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Abstract

Purpose: The writing of Chinese is non-alphabetic, but children in China learn *Pinyin*, a Romanised alphabetic system, to facilitate literacy development. This research investigates how Mandarin phonological awareness (PA) develops, and how it interacts with Pinyin in school-aged Mandarin-speaking children in China.

Method: In Beijing, 182 students in grades two through four (ages ranged between 91 and 135 months) were tested for PA (syllable manipulation and onset-rime oddity tasks) and Pinyin knowledge (Pinyin symbol naming and syllable reading tasks). ANOVAs were used to examine their developmental trajectories. Partial correlations and linear regressions were used to examine the relationships between PA and Pinyin knowledge.

Result: Syllable awareness has already reached the ceiling level by grade two, while onset-rime awareness is still developing across grades. The ability to name Pinyin symbols decreases over time, while the ability to read syllables written in Pinyin stays invariant across grades. PA and Pinyin knowledge are significantly correlated, and the results of linear regression indicated that the relationship between PA and Pinyin syllable reading is bi-directional.

Conclusion: This study suggests that Mandarin PA development shows features characteristic of a non-alphabetic language with Pinyin knowledge playing a crucial role. Implications for theory and practice of Mandarin-speaking children's literacy development are discussed.

Keywords: *phonological awareness; Pinyin knowledge; non-alphabetic language; Mandarin Chinese; school-aged children*

Introduction

Phonological awareness (PA) is a meta-linguistic skill used to consciously detect, identify, and manipulate speech sound structures independent of meanings (Lonigan et al., 2009). It is commonly accepted that PA develops from larger to smaller grain sizes, i.e. from syllables to onsets and rimes, and then to phonemes (Ziegler & Goswami, 2005). Phonics, related to but different from PA, is an instructional approach which emphasises letter-sound correspondence and pronunciation rules (Wren, 2000). Mastering phonics requires PA (Torgesen, Wagner, & Rashotte, 1994), and in turn, phonics stimulates the continuing development of PA (Foorman et al., 2003). PA and phonics are essential for literacy instruction (Castles, Rastle, & Nation, 2018), and are of interest to speech-language pathologists.

Compared to the thorough study of PA and phonics in English (Castles et al., 2018), the volume of research in Chinese is limited. Different from the alphabetic orthography in English, Chinese is a morphosyllabic language, where one character roughly maps onto a morpheme and corresponds to a syllable (Chen et al., 2004). Therefore, the grapheme-phoneme correspondence does not exist in Chinese literacy. To help learners access the sounds, 汉语拼音方案*Hànyǔ Pīnyīn Fāng'àn* (The Scheme of the Chinese Phonetic Alphabet, often abbreviated to *Pinyin*) was published in 1958 and taught in elementary schools around Mainland China (Commission of Written Language Reformation of the People's Republic of China, 1958). Pinyin includes 声母*shēngmǔ* (onset), 韵母 *yùnmǔ* (rime) and 声调*shēngdiào* (tone). A rime can comprise a 介音/韵头 *jièyīn*/*yùntóu* (pre-nucleus glide), a 韵核 *yùnhé* (nucleus) and a 韵尾 *yùnwěi* (coda), while only the nucleus is mandatory. See the Supplementary Materials for more details.

Pinyin is comparable to alphabetic orthography in several aspects. Pinyin is related to the movements which attempted to Romanise Chinese orthography

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(Li, 2011), so the Latin alphabet was fully adopted. It roughly follows the principle of grapheme-phoneme correspondence and is highly transparent (Bassetti, 2006).

One might expect that the relationship between Pinyin and Mandarin PA to be the same as that of phonics and English PA. However, Pinyin is unique in the course of learning and use. First, unlike alphabetic knowledge in English which emerges around the age of three and is complete by early school-age (Worden & Boettcher, 1990), Pinyin knowledge is not a prerequisite for Chinese literacy, and is not officially taught until grade one. Second, Pinyin is not the primary orthography of Mandarin, but only a system to facilitate literacy (Feng, 2008). In grades one and two, the curriculum emphasises learning Pinyin and Chinese characters spontaneously (Ministry of Education of the People's Republic of China, 2012). Third, Pinyin is no longer the emphasis of instructions after grade three, and is seldom involved in literacy activities. The exposure to Pinyin in higher grades is thus very different from phonics in English. As a result, it is expected that the development of Pinyin knowledge and its impacts on PA in Mandarin should be different from phonics in English.

Although previous research suggests that PA development follows a language-universal continuum of grain sizes (Ziegler & Goswami, 2005), the development of PA in Mandarin may be different from English due to its non-alphabetic orthography and the impacts of Pinyin. Chinese characters typically correspond to syllables. Therefore, syllable awareness is more important in Mandarin (Chen et al., 2004; So & Dodd, 2009), and phonemic analysis can be challenging for Mandarin speakers (Read, Zhang, Nie, & Ding, 1986). Pinyin as an alphabetic system plays an important role in the development of phonemic awareness in Mandarin. Holm and Dodd (1996) compared the PA in university students, finding that the students from Mainland China who learned Pinyin were better at phoneme segmentation tasks than the students from Hong Kong who learned only Chinese characters. At the levels of syllables and onset-rimes, studies also showed that children who learned Pinyin developed better PA (McBride-Chang, Bialystok, Chong, & Li, 2004). Pinyin may also cause difference in the analysis of sub-syllabic division. Syllable structure in Mandarin Chinese allows a pre-nucleus glide. Whether it is part of the onset or the rime remains controversial (Duanmu, 2007). Wang and Gao (2011) reported that learning Pinyin affected children's processing of pre-nucleus glides. The evidence suggests that the development of PA in Mandarin may also be, at least partly, different from English.

Understanding the similarities and differences of PA and phonics/Pinyin between English and Mandarin led us to the following questions: How do PA and Pinyin knowledge develop across age in Mandarin-speaking children? How do they impact each other? How do their development and relationships in Mandarin compare to those in English? Answering these questions will help speech-language pathologists with assessment and treatment for Mandarin-speaking children, and take advantage of the relationship between PA and Pinyin knowledge to facilitate the development of literacy skills.

There are three major types of studies exploring the relationship between Mandarin PA and Pinyin knowledge: observations before and after Pinyin learning, controlled experimental studies and correlational studies. Cross-sectional and longitudinal comparison between pre-school children and school-aged children suggested that syllable awareness was already highly developed before the age of five, while onset-rime awareness significantly developed at school, indicating the facilitative effects of Pinyin instruction (Shu, Peng, & Mcbride-Chang, 2008; Tang & Wu, 2009a; Xu, Dong, Yang, & Wang, 2004). In the controlled experimental studies, children at the age of five were assigned to Pinyin training and control groups. Results indicated positive effects of Pinyin training on onset-rime awareness, while the development of syllable awareness was independent of Pinyin experiences (Ren, Xu, & Zhang, 2006; Tang & Wu, 2009b).

These two types of studies can only be conducted before elementary school. They could not account for the cognitive progression from pre-school to school ages, or different response to Pinyin training at different ages. Little is known about the relationship between PA and Pinyin knowledge in school-aged children. Xu and Ren (2004) tested Pinyin knowledge by asking children to write down heard syllables in Pinyin and write Chinese characters according to Pinyin. Results showed that the scores were correlated with and predictive of PA. This study made a strong case for Pinyin's impacts on PA in school-aged children. However, the use of Chinese characters might have affected the findings due to children's writing ability and vocabulary. The interactions between PA and Pinyin should be further investigated, using more valid Pinyin knowledge tests and controlling general intelligence.

In this study, Pinyin knowledge was assessed through naming Pinyin symbols, reading syllables and sounding out pseudo-syllables. The measure of PA was composed of syllable deletion, transposition and insertion tasks, as well as onset-rime oddity tasks (Bradley & Bryant, 1983; Liang, Lau, & Leung, 2014), and pre-nucleus glides were specifically probed. Non-verbal intelligence was tested. We expected to see syllable awareness finish developing by school age, while the PA of smaller grain sizes would keep developing in school-aged children, consistent with the universality of PA development. On the other hand, we anticipated that the development of Pinyin knowledge would differ from that of the phonic knowledge in English. Chinese non-alphabetic orthography and Pinyin should affect the PA and Pinyin performance of school-aged Mandarin-speaking children.

Method

The data used in this study was from a dataset of a larger project: "Investigation and Research on Learning Difficulties in Elementary Students in Beijing".

Participants

The data was collected from grades two, three, and four at two elementary schools in Beijing, China. 182 children participated, among whom 58 were in grade two (ages ranged between 91 and 115 months, mean = 101.50, SD = 4.15), 62 in grade three (ages ranged between 104 and 120 months, mean = 112.53, SD = 3.75) and 62 in grade four (ages ranged between 117 and 135 months, mean = 124.63, SD = 3.74). The children were randomly selected from the classes and gender-balanced by the classroom teachers. They were anonymised starting from the beginning of the data collection.

Testers and administration

A total of 25 graduate and senior undergraduate students who majored in Linguistics were trained through a two-day protocol for testing fidelity. The tests were conducted in the schools. Fourteen tests were included to assess different aspects of literacy skills. Children attended a non-verbal intelligence test in a group setting, and rotated among testing stations to finish the individual tests on the day before or after the intelligence test. The whole protocol took about two and a half hours for each child. More details on the tasks used in the study are described below.

Tests

This study involves tests of non-verbal intelligence, PA and Pinyin knowledge

Raven's Progressive Matrices were used to control non-verbal intelligence due to their reliability across languages (Raven, 2000). The test included five sets of twelve items, each including a visual design with a missing piece. The children were asked to pick from six or eight choices to complete the design.

The *PA test* contained three subtests: 1) The *syllable awareness subtest* required the students to manipulate syllables in twenty-five di- or tri-syllabic words. Fifteen of them were to delete a syllable (e.g. deleting "儿 *ér* [ɚ^{35}]" in "幼儿园 *yòu'éryuán* [jo͡ʊ^{51} ɚ^{35} ɥɛn^{35}], kindergarten"), five were to transpose two syllables in a word (e.g. transposing "咖啡 *kāfēi* [k^{h}a^{55} fe͡ɪ^{55}], coffee" to "*啡咖 *fēikā* [fe͡ɪ^{55} ka^{55}]") and five were to insert a syllable to the middle of a word (e.g. adding "水 *shuǐ* [ʂwe͡ɪ^{214}], water" to "雷达 *léidá* [le͡ɪ^{35} ta^{35}], radar"). 2) The *rime awareness subtest* involved eighteen tasks which required the students to identify the syllable whose "second half" was different out of three options (e.g. 泪 *lèi* [l**e͡ɪ**^{51}], tear; 菜 *cài* [ʦʰ**a͡ɪ**^{51}], vegetable; and 袋 *dài* [t**a͡ɪ**^{51}], bag). Tones were controlled across the three options. There was a special subset of six tasks where the three syllables were only different in their pre-nucleus glides (e.g. 蝶 *dié* [t**j**ɛ^{35}], butterfly; 学 *xué* [ɕ**ɥ**ɛ^{35}], to study; and 茄 *qié* [ʨʰ**j**ɛ^{35}], eggplant). We will refer to them as *glide awareness tasks*, and the other twelve tasks as rime awareness tasks. 3) The *onset awareness subtest* involved fourteen oddity tasks which required the students to identify the syllable whose "first half" was different out of three options, tones controlled (e.g. 师 *shī* [**ʂ**ɻ̩^{55}], teacher; 生 *shēng* [**ʂ**əŋ^{55}], to live; and 孙 *sūn* [**s**wən^{55}], grandson). The test questions were played through pre-recorded audio files. The syllables in onset-rime awareness tasks were accompanied with pictures, while no Chinese character or Pinyin was provided. This was to reduce the load of working memory, and exclude the interference of orthography (Liang et al., 2014).

The *Pinyin knowledge test* was composed of two subtests: 1) The *onset-rime naming subtest* required the student to read printed Pinyin symbols for twenty-one onsets and twenty-four rimes in a randomised order. The students were reminded to not use the names of English letters, e.g. "Aa" is called [e͡ɪ] in English, but "*a*" is called [a] in Pinyin. The Scheme for the Chinese Phonetic Alphabet had set official names for each letter, e.g. "Bb" [bɛ], but these are seldom used. Practically, 呼读音 *hūdúyīn* (sound names) are more commonly used. Both sound names (e.g. "b" [po]) and sounds of the symbols (e.g. "b" [p]) were accepted as correct responses. 2) The *syllable reading subtest* required the students to read out loud thirty-six syllables according to printed Pinyin. Twenty-five of them were real syllables in Mandarin (e.g. dà [ta^{51}]), and the other eleven were pseudo-syllables (e.g. muǎ [mwa^{214}]). The students were informed that there would be unfamiliar syllables and were encouraged to sound them out.

Validity and reliability

Content validity of the PA test can be estimated through comparing with assessment tools and the tests that were used in similar studies. The syllable awareness subtest involved operations of deletion, substitution and blending, which were commonly included in PA assessment tools (see Paul, Norbury, & Gosse, 2018 for a summary of types of PA tasks). The onset-rime awareness subtest used "oddity tasks" (Bradley & Bryant, 1983) which were widely used in studies on Mandarin PA (e.g. Chen et al., 2004; Liang et al., 2014; Ren et al., 2006). For the PA and Pinyin knowledge tests, Cronbach's α was 0.843 for the PA test, and 0.878 for the Pinyin test, which suggests good internal consistency.

Data processing

For cross-grade comparison, the standardised scores were not calculated for the Raven test. Percent correctness of each test and subtest was calculated, and then converted to z-scores. Chronological ages were calculated by months based on the children's birth dates and the dates of testing.

In each grade, if a data point was more than three standard deviations away from the grade mean, it was defined as an outlier, and the case was excluded from further analysis. Two cases (3.30%) were excluded from each grade, leaving 176 valid cases in total.

IBM SPSS Statistics version 22.0 (SPSS Inc., Chicago, IL) was used for data analysis. One-way ANOVA and two-way ANOVA were used to examine the development of PA and Pinyin knowledge across the three grades. Partial correlations were tested to specify the relationships between PA and Pinyin knowledge. Linear regression was used to explore the directions of the relationships.

Result

The results of PA development (Table I) suggest that the students had already mastered syllable awareness by grade two (correctness = 97.428, SD = 4.276). The performance did not change significantly across grades ($F = 0.784$, $p = .458$), which indicates that syllable awareness had already reached the ceiling level. Rime awareness was still developing across grades ($F = 4.606$, $p = 0.011$), with a significant increase between grades two and four ($MD = 9.246$, $p = 0.009$) according to the *post-hoc* tests with Bonferroni correction. Onset awareness was also developing ($F = 4.381$, $p = 0.014$), with a significant increase between grades two and four ($MD = 7.798$, $p = 0.011$). Glide awareness did not develop significantly ($F = 2.041$, $p = 0.133$), and remained at a lower level compared to the other PA skills (correctness = 75.189, SD = 22.395).

As for Pinyin knowledge (Table II), two-way ANOVAs were conducted to examine the effects of grades (grades two through four) and tasks (onset-rime symbol naming tasks, real syllable reading tasks and pseudo-syllable reading tasks). When comparing symbol naming and real syllable reading, there was no significant effect of grade ($F = 0.743$, $p = 0.477$). A significant effect of task ($F = 0.024$, $p = 0.039$) was detected, but comparing the performance of these two tasks was not the main purpose of this study. More importantly, there was a significant interaction between grade and task ($F = 3.272$, $p = 0.039$). Specifically, the ability to name Pinyin symbols decreased from grade two to grade four ($MD = 5.556$, $p = 0.030$), while the ability to read syllables stayed invariant ($MD = 1.671$, $p = 1.000$). When comparing real and pseudo-syllable reading, the effect of grade was insignificant ($F = 0.253$, $p = 0.777$). There was a significant effect of task ($F = 287.775$, $p = 0.000$). As expected, reading pseudo-syllables (correctness = 47.417, SD = 19.532) was more challenging than real syllables (correctness = 82.523, SD = 13.253). The two types of syllable reading tasks developed parallelly with no significant interaction between grade and task ($F = 1.278$, $p = 0.278$).

Table III presents the results of correlation tests between the z-scores of each component of PA and Pinyin knowledge, controlling non-verbal intelligence. Except for syllable awareness which had already reached the ceiling, all the other components of PA were significantly correlated with Pinyin knowledge. PA showed significant correlations to syllable reading abilities (real syllable reading: $r = 0.429$, $p = 0.000$, pseudo-syllable reading: $r = 0.416$, $p = 0.000$) but not to onset-rime naming abilities (rime naming: $r = 0.225$, $p = 0.003$, onset naming: $r = 0.235$, $p = 0.002$, Bonferroni corrected criterion $\alpha = 0.002$). Glide awareness was significantly correlated with rime naming ($r = 0.256$, $p = 0.001$) but not onset naming ($r = 0.156$, $p = 0.040$).

Linear regressions were conducted to explore the effect of each independent variable, and the direction of the relationships. Table IV shows the results of stepwise linear regressions of PA and pinyin knowledge. PA was predicted by the ability to read Pinyin syllables ($\beta = 0.462$, $p = 0.000$) and non-verbal intelligence ($\beta = 0.267$, $p = 0.000$). The linear regressions

Table I. Percent mean correct (SD) of phonological awareness from grade two through grade four.

	Syllable awareness	Rime awareness	Onset awareness	Glide awareness
Grade 2	97.429 (4.276)	80.060 (20.081)	81.250 (15.869)	70.238 (20.772)
Grade 3	97.133 (5.315)	86.111 (15.994)	85.595 (14.965)	77.222 (22.333)
Grade 4	96.333 (5.011)	89.306 (13.295)	89.048 (11.500)	77.778 (23.504)
Total	96.955 (4.894)	85.275 (16.944)	85.390 (14.465)	75.189 (22.395)

Table II. Percent mean correct (SD) of Pinyin knowledge from grade two through grade four.

	Onset-rime naming			Syllable reading		
	Overall	Onset	Rime	Overall	Real syllable	Pseudo-syllable
Grade 2	82.778 (10.605)	83.163 (14.809)	82.441 (9.915)	70.437 (14.119)	80.929 (14.311)	46.591 (19.153)
Grade 3	78.482 (10.126)	80.556 (13.506)	76.667 (12.351)	72.963 (10.039)	83.933 (10.608)	48.030 (19.526)
Grade 4	77.222 (13.375)	78.889 (17.477)	75.764 (14.885)	71.898 (14.664)	82.600 (14.596)	47.576 (20.180)
Total	79.419 (11.653)	80.817 (15.377)	78.196 (12.869)	71.796 (13.315)	82.523 (13.253)	47.417 (19.532)

Table III. Correlation tests between each component of phonological awareness (PA) and Pinyin knowledge.

Partial correlations		Pinyin →	Rime naming	Onset naming	Real syllable	Pseudo-syllable
PA ↓	*r*	0.448*	0.225	0.235	0.429*	0.416*
	Sig.	0.000	0.003	0.002	0.000	0.000
Syllable	*r*	0.089	0.035	0.104	0.095	0.135
	Sig.	0.244	0.641	0.172	0.213	0.074
Rime	*r*	0.358*	0.254*	0.220	0.465*	0.418*
	Sig.	0.000	0.001	0.003	0.000	0.000
Onset	*r*	0.405*	0.184	0.191	0.335*	0.324*
	Sig.	0.000	0.015	0.011	0.000	0.000
Glide	*r*	0.360*	0.256*	0.156	0.376*	0.350*
	Sig.	0.000	0.001	0.040	0.000	0.000

Control variables: non-verbal intelligence.
*$p < .002$ (with Bonferroni correction, $\alpha_{critical}$ = 0.05/25 correlations = 0.002).

Table IV. Linear regression of phonological awareness (PA) and components of Pinyin knowledge.

	Model			Coefficients			
Dependent variables	R	F	Sig.	Predictors	β	*t*	Sig.
PA[a]	0.335	43.556	0.000	Syllable reading	0.462	7.295	0.000
				Intelligence	0.267	4.212	0.000
Rime naming[b]	0.127	12.586	0.000	Glide awareness	0.291	4.061	0.000
				Grade	−0.249	−3.470	0.001
Onset naming[b]	0.068	6.292	0.002	Onset awareness	0.241	3.197	0.002
				Grade	−0.166	−2.200	0.029
Syllable reading[c]	0.615	25.957	0.000	Symbol naming	0.329	5.214	0.000
				Rime awareness	0.189	2.570	0.011
				Glide awareness	0.182	2.454	0.015
				Onset awareness	0.164	2.257	0.025

Candidate variables:
[a]Grade, age, non-verbal intelligence, onset-rime symbol naming and syllable reading.
[b]Grade, age, non-verbal intelligence, syllable awareness, rime awareness, onset awareness and glide awareness.
[c]Grade, age, non-verbal intelligence, syllable awareness, rime awareness, onset awareness, glide awareness and onset-rime naming.

of rime awareness, onset awareness and glide awareness showed similar patterns with a significant contribution of syllable reading ability ($p = 0.000$ for all three models), thus are not specified here. The ability to name Pinyin symbols was not a factor of PA ($\beta = 0.069, p = 0.320$).

As for pinyin knowledge, both onset and rime naming were negatively impacted by grade ($\beta = -0.249$, $p = 0.001$; and $\beta = -0.166$, $p = 0.029$, respectively), as already indicated by the developmental trajectories. In addition, glide awareness was a significant factor of rime naming ($\beta = 0.291$, $p = 0.000$), while onset awareness was a significant factor of onset naming ($\beta = 0.241, p = 0.002$). Pinyin syllable reading was predicted by onset-rime naming ($\beta = 0.329$, $p = 0.000$) and all components of PA except for syllable awareness.

Discussion

Although phonics and PA have been widely investigated in alphabetic languages, little is known about Pinyin and PA in Mandarin. Mandarin is a non-alphabetic language, while the Mandarin-speaking children in China learn an alphabetic system, Pinyin, in their first years of school. This study tested PA skills and Pinyin knowledge of Mandarin-speaking school-aged children, and investigated their development and relationships. The results indicate the universality of literacy skill development, as well as the unique impact of non-alphabetic orthography and Pinyin instruction.

The developmental trajectory of PA suggests that the grain size theory (Ziegler & Goswami, 2005) does apply to Mandarin, but some unique features were observed. First, Mandarin-speaking children mastered syllable awareness before grade two. This is consistent with the consensus across languages that syllable awareness has emerged by Kindergarten without instruction (see Ziegler & Goswami, 2005). In fact, syllable awareness in Mandarin may have emerged and perfected at even younger ages. In Shu et al. (2008), children who were 39–47 months of age could detect words that contained the same syllable with 61% accuracy. This number increased to 92% in children who were 72–90 months of age. This could be due to Mandarin's simple syllable shapes, and the pronounced connections between syllables, tones and Chinese characters (Chen et al., 2004).

Second, grade-two children (age ranged between 91 and 115 months) detected the odd onset/rime out of three options with 80 and 81% accuracy, respectively. This is consistent with Shu et al. (2008) that grade-one children (ages ranged between 72 and 90 months) could detect onset/rimes with 70% accuracy. This result is also comparable to the similar measures in grade-one and grade-two English-speaking children, who detected the oddity out of four options with 52 and 64% accuracy, respectively (Wagner, Torgesen, & Rashotte, 1994). The results in higher grades suggest that onset-rime awareness continued developing after learning Pinyin. This is consistent with Xu et al. (2004) that onset-rime awareness continued developing in school age, and provides new evidence from a non-alphabetic language that alphabetic knowledge can promote PA's further development (Foorman et al., 2003).

Third, glide awareness involved the smallest grain size and had the lowest correctness among the PA tasks. Options in these tasks were auditorily similar and required phonemic analysis. This can be challenging for Mandarin speakers whose language is non-alphabetic (Holm & Dodd, 1996; Xu et al., 2004). Our result of glide awareness in grade-two children is comparable to So and Dodd (2009), where Mandarin-speaking children who had just received Pinyin training (mean age = 67 months) detected the odd phoneme out of three options with 71.8% accuracy. However, glide awareness in Mandarin did not see significant development from grade two to grade four. In comparison, phonemic awareness in English can be significantly boosted by alphabetic literacy and develop to a higher level. In Bruck (1992), phoneme deletion accuracy increased from 66 to 82% between grade two and grade three. Glide awareness plateauing at a lower level can be due to the fact that Chinese characters do not involve phonemic coding, and Pinyin instruction focusses on onsets and rimes but less on their constituent phonemes (Chen et al., 2004). In sum, the development of syllable awareness and onset-rime awareness in Mandarin-speaking school-aged children is consistent with the theory of grain sizes, while the development of glide awareness shows the impacts of Mandarin and Pinyin.

The results of Pinyin knowledge development demonstrate the uniqueness of Pinyin instruction. The ability to name Pinyin symbols significantly decreased between grade two and grade four. It is unlikely to see letter knowledge decreasing in English as children are exposed to alphabetic orthography continuously (c.f. Johnston & Watson, 1997). In contrast, Pinyin is a secondary and transient component of the curriculum (Ministry of Education of the People's Republic of China, 2012), so the knowledge of Pinyin symbols can reduce as the exposure reduces. On the other hand, the ability to read syllables written in Pinyin was retained. Why could not children name Pinyin symbols correctly but could sound out syllables according to the symbols? There are three possible explanations. First, Mandarin has a small inventory of syllables. It is much easier to develop a "naming effect" (Liang et al., 2014) or "sight words" (Murray, McIlwain, Wang, Murray, & Finley, 2019). Second, children often misnamed the symbols by letter names in English. The same letter in English and Pinyin usually corresponds to similar sounds, so naming errors do not necessarily lead to sound errors. Third, some naming errors could have been resolved by phonotactic rules. For example, even if a child named "*j*" [tɕ] as "Jj" [ʤeɪ̄] and consequently confused it with "*zh*" [tʂ], Mandarin phonology would not allow "*zh*" [tʂ] to be followed by high-front vowels when blending the onset and rime.

Consequently, Pinyin symbol naming ability was not associated with PA. This is different from the findings in English that letter skills can predict PA development (Paige, Rupley, Smith, Olinger, & Leslie, 2018). The lack of causal relationships between Pinyin naming and PA echoes an earlier debate. Venezky (1975) argued that naming letters might not be necessary for reading, since letter names do not always represent speech sounds. The relationship between Pinyin symbol naming and Mandarin PA in our study supports this argument.

On the other hand, Pinyin syllable reading and PA are closely related. Syllable reading skill was correlated with PA and was PA's significant predictor. This is consistent with the findings in English that synthetic phonics, which addresses blending sounds into words, promotes the development of PA (Johnston & Watson, 1997). Syllable reading skill was not only a predictive factor of PA, but it was predicted by PA, as well as Pinyin symbol naming. The bi-directional relationships suggest that reading Pinyin syllables is a comprehensive task that involves symbol recognition and phonological processing.

Before coming to implications of the study, some details in the results need to be discussed. While expecting pseudo-syllable reading to rely more on phonological processing, the results showed pseudo-syllable reading was no more related to PA than was real syllable reading. It is possible that naming effect (Liang et al., 2014) did not occur and the students relied on decoding even for real syllables. More specific probes are needed to determine students' strategies when reading Pinyin. Another explanation is that pseudo-syllable reading was more correlated with non-verbal intelligence ($r = 0.221$, $p = 0.003$) than real syllable reading was ($r = 0.152$, $p = 0.044$). Thus when intelligence was controlled, the correlation between pseudo-syllable reading and PA was weakened.

Glide awareness predicted rime naming, while onset awareness predicted onset naming. This indicates that the pre-nucleus glides in Mandarin might be more connected to rimes than onsets in phonological processing of children who learned Pinyin. Some phonologists believe the opposite due to the evidence from Classic Chinese and other Chinese dialects (see Duanmu, 2007). The PA tasks of glide awareness provide a new way to look at how contemporary users of Mandarin process the sub-syllabic structures, and how it has been impacted by the learning of Pinyin. Wang and Gao (2011) found that teachers followed the onset-rime division (i.e. glide belonging to rime) when teaching Pinyin, and the children who learned Pinyin developed a preference of onset-rime division. Our findings support the same hypothesis, although we need to acknowledge that

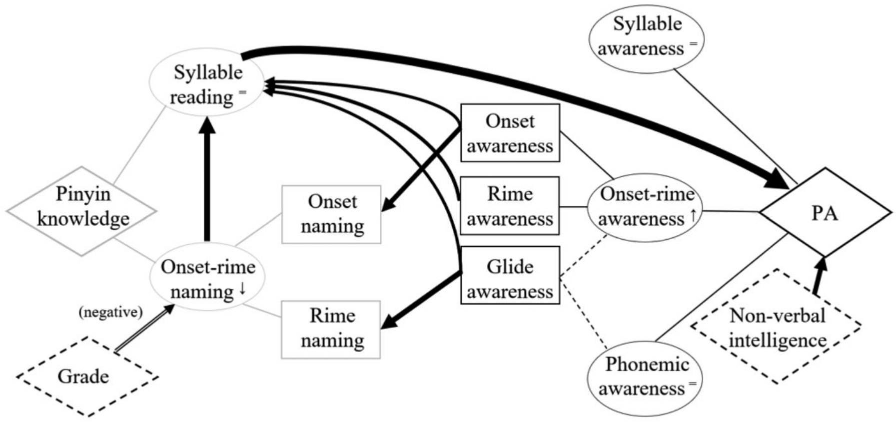

Figure 1. Conceptual model of the relationships between Pinyin knowledge and PA.
*Weight of the arrows conceptually demonstrates the coefficients in linear regression models.
↑: Increased across grades; ↓: Decreased across grades; =: Remained unchanged across grades.

our glide awareness tasks were a subset of rime awareness tasks. To make a valid argument, further studies should consider including similar items in both rime awareness and onset awareness tasks, and compare the relationships with onset and rime naming.

The major findings of this study are summarised in Figure 1. Syllable awareness reached ceiling level, onset-rime awareness continued developing in school-aged children and glide awareness was the least developed PA ability. These results are in line with the grain size theory (Ziegler & Goswami, 2005) and demonstrate the universality of PA development. Glide awareness plateaued at a lower level. Pinyin symbol naming skill decreased over time. These results indicate the uniqueness of Pinyin and PA development in Mandarin. The ability to name Pinyin symbols is not predictive of onset-rime awareness, which supports the argument that letter naming might not be necessary for PA development (Venezky, 1975). Reading Pinyin syllables is a comprehensive task which requires both symbol naming and PA skills. The relationship between syllable reading and PA is bi-directional, which means synthetic letter-sound training requires and promotes PA development (Johnston & Watson, 1997).

Investigations in PA and Pinyin in Mandarin open up several future directions for research. First, it is well-established in alphabetic languages that PA, orthographic knowledge and phonics are closely connected (Schuele & Boudreau, 2008), but more evidence is needed in non-alphabetic languages to see how these relationships generalise across languages. Second, non-alphabetic languages provide a context to examine the causal relationship between phonic instructions and the emergence of phonemic awareness through experimental studies, while in alphabetic languages, it is challenging to manipulate alphabetic literacy experimentally (Morais & Kolinsky, 2005). Third, Pinyin can be an issue of interest for bilingualism and biliteracy in the Mandarin speakers who are learning English as a second language (Ren et al., 2006) and second language learners of Mandarin (Zhang, Lin, Zhang, & Choi, 2019).

Some limitations of this study need to be mentioned. Ideally, the study should have taken English PA and alphabetic skills into account. The underlying cognitive skills, such as working memory (Vallar, 2006) should have been considered as well. The tests included in this study were designed for a larger project that did not include some specific tasks. For example, more PA tasks targeting phonemes and tones, as well as different skills of PA such as segmentation, deletion, substitution and blending at different levels (Schuele & Boudreau, 2008) would provide useful information. This study used a cross-sectional design and focussed on children in grades two through four. Longitudinal studies are desired to establish causal relationships among the literacy skills of question. The age range should be expanded earlier to the onset of alphabetic instructions, and later to late-childhood when students frequently interact with electronic devices and type with Pinyin input systems (Tan, Xu, Chang, & Siok, 2013).

This study has practical implications for education and speech-language pathology. It provides data on the typical development of Mandarin PA and Pinyin knowledge for speech-language pathologists who work with Mandarin-speaking children. The relationships between Mandarin PA and Pinyin provide insights on literacy instruction and intervention. The findings suggest that the ability to read Pinyin syllables is predictive of PA, while the ability to name Pinyin symbols is not. To better promote PA development, speech-language pathologists and educators should emphasise the practice of blending smaller sound units into larger units when training Pinyin (Tang & Wu, 2009b), instead of training Pinyin naming in isolation. For speech-language pathologists working in a multilingual context, knowing the positive effects of Pinyin on PA development, Pinyin and PA can be targeted in treatment to promote cross-linguistic generalisation.

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Supplementary data

Supplemental data for this article can be accessed at <https://doi.org/10.1080/17549507.2020.1819417>/description of location.

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Appendix: Phonological characteristics of Standard Mandarin[1]

Language: Modern Standard Mandarin Chinese, a.k.a. 普通话 *pǔtōnghuà*				
Language Family: Sino-Tibetan				
Words	There are more disyllabic words in Standard Mandarin. Speakers don't always reach agreement on what is or is not a word.[2]			
Syllable shapes	Onset	Rime		
		Pre-nucleus glide [3]	Rhyme	
			Nucleus	Coda
	$C_{0\text{-}1}$	$G_{0\text{-}1}$	V_1	$V/N_{0\text{-}1}$
	A syllable can be as short as 阿*ā* [a[55]], or as long as年, *nián* [njɛn[35]].			
Tones	T1: High level tone [55], e.g. *mā*; T2: High rising tone [35], e.g. *má*; T3: Low dipping tone [214], e.g. *mǎ*; T4: High falling tone [51] e.g. *mà* Tone sandhi can happen when there are more than one syllable.			
Syllable stress	The loss/lack of stress is more important than the presence of stress. The loss of the original tone is called 轻声 *qīngshēng* (neutral tone).			
Nucleus vowels	a, o, ɤ, i, u, y, ɿ/ɹ̩, ʅ/ɻ̩, ɚ, in compound rimes: ɛ, (æ), ɑ, ə			
Coda vowels	i/ɪ, u/ʊ			
Glides	i/j, u/w, y/ɥ A rime starting with a certain glide behaviours similarly to a rime starting with its counterpart vowel. In traditional Chinese Phonology, rimes were categorized into四呼 *sìhū* (four types of rime onset).[4]			
Consonants	p, p^h, m, f, t, t^h, n, l, k, k^h, ŋ, x, ʨ, $ʨ^h$, ɕ, ʦ, $ʦ^h$, s, tʂ, $tʂ^h$, ʂ, ʐ/ɻ, ∅/ʔ			
Clusters	There are no clusters within syllables.			
Examples of phonological constraints	/p, p^h, m/ cannot be followed by y/ɥ. /f/ has the strongest constraints on following vowels. It cannot be followed by any glides or close-front vowels. /ʨ, $ʨ^h$, ɕ/ can only be followed by i/j and y/ɥ, while /k, k^h, x, ʨ, $ʨ^h$, ɕ, ʦ, $ʦ^h$, s, tʂ, $tʂ^h$, ʂ, ʐ/ can only be followed by other vowels. Thus there is multiple complementary distribution among these classes.			

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[3]Duanmu, S. (2007).
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