/literacy) and frequency (number of the score), which may be more appropriate for the early readers, since many of them were in the transition from illiterate to literate. This result suggests that when the children are learning to read a character, syllable awareness is necessary for mapping the orthographic form onto the sound (Siok Fletcher, 2001). It is noted that the path from PA to illiteracy was not statistically significant ($p = .09$).

The unidirectional contribution from character reading to PA found in this study was aligned with the result in the study by Liu and Chung (2021), which also used the cross-lagged panel modeling to examine the relationship in Chinese

kindergarten children. The nonsignificant contribution from PA to character reading may be attributed to the lack of formal literacy instruction for the participants in the two studies (i.e., kindergarten children from mainland China) and the irregular grapheme-phonological relationship of the language. Specifically, the children in mainland China did not receive formal literacy instruction during the kindergarten period, the characters they had learned were from informal instruction by teachers and parents (McBride, 2016). Due to the irregular grapheme-phonological relationship of Chinese and a lack of phonetic coding system (*Pinyin*, the phonetic coding system used in mainland China, was not introduced before primary school), the informal instruction the children received may mostly consist of rote learning or "look-and-say", that is, memorize the pronunciation of each character with no reference to phonetic coding system, which limits the contribution of PA in character learning (Chan, 2013).

The rote learning may also explain the nonsignificant contribution of early MA on later character reading from K1 to K2. Because the initial learning phase may focus on the mapping from orthography to pronunciation, the semantic information brought by MA is not essential at the time. In other words, character learning from K1 to K2 mainly involves pairing the characters with the sounds but not semantic. Moreover, as the children's literacy experience is limited at the time, they have few encounters with homophones and homographs, therefore, MA is less needed for the discrimination of the characters with the same sound.

In sum, character reading was found to predict PA and MA at the very early phase of reading development in Chinese children. The contributions of early reading ability to later PA and MA have also been found in children who are learning to read alphabetic languages (e.g., Deacon et al., 2013), which suggests that reading experiences are beneficial to the development of the two metalinguistic awareness irrespective of the languages the children are learning to read.

From K2 to K3: MA contributed to reading

In this study, we found that MA contributed to character reading from K2 to K3. This beginning of MA supporting character reading has been proposed in previous studies, specifically, researchers have suggested that as children accumulate more literacy experience, they may rely on other information (i.e., in addition to phonological information) such as morphosyntactic cues to help them read (Li et al., 2012). The studies that examined the early predictors of reading difficulties in Chinese children also highlighted the importance of MA, as its score in kindergarten was found to predict reading difficulties later on (Lei et al., 2011; McBride-Chang et al., 2011).

This result of MA as the major contributor suggests a character-learning mechanism for early reading development in Chinese children. According to the triangle model of reading (Plaut et al., 1996), there are two pathways for word reading. The first is the direct phonological pathway from orthography to pronunciation, and the second is the semantic pathway from orthography to semantic representation and then to pronunciation. Unlike alphabetic languages, which provide plentiful pronunciation threads in orthography (e.g., recurring spelling patterns) for children to pick

up, thus facilitating access to the phonological pathway, Chinese characters provide little phonological information (McBride, 2016). As a result, children who are learning to read Chinese characters lack these "mnemonic devices" (Ehri, 2005, p. 176) to sustain the phonological pathway. Moreover, as children accumulate more literacy experience in Chinese, they will encounter more homophones, so that one syllable can branch out into more orthographic forms. Thus, the phonological pathway is not a sustainable way to learn Chinese.

After the children in this study had developed a certain degree of MA and literacy knowledge, they began to utilize the semantic pathway to learn characters. Because of the correspondence between character, morpheme, and syllable in Chinese, the ability to recognize morphemes in oral language could help children to connect the three elements in the semantic pathway. In other words, provided they have coupled the morpheme and its pronunciation in the oral language, they can map the character onto this unit that contains both meaning and sound. This makes the semantic pathway as straightforward as the phonological one. The addition of semantic information with the assistant of MA was also aligned with the lexical quality hypothesis, specifically, the semantic information increase the lexical quality of the word, which help the children processing the word more efficiently (Perfetti, 2007).

Because character and word are two closely related orthographic units in Chinese, the reliance on words during character reading has been found in Chinese children (Li et al., 2017). A study has also found that MA may facilitate the retrieval of the word-internal context (e.g., the neighboring morphemes in the family words) of the character during character learning (Wang Liu, 2020). The word-internal context can be viewed as a semantic mnemonic device for children to learn characters. Thus, with the support from MA, this word-internal context further strengthens the semantic pathway during character learning.

The developmental relationship between PA and MA

In this study, the non-significant cross-lagged paths between PA and MA from K1 to K2 suggested that the two kinds of metalinguistic awareness were largely developed independently at the early stage of reading development. In supporting this view, two year-old children (younger than our participant at K1) were found to exhibit lexical compounding awareness when coining words (e.g., named gardener as "plant-man") (Clark, 1995, p. 117). From K2 to K3, the significant path from MA to PA emerged. This contribution of MA to PA from K2 to K3 could be a byproduct of the vocabulary-learning process supported by MA. With a better developed MA, Chinese children could use MA to segment the word into morphemes and utilize the word structural information to increase their vocabulary (McBride-Chang, Tardif, et al., 2008). Because of the correspondence between morpheme and syllable, this analyzing process also entails the segmentation and manipulation of the syllables in words.

The result was similar to the experimental training study by Lyster (2002), which focused on the manipulation of compounding morphology in the MA training and

found the facilitative effect of MA training on PA in kindergarten children from Norway. However, the study (Lyster, 2002) also found the facilitative effect of PA training on MA, which was not found in the present study. Whereas PA was insolated (devoid of the meaning element) in the training scheme in Lyster (2002), it may be less utilized independently in a natural setting, particular in the Chinese context, where syllable, morpheme, and character are almost in a one-to-one-to-one correspondence. As language communication aims at transferring information, MA (with the added semantic information) may be more useful and more frequently utilized than PA (e.g., children may tend to figure out the meaning of what they hear, rather than how many syllables there are). Thus, the often-used MA drives the development of PA but not vice versa in natural setting. It should be noted that PA and MA were significantly correlated across the three waves (see Table 2), the nonsignificant effect of PA at K2 on MA at K3 may be shadowed by the strong autoregressive effect of MA from K2 to K3.

The result in the present study contrasts with the longitudinal study by Pan et al., (2016), which found that PA measured in kindergarten predicted MA in primary school in Chinese children. The differences in these results may be due to the different time scales and methods for handling longitudinal data in the two studies. Whereas the present study tracked the children in kindergarten and examined the relationships year by year, the study by Pan et al., (2016) used the preliterate PA (latent variable composed of PA measured at ages 4, 5, and 6 years) to predict post-literate MA (latent variable composed of MA measured at ages 7, 8, 9, and 10 years). Thus, the result reported by Pan et al., (2016) may reflect the developmental relationship between PA and MA over a larger time scale, while the result of this study focused on the relationship of the metalinguistic awareness in the kindergarten period.

As this study focused on the relationship between syllable awareness and morphological awareness at the structural level in the kindergarten period, other facilitative functions of PA on MA (e.g., tone awareness improve the differentiation of the morphemes with similar sounds) may exist in other levels and/or other developmental phases. In addition, this relationship may also vary in different languages. For example, Kuo and Anderson (2006) suggested that due to the phonological alterations in many morphologically complex words in English, the relationship between MA and reading development may be mediated by PA for early grade school children who are learning to read English. While for higher-grade students, PA and MA were thought to be more independent. Therefore, the finding of the present study may only apply to Chinese early readers.

Limitations

The present study has three main limitations. First, we did not included environmental factors (e.g., home literacy environment), which were found to contribute to metalinguistic awareness and reading ability in Chinese early readers (e.g., Liu et al., 2018; Zhang et al., 2019). Second, the sample size in this study is relatively small, future studies could use a larger sample size to validate the present results. Third,

this study examined observed variables only, specifically, PA measured by the syllable deletion task, MA measured by the compounding production task, and reading ability measured by a character reading task. It should be cautious in generalizing the results. More age-appropriate tasks may be developed for more comprehensive measures of the abilities under investigation, which in turn allow structural equation model with latent variables to be performed in future studies.

Implications and conclusion

The results of this study have advanced our knowledge about the dynamic relationships between PA, MA, and character reading in the very early stage of literacy development in Chinese children. The results of this study provided theoretical implications for learning to read in Chinese. First, at the very beginning of reading development, character learning mainly consisted of pairing the pronunciation with the orthographic form, with less emphasis on the mapping to the semantic representation of the character. The paring between pronunciation and orthographic form makes PA essential in the early reading development. After the children have more developed MA and reading ability, they began to utilize the semantic pathway in learning to read character. MA helps children to recognize morphemes during conversation and to retrieve word-internal context, which reinforces the semantic pathway and in turn makes MA a pivotal force in character learning.

Second, PA and MA are developed independently at the emergence of reading development. Because of the productivity and the transparency of compounding morphology in many cases (e.g., the morpheme 车 (vehicle) is in numerous words that relate to wheeled machine, such as 自行车 (self-propel vehicle, bicycle), 汽车 (gas-vehicle, automobile), and 婴儿车 (baby-vehicle, stroller)), MA is heavily utilized in Chinese. As children have more developed MA, MA began to contribute to PA (particularly syllable awareness) due to the correspondence between morpheme and syllable.

The results also provided implications for literacy teaching in early Chinese readers. PA in the form of syllable awareness appears to be a prerequisite for learning to read characters at the very beginning of reading development. Parents and kindergarten teachers are thus recommended to help children differentiating syllables during conversation and articulating the characters clearly when teaching the pronunciations during character learning. Moreover, it is also recommended to help children realize the productive nature of the morphology by showing them the common morpheme in the family words (e.g., the morpheme *vehicle* in the above-mentioned example). Additionally, early print exposure (e.g., shared book reading) is recommend for Chinese children, as the reading ability (even in its nascent form) promotes PA and MA, which in turn could refeed the growth of reading ability. In supporting this view, cross-region studies have found that kindergarteners from Hong Kong (who have more print exposure from formal literacy education in kindergarten) not only have better reading ability than their counterparts from mainland China (who have not received formal literacy education in kindergarten), but also better at utilizing metalinguistic awareness for character learning (e.g., Wang et al., 2021). A

balanced and connected instruction in literacy and oral language skills is recommended, for the two components were reciprocally developed. For example, when children have difficulties in differentiating homophones in oral language, teachers and parents could provide their corresponding characters to increase the distinctness of the morphemes. Character learning could also accompany the introduction of its family words and word structures (i.e., how characters are combined into words) to enrich the semantic cues of the character. It is beneficial to increase children's overall literacy exposure, such as shared book reading, road-sign or menu reading.

Finally, to examine whether the time lag duration influences the relationship between PA and MA, we removed the data at K2 and only used those from K1 and K3 to build the model in the main analysis. This showed a reciprocal relationship between PA and MA (early PA to later MA: $\beta = 0.28$, $SE = 0.09$, $p < .01$; early MA to later PA: $\beta = 0.39$, $SE = 0.11$, $p < .001$). Future study may attend to the duration of time lag when interpreting the relationship.

To conclude, the results of this study highlight the pivotal role of MA in both reading and oral language skills, and the benefits of reading experience to the development of oral language skills in early readers.

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Data availability The data of this study are available from the corresponding authors upon reasonable request.

Declarations

Conflict of interest The authors declare having no conflict of interest.

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