The Relationship Between Tone Awareness and Reading Ability in Chinese Children

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Abstract

As an important component of Chinese phonological awareness, Chinese tone awareness refers to the ability to perceive and manipulate Chinese tone units and plays a significant role in children' s reading development. Research has demonstrated significant correlations and longitudinal predictive effects between Chinese tone discrimination, categorical identification, and tone manipulation and children's Chinese and English reading abilities, suggesting a possible causal relationship. Future research could further differentiate the various components of Chinese tone awareness or tone awareness in different dialects, examine potential differential outcomes among children of different ages in reading abilities across different languages, and continue to investigate the causal relationship between them.

Full Text

The Relationship Between Chinese Lexical Tone Awareness and Children' s Reading Ability

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Abstract

As a crucial component of phonological awareness in Chinese, lexical tone awareness refers to the ability to perceive and manipulate tonal units, playing an important role in children' s reading development. Research has demonstrated significant associations and longitudinal predictive effects between the perception of lexical tone contrasts, categorical perception of lexical tones, and lexical tone manipulation and children' s reading abilities in both Chinese and English, suggesting a potential causal relationship. Future research should further investigate the differential relationships between distinct components of lexical tone awareness or tone awareness across different Chinese dialects and reading abilities in different languages among children of various ages, and continue to explore the causal relationship between the two.

Keywords: Chinese lexical tone awareness, reading, children, association, prediction

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1. Introduction

Reading development typically progresses through a long-term process from simple to complex, encompassing character recognition, vocabulary acquisition, sentence and paragraph comprehension, inference, and critical reading (Shu & Li, 2014; Paris, 2005). Reading ability interacts with fundamental cognitive and linguistic capacities (Cartwright, 2002; Cooper et al., 2014; Stanovich, 1993), and children with relatively delayed reading development are more likely to face academic and social challenges (Liu et al., 2006; Sparapani et al., 2018; Zhang, Xia, et al., 2023).

Among the multiple fundamental cognitive abilities influencing reading development, phonological awareness is widely regarded as a core cognitive component (Li et al., 2012; Morris et al., 1998). Phonological awareness is a universal speech processing ability referring to the capacity to perceive, identify, and manipulate phonemic segments of speech (Mattingly et al., 1972). Its impact on reading ability has been widely documented across various languages, including Chinese. Previous research indicates that Chinese phonological awareness in children of all ages positively correlates with their reading ability (e.g., Wu et al., 2017; Zhang et al., 2017; Zhou et al., 2023), and early Chinese phonological awareness can longitudinally predict subsequent reading development (e.g., Pan et al., 2011, 2016; Yang et al., 2020).

Chinese is a typical tonal language that distinguishes lexical meaning through suprasegmental features of pitch height and contour manifested across more than one phonemic unit—that is, through tone (Yip, 2002). Mandarin Chinese features four lexical tones: high-level (Tone 1), rising (Tone 2), low-dipping (Tone 3), and falling (Tone 4), as exemplified by /yang1/ (央, "center"), /yang2/ (阳, "sun"), /yang3/ (养, "nurture"), and /yang4/ (样, "appearance"). Regional

dialects exhibit even richer tonal categories; for instance, Cantonese has six tones, including high-level/55/, high-rising/25/, mid-level/33/, low-falling/21/, low-rising/23/, and low-level/22/ (Bauer & Benedict, 2011).

Previous research has identified four components of Chinese phonological awareness: syllable awareness, onset-rime awareness, phoneme awareness, and tone awareness (Tao et al., 2005). As an important component of Chinese phonological awareness, what is the relationship between lexical tone awareness and reading ability? Early studies examining phonological abilities in children with typical reading development also measured tone awareness and preliminarily found associations between reading ability and phonological skills including tone awareness (e.g., So & Siegel, 1997; Shu et al., 2008; Wang et al., 2005). Subsequent research has increasingly focused on measuring lexical tone awareness independently to reveal its relationship with children' s reading ability. This paper reviews these more focused studies.

First, drawing on the definition of phonological awareness, we define lexical tone awareness as the ability to perceive and manipulate tonal units in Chinese (Chen & Wang, 2008; McBride-Chang et al., 1997). Given that Chinese lexical tones have typical categorical properties, we introduce corresponding measurement tasks and early development according to three aspects: perception of lexical tone contrasts, categorical perception of lexical tones, and lexical tone manipulation. Next, we respectively elaborate on the relationships—including association, prediction, or causality—between perception of lexical tone contrasts, categorical perception of lexical tones, and lexical tone manipulation and children' s reading ability. Finally, based on existing research progress, we provide entry points for future studies to clarify the relationship between Chinese lexical tone awareness and children' s reading ability, propose possible cognitive mechanism models through which lexical tone awareness influences reading ability, and discuss the feasibility of interventions based on lexical tone awareness for children' s reading development.

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2. Measurement and Development of Chinese Lexical Tone Awareness

Previous research has defined phonological awareness as the ability to perceive and manipulate speech units (McBride-Chang et al., 1997) and tone awareness as individuals' reactive and controlling abilities regarding tonal features during tone perception and production (Chen & Wang, 2008). Since lexical tone awareness constitutes an important component of Chinese phonological awareness (Tao et al., 2005), we adopt the definition of tone awareness as the ability to perceive and manipulate tonal units in Chinese. According to this definition, tone awareness comprises two components: tone perception and tone production. Considering that Chinese lexical tones have typical categorical properties and play a crucial role in distinguishing lexical meaning, tone perception can be

further subdivided into two subcomponents: perception of lexical tone contrasts and categorical perception of lexical tones (Tong et al., 2014). Accordingly, tasks measuring Chinese lexical tone awareness can be categorized into three types: perception of lexical tone contrasts, categorical perception of lexical tones, and lexical tone manipulation (see Table 1).

The table outlines common tasks used to measure children' s Chinese lexical tone awareness. Perception of lexical tone contrast tasks typically employ classic discrimination paradigms. For example, the oddball paradigm requires listening to four syllables such as /ru3/, /tai4/, /ti4/, /tui4/ and identifying the one with a different tone or selecting the corresponding picture (Choi et al., 2016, 2017; Deng et al., 2019; Deng & Tong, 2021; Hong et al., 2018; Li & Ho, 2011; Tong et al., 2015a; Wang et al., 2012; Wang et al., 2017; Yin et al., 2011). Same/different judgment tasks involve listening to two syllables such as /tian1/ and /zhang1/ and determining whether they share the same tone (Lin et al., 2011; Tao et al., 2007; Yao & Chen, 2020; Anderson & Wang, 2012; Mok & Zuo, 2012; Zhang et al., 2023). Minimal pair comparison tasks, used primarily with Cantonese, present syllables with acoustically equidistant variations between high-level tone /si55/ and mid-level tone /si33/, requiring listeners to categorize each syllable as closer to one or the other (Lin et al., 2011; Cheung et al., 2009; Zhang et al., 2012).

Categorical perception tasks focus more on identifying the category to which a single tonal stimulus belongs. Tone-picture matching tasks require listening to a target syllable such as /fu3/ and selecting from alternative pictures corresponding to /fu3/ (裤, "pants") and /fu6/ (父, "father") the one that matches the target tone (Choi et al., 2016, 2017; McBride-Chang et al., 2008; McBride-Chang et al., 2011; Shu et al., 2008; Tong et al., 2015b, 2017, 2018). Other tasks include listening to a target syllable such as /tian1/ and selecting or writing its tone category (Yao & Chen, 2020; Cheng et al., 2018; Wang & Kuhl, 2003).

Lexical tone manipulation tasks are more diverse, including producing a syllable with the same tone as a target, producing a new syllable with a different tone after substitution, or evaluating tone production accuracy during pinyin spelling or word reading. For example, tasks may require producing another syllable that shares the same tone as the target (Li & Ho, 2011), listening to a syllable and then reading aloud a new syllable with a substituted tone (Tao et al., 2007), or rating the accuracy of tone production when reading words like "老虎" (Yan et al., 2021). During pinyin tasks, children may read or write the tone for a given character (Ju et al., 2021; Lin et al., 2010; Zhou & McBride, 2018).

Comparatively, perception of lexical tone contrast tasks involve classic discrimination paradigms, such as selecting a different tone from multiple stimuli or judging whether two tonal stimuli differ. The mechanisms underlying tone contrast perception primarily involve real-time monitoring of abnormal acoustic or phonetic information, including attention allocation and short-term memory comparison processes (Wong et al., 2009). In contrast, categorical perception tasks focus more on determining the category membership of individual tonal

stimuli, involving more discrete or semantic processing of tonal stimuli. These tasks generally require extracting stored tonal category information or lexical semantic information from long-term memory to identify the category to which a tonal stimulus belongs (Peng et al., 2010).

In early research, "tone perception" was used to describe individuals' categorical perception of tones, operationally defined as perceiving tonal continuum stimuli as belonging to specific tone categories, typically measured using psychophysical methods based on minimal pair comparison tasks (Yang, 1989; Yang & Jin, 1988; Fang, 1990; Yang & Liang, 1993). The primary distinction between perception of lexical tone contrasts and categorical perception lies in that the former mainly involves acoustic and phonetic-level information processing and anomaly detection, making it accessible even to young infants, whereas the latter requires long-term memory participation and can only be completed by children who have acquired certain tonal category knowledge or lexical semantic knowledge. Lexical tone manipulation tasks are even more diverse, involving additional perceptual processes compared to pinyin and word reading tasks, as they require perceiving and identifying the tonal category of target syllables before producing or substituting tones. Meanwhile, tone production performance in pinyin and word reading tasks requires knowledge of pinyin and vocabulary.

In addition to measurement task differences, the three components of tone awareness—contrast perception, categorical perception, and manipulation—show distinct developmental trajectories. Chinese lexical tone awareness emerges during infancy; for instance, infants exhibit native language tone preference at 4 months (Yeung, Chen et al., 2013) and begin integrating tonal information into lexical learning at 18 months (Singh et al., 2016). However, subsequent development of the three components is temporally uneven (Li & Thompson, 1977).

First, the ability to discriminate different tones emerges earliest and matures most rapidly. Research shows that 6-month-old infants can correctly discriminate pitch differences between nonadjacent tones, and by 9 months they can further distinguish subtle pitch differences between adjacent tones (Singh et al., 2018). Three-year-old children can discriminate the four Mandarin tones with 90% accuracy (Wong et al., 2005; Wong et al., 2017), and by age 6, children's accuracy in discriminating different tones approaches adult levels, reaching 92–97% (Lee et al., 2015). Second, in terms of categorical perception ability, 4-year-old children show significantly above-chance accuracy in tone category identification (Chen et al., 2017), and by age 6, their ability to categorically perceive adjacent tones approaches adult levels (Xi et al., 2009; Feng & Peng, 2023). Third, regarding tone manipulation, 3-year-old children differ from adults in tone production for isolated monosyllabic words (Wong et al., 2005; Wong, 2012), though by ages 5–6 their production of some tones approaches adult levels (Wong et al., 2018). Eight-year-old children still show significantly greater duration and variability in tone production than adults, only approaching adult levels in tone duration by age 12 (Yang et al., 2008), suggesting that tone manipulation ability matures relatively late.

3. The Relationship Between Children' s Chinese Lexical Tone Awareness and Reading Ability: Association, Prediction, and Causality

Cross-sectional studies first reveal associations by comparing tone awareness differences between children with typical reading development and those with reading difficulties and examining their correlations. Longitudinal studies further demonstrate that early Chinese lexical tone awareness significantly predicts future reading development. Subsequent research controlling for other potential influencing factors (such as other phonological awareness skills, basic auditory processing abilities, and rapid naming) further reveals independent associations and predictive power of lexical tone awareness in children' s reading ability and its development. Additionally, a small number of intervention studies manipulate children' s tone awareness and measure their post-intervention reading performance, suggesting a potential causal relationship. Below, we categorize and elaborate on these findings according to perception of lexical tone contrasts, categorical perception of lexical tones, and lexical tone manipulation.

3.1 The Relationship Between Perception of Lexical Tone Contrasts and Chinese and English Reading Ability: Association, Prediction, and Causality

Cross-sectional studies first reveal that school-age Chinese children with reading disabilities show delayed development in perceiving lexical tone contrasts, which significantly correlates with character recognition and word reading performance (Table 2). For example, Li and Ho (2011) studied Cantonese-speaking children with Chinese reading disabilities in Hong Kong with a mean age of 8.1 years in early elementary grades, finding that they performed significantly worse than age-matched controls (CA) on Cantonese tone contrast discrimination in an oddball task, though not differing from reading-level matched controls (RL), and that performance positively correlated with Chinese word reading ability. In Taiwan, Wang et al. (2012) studied children with a mean age of 9.7 years in middle elementary grades, revealing that Chinese children with reading disabilities showed significantly lower accuracy in perceiving Mandarin tone contrasts in an oddball task compared to both CA and RL controls, with performance positively correlating with Chinese character recognition. Regression analysis further indicated that among various basic auditory processing abilities, tone contrast perception explained the largest variance in children' s character recognition performance. Wang et al. (2017) more comprehensively examined the diagnostic efficacy of tone contrast perception for Chinese reading disabilities across lower, middle, and upper elementary grades (grades 2, 4, and 6), finding that children with reading disabilities in all grades performed significantly worse than both CA and RL controls, suggesting that tone contrast perception deficits remain consistently delayed across school ages with cross-grade stability.

Subsequent studies further confirmed the independent association between tone contrast perception and Chinese reading ability in early elementary grades by statistically controlling for potential confounding variables. For instance, Choi et al. (2017) classified second-grade students in Hong Kong into Chinese reading comprehension difficulty and CA control groups based on reading comprehension performance, finding significant group differences on Cantonese tone contrast discrimination after controlling for nonverbal intelligence. Deng et al. (2019) studied second-grade students in Hong Kong with a mean age of 7.8 years, finding that children with Chinese reading disabilities still performed significantly worse than CA controls on Cantonese tone contrast perception in an oddball task after controlling for nonverbal intelligence, word reading performance, and working memory. Yuan et al. (2022) extended these association findings to preschool children with typical development in mainland China, studying children with a mean age of 5.6 years in kindergarten. Regression analysis revealed that after controlling for vocabulary, rapid naming, and short-term memory, preschoolers' Mandarin tone contrast perception in a same/different judgment task still made a significant and the largest contribution to character recognition and word reading, surpassing even syllable awareness.

Longitudinal studies demonstrate that preschool children' s ability to perceive lexical tone contrasts significantly predicts their Chinese reading ability in early elementary grades (Table 2). For example, Hong et al. (2018) in Beijing studied preschool children with a mean age of 6.4 years who varied in phonological awareness, measuring multiple components including tone contrast discrimination via oddball tasks and recording neural responses via EEG. One year later, they assessed the children' s Chinese character recognition performance. Regression analysis revealed that both preschoolers' behavioral performance on tone contrast discrimination and their EEG responses to tonal stimuli significantly predicted their character recognition performance one year later. Subsequent research further found that school-age children' s tone contrast perception also predicts Chinese reading ability in middle and upper elementary grades. Deng and Tong (2021) in Hong Kong recruited fourth-grade bilingual children with varying reading comprehension levels and retrospectively analyzed their Cantonese phonological awareness development from grades 2 to 4. They found that children with Chinese reading comprehension difficulties in grade 4 showed significantly poorer Cantonese tone contrast discrimination in grades 3 and 4 (though not in grade 2) compared to CA controls, while showing no differences in other phonological awareness skills. In Zhejiang, Zhang and Lin et al. (2023) recruited typically developing fifth-grade students with a mean age of 11.1 years, measuring multiple phonological awareness components including tone contrast discrimination via same/different judgment tasks. One year later, they assessed the children' s ability to infer meanings of unfamiliar words from context. The results revealed that only fifth-grade tone contrast discrimination significantly correlated with sixth-grade word meaning inference. When age and nonverbal intelligence were controlled in regression models, fifth-grade tone contrast discrimination still significantly predicted sixth-grade word meaning inference,

while other phonological awareness skills showed no similar longitudinal predictive effect. These results partially support a potential sequential and exclusive causal relationship between tone contrast perception and lexical inference in reading among upper elementary grade children.

Furthermore, intervention studies have experimentally manipulated tone contrast perception ability in children with Chinese reading disabilities. Wang et al. (2017) provided tone contrast perception training to reading-disabled children across lower, middle, and upper elementary grades in Taiwan. The training consisted of 16 sessions, each approximately 15 minutes, delivered over 3 to 4 weeks. Compared to age-matched control groups, second-grade experimental groups showed significant improvements in both tone contrast discrimination and Chinese word reading, while fourth-grade children improved only in tone contrast discrimination, and sixth-grade children showed no significant improvements. These findings suggest a potential causal relationship between tone contrast perception and Chinese word reading ability that may have a critical age period.

On the other hand, cross-sectional studies also reveal significant associations between Chinese tone contrast discrimination and English reading ability in school-age children (Table 2). Tao et al. (2007) in Beijing examined how different components of phonological awareness affect English reading in Chinese children, initially finding that accuracy on Mandarin tone discrimination in same/different judgment tasks positively correlated with English reading performance in third and fifth graders with typical development. Anderson and Wang (2012) in the United States studied native English-speaking children with typical reading development and English reading disabilities, finding that despite not understanding Chinese, children with English reading disabilities showed lower accuracy than CA controls on Mandarin tone contrast discrimination in same/different judgment tasks. Regression analysis of typically developing readers revealed significant associations between Mandarin tone contrast discrimination and English real word reading, though this association was not found in children with English reading disabilities.

Focusing on school-age children in Hong Kong learning English as a second language, Tong et al. (2015a) found that second and fifth graders with English reading disabilities performed significantly worse than CA controls on Cantonese tone contrast discrimination in oddball tasks. Subsequent studies further confirmed the independent association between tone contrast perception and English reading ability in early elementary grades by controlling for potential confounds. Choi et al. (2017) found that second-grade English reading comprehension difficulty children in Hong Kong performed significantly worse than CA controls on Cantonese tone contrast perception after controlling for nonverbal intelligence. Deng et al. (2019) studied second-grade students in Hong Kong with a mean age of 7.8 years, finding that children with English reading disabilities still showed significantly poorer Cantonese tone contrast discrimination in oddball tasks than CA controls after controlling for nonverbal intelligence, word

reading performance, and working memory.

Longitudinal studies indicate that early tone contrast perception ability in school-age children significantly predicts future English reading ability (Table 2). Choi et al. (2016) conducted a one-year longitudinal study of typically developing children learning English as a second language in Hong Kong, measuring Cantonese tone contrast discrimination and categorical perception at age 6.9 (later integrated into a single tone awareness index) and assessing English reading comprehension at age 8.1. Structural equation modeling revealed that tone awareness at age 6.9 predicted English reading comprehension one year later. In another Hong Kong study, Deng and Tong (2021) retrospectively analyzed three consecutive years of Cantonese phonological awareness from grades 2 to 4 in fourth-grade bilingual students with varying reading comprehension levels. They found that children with English reading comprehension difficulties in grade 4 showed significantly poorer Cantonese tone contrast discrimination in grades 3 and 4 (though not in grade 2) compared to CA controls, while showing no differences in other phonological awareness skills.

3.2 The Relationship Between Categorical Perception of Lexical Tones and Chinese and English Reading Ability: Association and Prediction

Cross-sectional studies first reveal that preschool children with Chinese reading disabilities show delayed development in categorical perception of lexical tones, which significantly correlates with character recognition and word reading performance (Table 3). In Hong Kong, McBride-Chang et al. (2008) measured multiple cognitive abilities in preschool children with a mean age of 5.1 years, including Cantonese tone categorical perception via tone-picture matching tasks, to examine the diagnostic efficacy of different cognitive abilities for preschool Chinese reading disability risk. The sample included children with typical reading development and those with delayed reading development (including familial risk for dyslexia and preschool literacy difficulties). Results showed that tone categorical perception significantly correlated with Chinese character recognition and word reading, with the typical development CA group outperforming the delayed group on both measures. Regression analysis indicated that preschoolers' tone categorical perception was among the cognitive abilities explaining Chinese character recognition and word reading.

Subsequent research extended association evidence between tone categorical perception and character recognition/word reading to school-age children. Cheung et al. (2009) in Hong Kong more specifically measured phonological awareness in children with a mean age of 10.5 years with varying reading development levels, including Cantonese tone categorical perception via minimal pair comparison tasks, to examine diagnostic efficacy for school-age Chinese reading disabilities. They found that children with Chinese reading disabilities showed significantly lower accuracy in tone categorical perception than CA controls, though not differing from RL controls. In Beijing, Zhang et al. (2012) recruited children with reading disabilities and typical controls with a mean age of 10.3 years, measur-

ing their tone categorical perception ability via minimal pair comparison tasks, and found that children with reading disabilities showed lower accuracy in tone categorical perception than CA controls.

Subsequent studies further confirmed the independent association between tone categorical perception and Chinese reading ability in preschool and school-age children by controlling for potential confounds. In Beijing, Yin et al. (2011) recruited typically developing second and third graders aged 8–9 years, measuring multiple phonological awareness components including tone categorical perception via oddball paradigms, as well as rapid naming ability closely related to reading and Chinese sentence comprehension. Building on the finding that tone categorical perception positively correlated with sentence comprehension, multiple regression analysis controlling for other phonological awareness skills and rapid naming still identified tone categorical perception as a significant and independent predictor of Chinese sentence comprehension. In Hong Kong, Tong et al. (2015b) found that in typically developing preschool children with a mean age of 5.1 years, Cantonese tone categorical perception measured via tone-picture matching tasks showed unique explanatory power for vocabulary knowledge and Chinese character recognition after controlling for age, nonverbal ability, morphological awareness, and other phonological awareness skills through hierarchical regression. Choi et al. (2017) classified second-grade students in Hong Kong into Chinese reading comprehension difficulty and CA control groups, finding significant group differences on Cantonese tone categorical perception tasks after controlling for nonverbal intelligence. Tong et al. (2018) recruited typically developing children and children with developmental dyslexia with a mean age of 7.8 years in Hong Kong, finding through multiple hierarchical regression analysis that Cantonese tone categorical perception accuracy on tone-picture matching tasks uniquely explained Chinese word reading ability after controlling for age, nonverbal ability, and basic auditory processing abilities. Further, based on logistic regression models controlling for basic auditory processing abilities, Cantonese tone categorical perception ability remained an independent diagnostic indicator distinguishing the dyslexia group from CA controls.

Longitudinal studies demonstrate that preschool children' s categorical perception ability significantly predicts their Chinese reading ability in early elementary grades (Table 3). In Hong Kong, McBride-Chang et al. (2011) recruited typically developing preschool children and those at risk for reading disabilities with a mean age of 5.1 years, measuring multiple cognitive abilities including Cantonese tone categorical perception via tone-picture matching tasks. At age 7.3 years, they assessed the children' s Chinese word reading ability using standardized dyslexia tests. Regression analysis revealed that tone categorical perception ability in preschool successfully predicted Chinese word reading ability two years later in typically developing children, though this prediction did not hold for children at risk for reading disabilities.

On the other hand, cross-sectional studies also reveal significant associations be-

tween Chinese tone categorical perception and English reading ability in early elementary grades (Table 3). Research on school-age children in Hong Kong learning English as a second language found that second graders with English reading difficulties showed significantly lower accuracy in Cantonese tone categorical perception than CA controls after controlling for nonverbal intelligence (Choi et al., 2017).

Longitudinal studies indicate that early tone categorical perception ability in school-age children significantly predicts subsequent English reading ability (Table 3). Choi et al. (2016) conducted a one-year longitudinal study of typically developing children learning English as a second language in Hong Kong, measuring Cantonese tone categorical perception and contrast discrimination at age 6.9 (later integrated into a single tone awareness index) and assessing English reading comprehension at age 8.1. Structural equation modeling revealed that tone awareness at age 6.9 predicted English reading comprehension one year later. In another Hong Kong study, Tong et al. (2017) found that Cantonese tone categorical perception ability measured via tone-picture matching tasks at age 7.8 in typically developing children predicted their English word reading ability one year later.

3.3 The Relationship Between Lexical Tone Manipulation and Chinese and English Reading Ability

Cross-sectional studies indicate that school-age children with Chinese reading disabilities show poorer lexical tone manipulation ability compared to age-matched controls, and that tone manipulation correlates with reading level (Table 4). In Hong Kong, Li and Ho (2011) found that Chinese reading-disabled children with a mean age of 8.1 years performed significantly worse than CA controls on Cantonese tone production tasks, though not differing from RL controls, and that tone production positively correlated with Chinese word reading ability. In another Hong Kong study, Zhou and McBride (2018) recruited third and fourth grade bilingual children learning Chinese as a second language from international schools, finding that tone accuracy during Chinese pinyin spelling positively correlated with Chinese character recognition and word reading performance. In the United States, Ju et al. (2021) recruited third-grade students whose native language was English and who were enrolled in Mandarin immersion programs, finding that tone accuracy in Chinese pinyin spelling and oral vocabulary semantics explained more variance in Chinese character recognition than phonological awareness and pinyin initial-final spelling, suggesting that lexical tone manipulation can synergistically influence Chinese character recognition together with oral semantics.

On the other hand, cross-sectional studies also reveal significant associations between Chinese tone manipulation and English reading ability in school-age children (Table 4). For instance, Tao et al. (2007) examined how different components of phonological awareness affect English reading in Chinese children in Beijing, finding that accuracy on Mandarin tone substitution tasks positively

correlated with English reading performance in third and fifth graders. Additionally, some studies measured children' s pinyin ability, with one scoring metric being tone accuracy during spelling, and found significant associations between pinyin performance and reading comprehension (Ma et al., 2020; Xiao et al., 2020).

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4. Research Summary and Outlook

This paper clarifies the concept and main component definitions of Chinese lexical tone awareness, describes the measurement and development of different components of tone awareness, and subsequently focuses on elaborating the relationship between children' s Chinese lexical tone awareness and reading ability. Specifically, Chinese lexical tone awareness is associated with reading ability in both Chinese and English, and early lexical tone awareness in children significantly predicts their future reading development. By controlling for other potential influencing factors, research further reveals independent associations and predictive power of lexical tone awareness in children' s reading ability and its development. Future research should continue to refine the association and prediction between Chinese lexical tone awareness and children's reading ability, explore possible cognitive mechanism models, and investigate the feasibility of interventions.

4.1 Refining the Association and Prediction Between Chinese Lexical Tone Awareness and Children' s Reading Ability

Overall, existing research provides multiple lines of evidence for associations and predictive relationships between Cantonese or Mandarin tone awareness and Chinese and English reading abilities in preschool and school-age children. On one hand, cross-sectional studies demonstrate significant correlations between Chinese children' s tone awareness and their Chinese and English reading abilities, consistently revealing that children with reading difficulties generally perform worse than typically developing age-matched peers in tone contrast perception, categorical perception, and tone manipulation, though findings are not stable in reading-level matched designs. This pattern aligns with previous meta-analytic results on phonological awareness, which found that phonological awareness deficits in Chinese reading disabilities are stable only in age-matched designs but not in reading-level matched designs (Peng et al., 2016). On the other hand, longitudinal studies further reveal that early tone awareness predicts future reading ability. This predictive relationship may be influenced by other factors such as basic auditory processing abilities, other phonological awareness skills, short-term memory, and vocabulary knowledge, though research has verified a certain degree of independent predictive power.

These findings align with theoretical hypotheses proposed to explain the cognitive mechanisms through which phonological awareness affects children' s read-

ing, including the phonological deficit hypothesis, lexical quality hypothesis, and prosodic bootstrapping hypothesis. The phonological deficit hypothesis posits that phonological awareness problems interfere with establishing letter-sound mappings, leading to orthographic-phonological binding deficits that subsequently disrupt word recognition (Aravena et al., 2013). Based on this theory, when children cannot accurately discriminate different Chinese tones—a core element of Chinese phonological awareness—they are likely to experience reduced quality of word-tone binding, thereby interfering with word recognition during reading. Consequently, previous research has found significant associations between character recognition/word reading and Chinese tone contrast discrimination (e.g., Wang et al., 2012; Yuan et al., 2022; Tong et al., 2015a; Choi et al., 2017). The lexical quality hypothesis proposes that accurate phonological representations promote reading by increasing the quality of semantic representations (Perfetti & Hart, 2002). Since a primary function of Chinese lexical tones is to mark lexical meaning through different categories, this theory suggests that lower accuracy in tone categorical perception may lead to degraded semantic representations, subsequently affecting vocabulary knowledge during reading. Thus, previous research has found significant associations between vocabulary knowledge and Chinese tone categorical perception (Tong et al., 2015b). The prosodic bootstrapping hypothesis posits that prosodic information—including intonation, pauses, and rhythm—provides cues for identifying grammatical structure boundaries to aid sentence comprehension (Wanner & Gleitman, 1982). Although tones themselves do not directly indicate syntactic structure, when Chinese lexical tones function together with intonation, pauses, and rhythm, this theory suggests that readers' perception of syntactic structure (e.g., distinguishing subjects, predicates, objects) may be affected, thereby influencing sentence comprehension. Consequently, previous research has found significant associations between Chinese pinyin performance (involving tone production accuracy metrics) and sentence comprehension (Ma et al., 2020; Xiao et al., 2020).

4.1.1 The Relationship Between Different Components of Lexical Tone Awareness and Children' s Reading Ability Existing research typically uses a single task to measure children' s performance on one aspect of Chinese lexical tone awareness—contrast perception, categorical perception, or manipulation. Although a few studies employ multiple tone awareness measurement tasks, most integrate performance across different tasks into a single tone awareness index for subsequent analysis. For example, Tao et al. (2007) simultaneously measured elementary school children' s Mandarin tone discrimination and substitution abilities but integrated scores from both tasks into a single tone awareness index for subsequent analysis. Other studies simultaneously measured Cantonese tone contrast discrimination and categorical perception in children but also integrated them into a single tone awareness index (Choi et al., 2016, 2017). However, in Li and Ho' s (2011) study, both tone contrast perception and tone production were measured in

Chinese reading-disabled and age-matched control children, with both indices retained in subsequent analysis. The study reported effect sizes for differences between reading-disabled and age-matched control children on lexical tone contrast perception (0.24) and tone production (0.11), suggesting that tone contrast perception may be more effective than tone production for identifying children with reading disabilities. Future research could simultaneously measure multiple tone awareness tasks without integrating indices to explore potential subtle differences in how different components of tone awareness identify children with reading disabilities.

Furthermore, existing research rarely measures Chinese lexical tone manipulation independently; more commonly, it measures children' s pinyin ability, with one scoring metric being tone accuracy during spelling, and finds significant associations between pinyin performance and reading comprehension (Ma et al., 2020; Xiao et al., 2020). Therefore, future research could independently measure lexical tone manipulation to address questions such as whether children' s lexical tone manipulation can identify English reading disabilities, and whether children' s lexical tone manipulation can predict Chinese reading ability or longitudinally predict English reading development across languages.

4.1.2 The Relationship Between Lexical Tone Awareness and Reading Ability in Children With and Without Reading Difficulties First, numerous cross-sectional studies comparing children with and without reading difficulties have consistently concluded that tone awareness (including contrast perception and categorical perception) is a reliable indicator for identifying children with reading difficulties (e.g., Choi et al., 2017; Deng et al., 2019; Li & Ho, 2011; Tong et al., 2018). Subsequently, cross-sectional studies focusing separately on children with or without reading difficulties have shown, based on correlation and regression results, that better tone awareness (including contrast perception and categorical perception) in typically developing children is associated with better reading performance (e.g., Anderson & Wang, 2012; Tong et al., 2015b; Yuan et al., 2022). However, the relationship between tone contrast perception and reading ability in children with reading difficulties is not stable, with some studies reporting significant results (Li & Ho, 2011; Wang et al., 2012; Deng et al., 2019) and others reporting nonsignificant results (Anderson & Wang, 2012). Research on the association between tone categorical perception and reading ability in children with reading difficulties is lacking. These results suggest that the causes of reading difficulties are complex; although tone awareness deficits are a relevant factor, they are not the only or decisive factor.

Second, longitudinal studies tracking typically developing children have consistently found that tone awareness (including contrast perception and categorical perception) significantly predicts reading ability 1–2 years later (Choi et al., 2016; Hong et al., 2018; McBride-Chang et al., 2011; Tong et al., 2017; Zhang, Lin et al., 2023). These predictive results suggest that tone awareness development is likely an important factor promoting typical reading development.

However, relevant longitudinal tracking studies for children with reading difficulties are scarce, with only one tracking study reporting nonsignificant predictive effects (McBride-Chang et al., 2011). Another study retrospectively analyzed differences in tone awareness performance from the previous year between children with reading difficulties and typically developing children, finding that children with reading difficulties already showed delayed tone contrast perception one year earlier (Deng & Tong, 2021). This result partially supports that early tone contrast perception performance may predict whether children will experience reading difficulties in the future. However, additional longitudinal studies are needed to verify the predictive effect of tone awareness on reading ability in children with Chinese reading difficulties and its explanatory power.

4.1.3 The Relationship Between Lexical Tone Awareness and Reading Ability Across Different Languages Existing research reveals significant associations and predictive effects between Chinese lexical tone awareness and both Chinese and English reading abilities, but few studies have compared the relative strength of these relationships. In Choi et al.' s (2017) study, both Chinese reading comprehension difficulty children and English reading comprehension difficulty children performed worse than typical children on Cantonese tone awareness tasks, but no direct comparison was made between the tone awareness of Chinese and English reading difficulty groups. In Deng et al.' s (2019) study, Cantonese tone contrast perception was simultaneously measured in Chinese and English reading-disabled children, with correlation values between Cantonese tone contrast perception and English word reading and comprehension reported as 0.35 and 0.43, respectively, and correlations with Chinese word reading and comprehension reported as 0.20 and 0.34, respectively. In Deng and Tong' s (2021) study, primary school children with English reading comprehension difficulties scored lower on Cantonese tone contrast discrimination than those with Chinese reading comprehension difficulties. However, these two studies only demonstrated numerical differences without statistical support, warranting further investigation into whether Cantonese tone contrast discrimination is more effective for identifying reading difficulties across languages than for Chinese reading difficulties.

4.1.4 The Relationship Between Lexical Tone Awareness and Reading Ability Across Reading Education Stages Using the time when children formally receive systematic reading instruction as a reference, they can be roughly divided into three stages: preschool, early elementary grades, and middle/upper elementary grades. Based on this division, existing research first finds that evidence for associations between tone awareness (including contrast perception and categorical perception) and reading ability is concentrated in early elementary grades (Anderson & Wang, 2012; Choi et al., 2017; Deng et al., 2019; Li & Ho, 2011; Tong et al., 2015a, 2018; Wang et al., 2017; Yin et al., 2011) and middle/upper elementary grades (Tao et al., 2007; Cheung et al., 2009; Tong et al., 2015a; Wang et al., 2012, 2017; Zhang et al., 2012). In con-

trast, research on the relationship between preschool children' s tone awareness and reading ability is relatively scarce (McBride-Chang et al., 2008; Tong et al., 2015b; Yuan et al., 2022), particularly lacking empirical support for associations between preschool children' s tone awareness and English reading ability. This research gap may be related to the fact that Chinese-speaking children have limited exposure to English reading before elementary school. Future research could focus on preschool children who are native English speakers or bilingual learners to further investigate the relationship between Chinese lexical tone awareness and preschool children' s English reading ability.

Second, existing research indicates that tone awareness has certain forward-looking predictive effects. For example, preschool children' s tone awareness can predict their reading level in early elementary grades (Hong et al., 2018; McBride-Chang et al., 2011), and middle/upper elementary students'tone awareness can also predict their reading performance one year later (Deng & Tong, 2021; Zhang, Lin et al., 2023). However, studies examining whether early elementary grade children's tone awareness can predict their reading ability in middle/upper grades have yielded inconsistent results: Tong et al. (2017) found that second graders' tone awareness significantly predicted third-grade reading level; Deng and Tong (2021) found that third graders' tone awareness significantly predicted fourth-grade reading level, but that second graders' tone awareness did not significantly predict fourth-grade reading ability. Currently, there is a lack of longer-term longitudinal studies to further reveal longitudinal predictive relationships between different stages, such as the predictive effect of preschool children' s tone awareness on middle/upper elementary grade reading ability.

Third, based on existing research, evidence for the relationship between lexical tone manipulation and reading ability primarily comes from middle/upper elementary grade children, while relevant research on preschool children is still lacking. This may be related to the fact that tone manipulation involves more diverse cognitive processes and matures later (Yang et al., 2008). Future research examining the relationship between lexical tone manipulation and children' s reading ability could focus on preschool and early elementary grade children.

Finally, in an intervention study, Wang et al. (2017) examined performance of reading-disabled children across different elementary grades after receiving tone perception training, finding that lower elementary grade children showed significant improvements in both tone discrimination and Chinese word reading, while middle/upper elementary grade children showed improvements only in tone discrimination or no significant improvements on either task. These results suggest that the influence of tone perception ability on Chinese word reading may have a critical intervention period during early reading education. Therefore, future research should provide more evidence regarding critical periods to guide timely and effective interventions to reduce potential negative impacts of early tone awareness deficits on children' s reading development.

4.1.5 The Relationship Between Lexical Tone Awareness in Different Chinese Dialects and Children' s Reading Ability Existing research has focused extensively on Cantonese tone awareness in Hong Kong children, revealing that Cantonese tone contrast perception can longitudinally predict English reading ability across languages (Choi et al., 2016; Deng & Tong, 2021; Tong et al., 2017). However, research on Mandarin tone contrast perception lacks cross-linguistic predictive evidence. Previous research has revealed associations and predictive relationships between Cantonese tone categorical perception and Chinese and English reading abilities (e.g., McBride-Chang et al., 2008, 2011; Choi et al., 2016, 2017), but research on Mandarin tone categorical perception only provides association evidence with Chinese reading ability (Yin et al., 2011; Zhang et al., 2012), lacking other corresponding evidence. Research has also revealed associations between Cantonese tone manipulation and Chinese reading level in children (Li & Ho, 2011; Zhou & McBride, 2018), but lacks associations with cross-linguistic reading ability or longitudinal predictive evidence for Chinese and English reading levels. Evidence exists for associations between Mandarin tone manipulation and Chinese and English reading levels in children (Ju et al., 2021; Tao et al., 2007), but longitudinal predictive evidence is lacking. Future research needs to supplement more evidence on the relationship between Mandarin tone awareness and children' s reading ability.

Furthermore, there are approximately sixty to seventy languages within China, including Cantonese and Mandarin, each with internal dialectal variations and distinct tonal category classifications (You & Zhou, 1985). Research indicates that different dialectal experiences have complex effects on Mandarin tone awareness (Lin et al., 2011; Yu & Huang, 2019) and lexical awareness (Wu & Li, 2014). Future research could continue to investigate the impact of lexical tone awareness in other dialect regions on children' s reading ability.

4.2 Exploring the Causal Relationship Between Children' s Chinese Lexical Tone Awareness and Reading Ability

Existing research on the relationship between children' s Chinese lexical tone awareness and reading ability primarily provides two types of evidence—association and prediction—with only a few studies offering preliminary evidence for causality. For example, Zhang and Lin et al. (2023) found that only fifth-grade tone contrast discrimination ability significantly correlated with word meaning inference ability one year later; when age and nonverbal intelligence were controlled in regression models, fifth-grade tone contrast discrimination ability still significantly predicted sixth-grade word meaning inference ability, while other phonological awareness skills showed no similar longitudinal predictive effects. These results partially support a potential sequential and exclusive causal relationship between children' s tone contrast perception and lexical inference in reading. Additionally, Wang et al. (2017) conducted an intervention study providing tone contrast perception training to reading-disabled children across elementary grades in Taiwan. Compared to age-matched control groups, only

second-grade experimental groups showed significant improvements in both tone contrast discrimination and Chinese word reading, while fourth-grade children improved only in tone contrast discrimination and sixth-grade children showed no significant improvements. These findings suggest a potential causal relationship between children' s tone contrast perception and Chinese word reading ability, though this causal influence may have a critical age period.

However, there is currently a lack of large-scale, long-term intervention studies with careful control of other potential confounding variables, limiting the reliability of causal inferences. Therefore, future research should emphasize multidimensional, long-term tracking designs and experimental interventions to further explore the causal relationship between children' s tone awareness and reading ability and verify its generalizability across different age groups and language environments.

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Note: Figure translations are in progress. See original paper for figures.