Reading and Writing (2021) 34:337–353
https://doi.org/10.1007/s11145-020-10075-9

Mandarin-speaking preschoolers' pitch discrimination, prosodic and phonological awareness, and their relation to receptive vocabulary and reading abilities

Wei-Lun Chung[1,3] · **Gavin M. Bidelman**[2,4,5]

Published online: 20 July 2020

Abstract

Cross-linguistic studies have reported that prosodic pattern awareness (e.g., lexical stress and lexical tone) is more important to reading acquisition than phonological awareness. However, few longitudinal studies have been conducted to explore the relations between these variables. This study examined preschoolers' pitch discrimination, prosodic and phonological awareness, and their connection to receptive vocabulary in preschool and reading abilities in first grade. Findings reveal (1) children improve their pitch discrimination and prosodic awareness from preschool to fourth grade; (2) pitch interval discrimination (frequency separation between tones) contributes to receptive vocabulary whereas pitch contour discrimination (patterns of rising and falling pitch) predicts word reading; (3) phonological awareness accounts for more variability in receptive vocabulary than prosodic awareness; whereas the reverse was found for word reading and reading comprehension. Together, prosody and its acoustic cue (i.e., pitch) play a vital role in learning to read Mandarin.

Keywords Auditory perception · Suprasegmentals · Prosody · Vocabulary · Reading

✉ Wei-Lun Chung
wwlchung@mail.ntue.edu.tw

Gavin M. Bidelman
gmbdlman@memphis.edu

1 Department of Education, National Taipei University of Education, No. 134, Sec. 2, Heping E. Rd, Da-an District, Taipei 10671, Taiwan

2 School of Communication Sciences and Disorders, University of Memphis, 4055 North Park Loop, Memphis, TN 38152, USA

3 Center for Teacher Education and Career Service, National Taipei University of Education, Taipei, Taiwan

4 Institute for Intelligent Systems, University of Memphis, Memphis, USA

5 Department of Anatomy and Neurobiology, University of Tennessee Health Sciences Center, Memphis, USA

Introduction

In recent years, there has been a dramatic proliferation of research concerned with the relation between prosody and reading in an alphabetic language like English. It appears that awareness and use of English prosodic cues (e.g., stressed and unstressed syllables) serve as an anchor to segment words to syllables, map sounds to letters, and then sound out words. Turning to a tonal language like Mandarin, prosodic patterns offered by lexical tones can be used to distinguish between syllables based on pitch (e.g., *tang*[1] "soup", *tang*[2] "sugar", *tang*[3] "lie down", *tang*[4] "hot"), associate sounds to characters, and then pronounce characters. However, the relationship between prosody and reading might not be isolated from how children are taught to read. Specifically, in Taiwan, first graders receive instruction in a phonological coding system as an aid for pronouncing characters. Taiwanese first graders may benefit from this teaching by sensitizing to phonological structures (i.e., individual sounds and lexical tones) of Mandarin words. To date, there has been no studies examining preschoolers' pitch discrimination, prosodic and phonological awareness *before* they receive instruction in a phonological coding system. Moreover, the link between these perceptual abilities and (1) receptive vocabulary in preschool and (2) later reading abilities in first grade are currently unspecified.

Prosodic awareness, receptive vocabulary, and reading abilities

A word can be represented by individual sounds and prosodic patterns spanning across individual sounds (e.g., lexical stress or lexical tone) (Pierrehumbert, 2003; Vihman & Croft, 2007). In Mandarin, fundamental frequency is the primary acoustic cue for lexical tone perception (Howie, 1976). Based on Chao's (1948) five-point scale, the Mandarin tonal system can be represented as follows: tone 1 is a high-level tone; tone 2 a rising tone; tone 3 a dipping/falling-rising tone; tone 4 a falling tone. Thus, Mandarin speakers must exploit the level and directional movement of fundamental frequency for word meanings (Gandour, 1983). In tonal languages, prosodic patterns are mastered before individual sounds in Mandarin (Li & Thompson, 1977; Siok & Fletcher, 2001), whereas the reverse is true in Cantonese (Ho & Bryant, 1997). This reflects that Mandarin has a less complex prosodic system than Cantonese (four tones < six tones). Interestingly, awareness of prosodic patterns (in a tone oddity task) was found to improve from grade 1 to grade 5 in Mandarin-speaking children (Siok & Fletcher, 2001). It is worth noting children were asked to choose the words with odd tones in tetrads (Siok & Fletcher, 2001), but not to match words to their corresponding DEEDEE sequences in which each syllable was replaced by DEE (i.e., phonemic information was eliminated) with tone patterns (Chung et al., 2017). Conceivably, the Mandarin DEEDEE task measured children's prosodic awareness isolated from phonetic information, which has not been considered in previous research (Siok & Fletcher, 2001). The current study aimed to examine whether children's awareness of prosodic patterns measured by Chung et al.'s (2017) DEEDEE task improves from preschool to school age.

Individual learners in a given language are likely to have a periodicity bias (e.g., a stressed syllable preceding an unstressed syllable in English) toward the continuous variations of native prosodic patterns (Cutler & Mehler, 1993). Prosodic patterns are important to language learning because these sound patterns can be used as a scaffold to organize syllables (Frazier et al., 2006), store auditory information in short-term memory (Reeves et al., 2000; Sturges & Martin, 1974), segment large sound units into smaller ones (Cutler, 1996; Echols, 1996), and enhance perception of individual sounds (Mehta & Cutler, 1988; Wood & Terrell, 1998). Two mechanistic hypotheses of the mental lexicon have been proposed to delineate the role of prosody in vocabulary acquisition. First, the *lexical restructuring hypothesis* (Metsala, 1997a, b) proposes that children's lexicon relies on a phonological re-representation from lexical items to syllables, onsets/rhymes and finally phonemes. Second, the *distinctness hypothesis* (Elbro, 1996) states that prosodic patterns help individuals identify the most distinct variants of spoken words, which in turn enhances their vocabulary acquisition. In line with these propositions, studies have shown that 5-month-old infants' increased interest to strong-weak stress patterns is linked to their later vocabulary knowledge at 12 months of age (Ference & Curtin, 2013).

Building on vocabulary acquisition, several models have been proposed to suggest that awareness of prosodic patterns fosters phonological awareness (individual sounds), which in turn enhances reading acquisition (Wood et al., 2009; Zhang & McBride-Chang, 2010). This suggests that individuals aware of prosodic patterns at the word level might use prosodic patterns to segment words into syllables, map sounds onto letters for word reading, which in turn could help increase word reading fluency and free up cognitive resources to deploy for reading comprehension. Indeed, several empirical studies have reported that English prosodic awareness, independent of phonological awareness, predicts significant variance in word reading (Goswami et al., 2010; Holliman et al., 2008; Jarmulowicz et al., 2007; Whalley & Hansen, 2006) and reading comprehension (Whalley & Hansen, 2006).

Turning to tonal languages, vocabulary knowledge is associated with prosodic awareness in Cantonese (Wong et al., 2009) and Mandarin (Wang et al., 2016). Moreover, character recognition was correlated with prosodic awareness in Cantonese (McBride-Chang et al., 2008; So & Siegel, 1997; Zhang & McBride-Chang, 2014) and Mandarin (Wang et al., 2012). Recently, Chung et al. (2017) showed that Mandarin prosodic awareness made more significant contributions to character recognition than phonological awareness in Mandarin-speaking fourth graders. Given a phonological coding system (similar to phonics in learning to read English) they learned in the first grade might enhance Taiwanese children's prosodic and phonological awareness (Cheung et al., 2001; Siok & Fletcher, 2001), their diminished individual differences in prosodic and phonological awareness would make minimal contributions to reading abilities. Thus, we would expect that Taiwanese preschoolers' prosodic awareness, before the instruction in a phonological coding system in the first grade, would make more contributions to reading abilities than their school-aged peers.

Pitch discrimination, receptive vocabulary, and reading abilities

To utilize prosody in a language, individuals need to detect how their native prosodic patterns are physically represented by different acoustic features such as fundamental frequency, intensity, or duration [i.e., language-specific auditory cue hypothesis; Antoniou et al.'s (2015)]. Children's pitch discrimination improves with age as assessed using pure tone frequency difference limens (Jensen & Neff, 1993), but not tone sequences varying in contour (i.e., patterns of rising and falling tones) and interval (i.e., separation between adjacent tones) (Chung et al., 2017). Thus, it is of interest to explore whether Mandarin children's sensitivity to pitch variations improves above and beyond this normal developmental trajectory during early reading years.

In attempting to test the language-specific auditory cue hypothesis (Antoniou et al., 2015), studies have examined how children process acoustic features, singling out native prosodic patterns on vocabulary and reading acquisition. Several empirical studies have reported links between English-speaking children's sensitivity to prosodic cues (i.e., amplitude envelope onset signaling stressed and unstressed syllables) and language learning (Corriveau et al., 2007; Goswami et al., 2010, 2011, 2013). Thus, Corriveau and Goswami (2009) adapted a modular framework for music and language processing (Peretz & Coltheart, 2003) and proposed that temporal (i.e., rhythm and meter analyses), but not pitch organization (i.e., contour and interval analyses and tonal encoding), is relevant to children's language and literacy acquisition. However, this framework might not fit tonal language speakers who rely more heavily on pitch processing.

As an acoustic marker of prosody (Patel et al., 1998), pitch contour (patterns of rising and falling pitch) was found to be important to English reading in English-speaking adults (Foxton et al., 2003). Chung et al. (2017) also demonstrated that pitch contour discrimination made independent contributions to character recognition in Mandarin-speaking fourth graders. In line with Antoniou et al.'s (2015) language-specific auditory cue hypothesis, the findings suggested that individual readers might use pitch contour variations to signal different tonal patterns or syllable boundaries in order to sound out words. As an extension, the current study, we posited that Taiwanese preschoolers would place heavier weight on pitch for learning spoken words and sounding out characters.

Impact of literacy instruction

Taiwanese provides an interesting window to assess how prosodic and phonological awareness might be influenced by how children are taught to read. Taiwanese children pronounce characters that rely on a phonological coding system—*Zhuyin Fuhao* "phonetic symbols," which has not been adopted in Hong Kong or China (Zhang & McBride-Chang, 2011). This phonological coding system could help children segment Mandarin monosyllabic words into three types of sub-syllabic units: onsets (i.e., initial consonants in a syllable), rhymes (i.e., syllable vowels, diphthongs or vowels followed consonants) and four tones, just as young English readers learn the sounds for letters. This type of explicit phonological instruction might foster prosodic and phonological awareness (Cheung et al., 2001; Siok & Fletcher, 2001), which in turn, might facilitate Mandarin reading. Taiwanese children also learn to distinguish between four tones (Duanmu, 2007; Li & Thompson, 1977) but their peers in Hong Kong discriminate between six or more tones in Cantonese (McBride-Chang & Chen, 2003). Thus, it is worthwhile to examine whether prosodic awareness in a relatively simple tone system like Mandarin still contributes to reading acquisition. Lastly, Taiwanese children learn to decode traditional Chinese characters that cannot be decoded into sounds directly (Hu & Catts, 1998; Siok & Fletcher, 2001); the link between prosodic awareness and reading might be differentially affected in a logographic language like Mandarin. Given the potential impact of instruction in a phonological coding system on children's prosodic and phonological awareness, we were interested to assess these skills in preschoolers before they received the 10-week intensive instruction in the phonological coding system during first grade.

The current study focused on three primary aims: (1) examine whether Mandarin-speaking children's pitch discrimination and prosodic awareness improves from preschool to school age; (2) determine which aspect of pitch discrimination predicts receptive vocabulary in preschool and reading abilities in first grade; (3) examine the relative contributions of prosodic and phonological awareness to receptive vocabulary in preschool and reading abilities in first grade. The latter two aims were controlled for age.

Methods

Participants

Forty-nine Mandarin-speaking preschoolers (22 boys, 27 girls; age: $M = 6.36$ years, $SD = 0.30$) were recruited in Pingtung, Taiwan. They passed a hearing screening at octave frequencies between 1 and 4 kHz (i.e., thresholds ≤ 25 dB SPL). All children were enrolled in public kindergartens and had not received any formal instruction in character recognition or a phonological coding system (e.g., *Zhuyin fuhao* "phonetic symbols"). In classroom settings, they probably would recognize some characters with a few strokes and learn to write their names in characters (Chung & Hu, 2007).

To examine whether preschool children were less sensitive to pitch and prosodic patterns than their school-aged peers, we, initially, had hoped to test children's pitch discrimination and prosodic awareness longitudinally from preschool to first grade. However, preschool children in our study were enrolled in different elementary schools and only stayed at school from 08:00 to 12:00 (16:00 on Tuesdays). Additional testing would have put undue burden on the children by unnecessarily increasing school absences during critical self-study times in the morning. Thus, we compromised and compared preschoolers' pitch discrimination and prosodic awareness in the current study with their fourth-grade peers' performance in a previous study (Chung et al., 2017). We chose to test fourth graders because Chung et al.'s (2017) study, to our knowledge, is the only study examining children's pitch contour and interval discrimination and prosodic awareness via a DEEDEE task in a tone language like Mandarin. In Chung et al.'s (2017) study, 61 fourth-grade children (29 boys, 32 girls; age: $M = 9.82$ years, $SD = .25$) were recruited from an urban community in Taipei, Taiwan. They also passed a hearing screening at octave frequencies between 1 and 4 kHz (i.e., thresholds ≤ 25 dB SPL) and had no speech, language, emotional, or physical problems reported by classroom teachers.

Procedure

Children's parents were informed of the longitudinal study through preschool teachers. Informed consent was obtained from parents of all the children who participated in the study in accordance with the Ethics Committee at National Cheng Kung University, Taiwan. Children participated over two sessions in their last semester in kindergarten. These included pitch discrimination and phonological awareness tasks which occurred before prosodic awareness and receptive vocabulary tasks. N = 47 children also took reading tests through one session in the second semester of first grade (N = 2 reading tests were lost due to un-enrollment).

Materials and task paradigms

Pitch discrimination

Pitch processing was assessed through pitch contour and interval discrimination tasks (Chung et al., 2017; Foxton et al., 2003). Both pitch tasks consisted of 40 pairs of six-tone sequences and were presented in a two-interval forced choice (2IFC) paradigm. Half of the pairs contained identical tone sequences; the other half contained different tone sequences in which a random tone was altered mid-sequence. As shown in a test-retest reliability study (Christopherson & Humes, 1992), estimates of Cronbach's alpha for similar pitch discrimination tasks ranged from .80 to .93. This suggests that the same-different design was a reliable method for pitch tasks.

As shown in Fig. 1, the pitch contour discrimination task measured children's sensitivity to pitch contour violation (e.g., the fourth tone went down instead of up), whereas the pitch interval discrimination task measured children's sensitivity to pitch distance between adjacent tones without contour violation (e.g., the fifth tone went down but not low enough). Responses were quantified using the signal detection metric d'. d' scores account for both correct (hits) and incorrect (false alarm) responses, larger values denote better discrimination sensitivity of interval/contour information. To compare preschoolers with their school-aged peers, current data were compared to fourth graders' performance on the same tasks as reported in Chung et al. (2017).

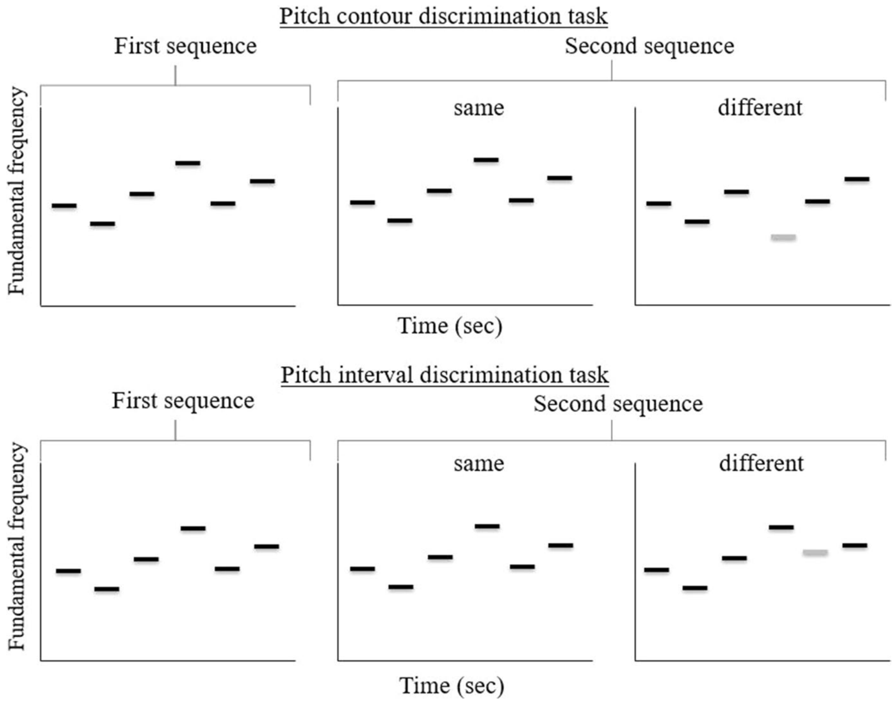

Fig. 1 Pitch contour and interval discrimination tasks

Mandarin prosodic awareness

The DEEDEE task in Mandarin version (Chung et al., 2017) was adopted to tap children's Mandarin prosodic awareness. In the DEEDEE task, the phonemic information of each syllable was eliminated and replaced by the syllable 'DEE', but tone patterns were retained in each word. The Mandarin DEEDEE task consisted of 4 practice trials and 9 experimental trials. Each child heard pre-recorded DEEDEE sequences with tone patterns (e.g., DEE^4DEE^1—the superscript numbers indicate tone patterns). He or she heard a target Mandarin word (e.g., qi^4che^1 "car") and then selected from two choices the DEEDEE phrase with the same tone pattern as the target Mandarin word (e.g., DEE^4DEE^1 for qi^4che^1 "car"). Its Cronbach's alpha was .674. These data were again compared to those of Chung et al. (2017) to compare preschoolers' with fourth graders' performance on Mandarin prosodic awareness. Thus, the 9 experimental trials in the current study and those in Chung et al.'s (2017) were matched.

Mandarin phonological awareness (PA)

Sound deletion and sound oddity tasks were used to assess children's PA at the phoneme level in Mandarin (Hu, 2013). The sound deletion task included 2 practice trials and 10 experimental trials for onsets. The first half of the experimental trials consisted of real words and the other half nonwords. In each trial, only one word/nonword was auditorily presented to children. Children were asked to produce words/nonwords without initial sounds (e.g., *mi⁴feng¹* 'bee' becomes *i⁴feng¹*). Its Cronbach's alpha was .953. The sound oddity test involved 4 practice trials and 6 experimental trials. The first half of the experimental trials consisted of onset contrast and the other half rhyme contrast. In each trial, three words were auditorily presented to children. Children needed to determine which one of the three words differed in onsets or rhymes. Its Cronbach's alpha was .626.

Mandarin receptive vocabulary

The Mandarin version of the Peabody Picture Vocabulary Test-Revised test (*PPVT-R*; Lu & Liu, 1998) was used to tap children's Mandarin receptive vocabulary. The Mandarin PPVT-R consists of 125 test items. The task required children to select from four pictures, the one that best matched the word that they heard. Its internal consistency ranges from .90 to .97.

Mandarin word reading

The Graded Chinese Character Recognition Test (Huang, 2004) was used to assess Mandarin word reading. The test includes 200 characters arranged from high to low frequency. Each child wrote down how he or she pronounced a character in phonetic symbols for each character within 30 min. The task is a standardized test, which has been adopted in several published studies (Chung et al., 2017; Chung & Hu, 2007). It has an internal consistency of .99 and test-retest reliability ranging from .81 to .95.

Mandarin reading comprehension

Elementary School Reading Comprehension Diagnostic Assessment-Grades 1-3 (Meng et al., 2015) was used to measure Mandarin reading comprehension. Children were instructed on the task for five minutes and asked to answer 25 forced-choice questions within 15 min. The task has four parallel forms and consists of five types of questions: literal comprehension, syntactic analyses, content comprehension, inference, and summarization. It has parallel-form reliability ranging from .53 to .75, and internal consistencies $>.83$.

Results

The maximum scores, means, and standard deviations for all measures are shown in Table 1. Several tests of homogeneity of regression found that there is no significant interaction between grade (i.e., preschool versus fourth grade) and gender on pitch contour ($F_{1, 101}=.84$, $p>.05$) and interval ($F_{1, 98}=.45$, $p>.05$) discrimination and disyllabic tone perception ($F_{1, 106}=.28$, $p>.05$). This suggests that the covariate (i.e., gender) was not affected by the independent variable (i.e., grade) in the analyses. Next, several analyses of covariance (ANCOVA) were conducted to examine

Table 1 Descriptive statistics for all measures (N = 49)

Measures	Maximum	Mean	*SD*
Preschoolers' age in first grade (years)	–	7.36	.30
Auditory processing			
Preschoolers' pitch contour discrimination (*d′*)	–	.72	1.22
Preschoolers' pitch interval discrimination (*d′*)	–	.62	.83
Fourth graders' pitch contour discrimination (*d′*)	–	1.92	1.06
Fourth graders' pitch interval discrimination (*d′*)	–	1.11	.78
Mandarin prosodic awareness			
Preschoolers' tone perception	9	4.45	2.43
Fourth graders' tone perception	9	7.61	1.74
Mandarin phonological awareness			
Sound deletion	10	.41	1.67
Sound oddity	6	1.82	1.62
Mandarin vocabulary knowledge			
Receptive vocabulary	125	70.27	17.27
Mandarin reading			
Character recognition	200	29.91	18.95
Reading comprehension	25	11.47	5.80

whether preschoolers and fourth-graders differed in pitch contour and interval discrimination and disyllabic tone perception after controlling for gender. The Levene's test indicated homogeneity of the dependent variables (i.e., pitch contour and interval discrimination and disyllabic tone perception) was met. Results indicated that only grade reached significance for pitch contour ($F_{1, 102} = 28.59$, $p < .001$, $\eta^2 = .21$) and interval ($F_{1, 99} = 8.77$, $p < .01$, $\eta^2 = .08$) discrimination and disyllabic tone perception ($F_{1, 107} = 63.48$, $p < .001$, $\eta^2 = .37$). As expected, we found significant task improvements with age whereby fourth graders outperformed preschoolers on pitch contour and interval discrimination and disyllabic tone perception.

Pearson's correlations revealed that pitch contour discrimination was significantly correlated with character recognition ($r = .29$, $p < .05$), whereas pitch interval discrimination was significantly associated with receptive vocabulary ($r = .33$, $p < .05$). Mandarin prosodic awareness was significantly associated with receptive vocabulary ($r = .33$, $p < .05$), character recognition ($r = .40$, $p < .01$), and reading comprehension ($r = .63$, $p < .01$). Mandarin phonological awareness, measured by the sound deletion task, was significantly associated with both receptive vocabulary ($r = .34$, $p < .05$) and reading comprehension ($r = .36$, $p < .05$). However, Mandarin phonological awareness, measured by the sound oddity task, was not associated with receptive vocabulary nor reading abilities (Table 2).

Preliminary exploratory analyses indicated minimal multicollinearity in the data (variance inflation factors < 2) and that the assumptions of independence, normality, and homoscedasticity were met. Consequently, we conducted hierarchical regression analyses to examine the relative contributions of age and separate pitch discrimination abilities to receptive vocabulary, character recognition, and reading

Table 2 Correlations between variables (N = 49)

	1	2	3	4	5	6	7	8	9
1. Age	–								
2. Pitch contour discrimination	−.050	–							
3. Pitch interval discrimination	.067	**.723****	–						
4. Tone perception	**.372****	.254	.286	–					
5. Sound deletion	−.178	.014	.025	.154	–				
6. Sound oddity	−.083	.141	**.303***	−.126	−.048	–			
7. Receptive vocabulary	**.317***	.173	**.339***	**.336***	**348***	.040	–		
8. Character recognition	**.339***	**.295***	.249	**.408****	.240	.017	**.528*****	–	
9. Reading comprehension	**.348***	.188	.280	**.634*****	**.362***	−.154	**.500*****	**.727*****	–

Significant values ($p \leq .05$) are marked in boldface

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

Table 3 Hierarchical regressions showing the variance in receptive vocabulary, character recognition, and reading comprehension accounted for by separate pitch discrimination abilities after controlling for age

Model	Step	Receptive vocabulary		Character recognition		Reading comprehension	
		Final β	R^2 change	Final β	R^2 change	Final β	R^2 change
1	1. Age	.321	.097*	.371	.126*	.376	.133*
	2. Pitch contour	.189	.036	.314	.098*	.207	.043
2	1. Age	.309	.109*	.322	.117*	.307	.109
	2. Pitch interval	.318	.101*	.220	.048	.253	.063

*$p \leq .05$

comprehension (Table 3). For these analyses, we used 2-step, fixed entry hierarchical regression, in which age was entered at Step 1 and separate pitch discrimination abilities at Step 2. We aimed to examine which aspect of pitch discrimination could predict receptive vocabulary in preschool and reading abilities in first grade after controlling for age. We found that pitch interval discrimination explained 10.1% of the variance in receptive vocabulary and pitch contour discrimination accounted for 9.8% of the variance in character recognition.

We conducted additional hierarchical regression analyses to examine the relative contributions of age, prosodic and phonological awareness to receptive vocabulary, character recognition and reading comprehension (Table 4). We used 3-step, fixed entry hierarchical regression equations, in which age was entered at Step 1, prosodic awareness at Step 2, and phonological awareness at Step 3. We aimed to examine whether prosodic and phonological awareness play different roles in receptive vocabulary, character recognition and reading comprehension. Thus, the entry order

Table 4 Hierarchical regressions showing the variance in receptive vocabulary, character recognition, and reading comprehension accounted for by prosodic awareness compared to phonological awareness after controlling for age

Model	Step	Receptive vocabulary		Character recognition		Reading comprehension	
		Final β	R^2 change	Final β	R^2 change	Final β	R^2 change
1 and 2	1. Age	.327	.101*	.278	.115*	.201	.121*
1	2. Tone perception	.156	.055	.259	.089*	.505	.293***
	3. Sound deletion	.382	.133*	.248	.056	.319	.093**
2	2. Sound deletion	.382	.169**	.248	.092*	.319	.183**
	3 Tone perception	.156	.020	.259	.053	.505	.202***
Total variance explained		.289**		.260**		.506***	
3 and 4	1. Age	.227	.101*	.212	.115*	.110	.121*
3	2. Tone perception	.263	.055	.330	.089*	.582	.293***
	3. Sound oddity	.092	.008	.062	.004	– .093	.008
4	2. Sound oddity	.092	.004*	.062	.002	– .093	.018
	3. Tone perception	.263	.059	.330	.091*	.582	.284***
Total variance explained		.164*		.207*		.422***	

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

of prosodic and phonological awareness was also reversed as in previous studies (Chung et al., 2017; Goswami et al., 2010; Whalley & Hansen, 2006). It is worthy to note that phonological awareness was entered through two tasks: sound deletion (models 1 and 2) and sound oddity (models 3 and 4).

When the sound deletion task was entered as phonological awareness, the omnibus models reached significance in receptive vocabulary ($F_{3, 45}=6.10$, $p<.01$), character recognition ($F_{3, 43}=5.02$, $p<.01$), and reading comprehension ($F_{3, 43}=14.68$, $p<.001$). Compared with tone perception, only sound deletion predicted significant variance in receptive vocabulary (13.3–16.9%). Tone perception, independent of sound deletion, did not predict significant variance in character recognition, whereas tone perception was a significant predictor of character recognition when entered before sound deletion. Tone perception, independent of sound deletion, made significant contributions to reading comprehension (20.2%)

When the sound oddity task was entered as phonological awareness, the omnibus models reached significance in receptive vocabulary ($F_{3, 45}=2.94$, $p<.05$), character recognition ($F_{3, 43}=3.75$, $p<.05$) and reading comprehension ($F_{3, 43}=10.46$, $p<.001$). Compared with tone perception, only sound oddity accounted for significant variance in receptive vocabulary (0.4%). Tone perception, independent of sound oddity, made significant contributions to character recognition (9.1%) and reading comprehension (28.4%). Finally, age, sound deletion and tone perception together predicted more variance in receptive vocabulary (28% > 16%), character recognition (26% > 20%) and reading comprehension (50% > 42%) than did age, sound oddity and tone perception together.

Discussion

Given the unique literacy instruction in Taiwan, the present study examined preschoolers' pitch discrimination, prosodic and phonological awareness, and their relation with receptive vocabulary in preschool and reading abilities in first grade. Our findings reveal that (1) pitch discrimination is important to language learning (pitch contour for characters and pitch interval for receptive vocabulary), (2) phonological awareness is more important to early vocabulary acquisition than is prosodic awareness, and (3) prosodic awareness plays an increasing important role in reading acquisition from character recognition to reading comprehension. Together, our data suggest prosody and its acoustic cue (i.e., pitch) play a vital role in learning to read Mandarin.

Our first research question addressed whether preschoolers' pitch discrimination and prosodic awareness improves from preschool to school age. Results confirmed that fourth graders outperformed preschoolers on pitch contour and interval discrimination as well as tone perception. This suggests school-aged children would be more sensitive to pitch patterns and prosodic patterns than their preschool peers, supporting previous studies (Jensen & Neff, 1993; Siok & Fletcher, 2001).

Our second research question aimed to answer whether preschoolers' pitch discrimination contributes to their receptive vocabulary in preschool and later reading abilities in first grade. In accordance with previous studies (Chung et al., 2017; Foxton et al., 2003), we found that preschoolers' pitch contour discrimination made significant contributions to character recognition in first grade after controlling for age. This suggests that preschoolers' awareness of rising and falling pitch is important to word reading even before they acquire a phonological coding system that might enhance awareness of Mandarin tone patterns signaled by pitch. Interestingly, pitch interval (but not contour) discrimination predicted significant variance in receptive vocabulary after partialling out age. These results might be explained by the nature of the two pitch tasks. Interval discrimination is more challenging than contour discrimination (e.g., Table 1). The latter required children to distinguish between tone sequences which have pure tones violating the patterns of rising and falling pitch (e.g., the fourth tone does not go up but down in Fig. 1), whereas the former asked children to discriminate between tone sequences which have pure tones not reaching exact pitch values (e.g., the fifth tone does go down but not low enough in Fig. 1). Thus, children who are more sensitive to subtle pitch patterns would be better at Mandarin pitch organization, which in turn helps foster their vocabulary acquisition. Preschoolers in the last semester of kindergarten have acquired several spoken words and therefore show greater individual difference in receptive vocabulary. This may explain why pitch interval, but not contour discrimination, was predictive of receptive vocabulary. Given pitch contour and interval, signaling Mandarin word meaning (Gandour, 1983), might play different roles in Mandarin vocabulary and reading acquisition, the importance of pitch organization in language and literacy acquisition might be reconsidered in Corriveau and Goswami's (2009) adapted modular framework for music and language processing.

Our third research question assessed the relative contributions of prosodic and phonological awareness to receptive vocabulary in preschool and reading abilities in first grade. In accordance with previous studies (Ference & Curtin, 2013; Wang et al., 2016; Wong et al., 2009), we found that tone perception correlated with receptive vocabulary, even after controlling age. Furthermore, sound deletion and sound oddity, but not tone perception, contributed to receptive vocabulary in preschool. This suggests that preschoolers might rely on phonological awareness, but not prosodic awareness, to detect resemblance and differences between phoneme combinations for spoken word learning.

Additionally, hierarchical regression analyses showed that tone perception was the only significant predictor of character recognition in first grade when sound oddity was entered before and after tone perception. These findings suggest that prosodic awareness is more important to word reading in Mandarin than is phonological awareness, supporting previous studies in an alphabetic language like English (Goswami et al., 2010, Holliman et al., 2008; Jarmulowicz et al., 2007; Whalley & Hansen, 2006) and a tonal language like Mandarin (Chung et al., 2017). Similarly, tone perception made more significant contributions to reading comprehension than did sound deletion and sound oddity, supporting a previous study with English monolingual children (Whalley & Hansen, 2006). Taken together, children aware of Mandarin tone patterns would be good at discriminating between syllables varying in lexical tones, associate sounds to characters, sound out characters, and then spare more cognitive resources for text comprehension.

Interestingly, phonological awareness, measured by the sound deletion task but not the sound oddity task, made significant contributions to character recognition after controlling for age. This suggests that Taiwanese preschoolers' phonological awareness is not a robust predictor of Mandarin word reading, contradicting previous research in an alphabetic language like English (Muter et al., 1998) and a logographic language like Mandarin (Hu & Catts, 1998; Siok & Fletcher, 2001). This discrepancy might be attributable to where our study was conducted. Our sample included preschool children raised in a non-urban city in southern Taiwan. Relative to their peers in an urban city like Taipei (Chung et al., 2017; Hu & Catts, 1998), our preschoolers have more limited access to educational and literacy resources, which in turn might result in emergent phonological awareness that is not a strong predictor of early Mandarin word reading.

Compared with previous research (Chung et al., 2017), we measured children's tone perception before they learned a phonological coding system. Thus, previous results might underestimate those had children be exposed to a phonological coding system, which might enhance their sensitivity to Mandarin syllable structures (Cheung et al., 2001; Siok & Fletcher, 2001). Our current findings extend previous research (Chung et al., 2017) by showing preschoolers' prosodic awareness, measured before the instruction in a phonological coding system, contributes to character recognition and reading comprehension by first grade. Our research with studies examining prosodic awareness and reading abilities in an alphabetic language like English suggest that prosody at the word level (i.e., lexical stress and lexical tone) might play a prominent role in early reading acquisition across languages.

Our data offer encouraging evidence of links among pitch discrimination, prosodic/phonological awareness, and early linguistic abilities. Still, future studies should compare prosody-and-reading relations in different populations (e.g., preschool children with siblings with dyslexia or their peers with typically developing siblings; children raised in cities vs. their peers in rural areas; first language learners vs. second language learners) to assess the robustness of the present findings. Conceivably, different populations of children might place different weightings on prosodic and phonological awareness during reading acquisition. Moreover, future studies should examine whether prosodic cues used at the sentence level, independent of vocabulary, syntax, and word reading, contribute to text comprehension. This could further delineate linking mechanism(s) and relations between prosody and reading comprehension. Third, future studies might measure children's word reading ability through sounding out characters, because some Taiwanese first-grade children might not efficiently use the phonological coding system as their peers. Finally, future research might use structural equation modeling or path analyses to examine preschoolers' pitch discrimination, prosodic and phonological awareness and their contributions to later reading abilities in first and second grade.

In sum, the present research found that preschoolers' awareness to Mandarin prosodic patterns signaled by pitch predicts their later reading abilities in first grade. Thus, educators may need to take into consideration the importance of prosodic awareness at the word level in learning to read. Preschool teachers might design teaching activities to foster children's awareness to prosodic patterns specific to a given language at early stage of language learning.

Acknowledgements G. M. B. was supported by NIH/NIDCD R01DC016267. W. L C. was supported by the Grant MOST 107-2410-H-152-027

Authors' contributions The first author designed and conducted the study, analysed data, wrote and edited the manuscript. The second author designed the pitch tasks, read and edited the manuscript.

Funding This study was supported by government agencies.

Compliance with ethical standards

Conflict of interest Neither authors have any disclosures to declare.

Availability of data and materials The data reported in this manuscript have not been published.

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