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Spoken word recognition in young tone language learners: Age-dependent effects of segmental and suprasegmental variation

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ABSTRACT

The majority of the world's languages rely on both segmental (vowels, consonants) and suprasegmental (lexical tones) information to contrast the meanings of individual words. However, research on early language development has mostly focused on the acquisition of vowel-consonant languages. Developmental research comparing sensitivity to segmental and suprasegmental features in young tone learners is extremely rare. This study examined 2- and 3-year-old monolingual tone learners' sensitivity to vowels and tones. Experiment 1a tested the influence of vowel and tone variation on novel word learning. Vowel and tone variation hindered word recognition efficiency in both age groups. However, tone variation hindered word recognition accuracy only in 2-year-olds, while 3-year-olds were insensitive to tone variation. Experiment 1b demonstrated that 3-year-olds could use tones to learn new words when additional support was provided, and additionally, that Tone 3 words were exceptionally difficult to learn. Experiment 2 confirmed a similar pattern of results when children were presented with familiar words. This study is the first to show that despite the importance of tones in tone languages, vowels maintain primacy over tones in young children's word recognition and that tone sensitivity in word learning and recognition changes between 2 and 3 years of age. The findings suggest that early lexical processes are more tightly constrained by variation in vowels than by tones.

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1. Introduction

Children are exposed to numerous sources of phonemic and non-phonemic variation in speech, such as vowels, consonants, tones, and intonations. However, only a subset of this variation distinguishes the meanings of words in a language, placing onus on the learner to discern lexically relevant cues. There is an extensive body of literature on how learners accomplish this, most of which has focused on children learning vowel-consonant languages such as English and French (e.g., Mani & Plunkett, 2007; Nazzi, 2005; Quam & Swingley, 2010; Swingley & Aslin, 2000, 2002; White & Morgan, 2008; but see Mattock & Burnham, 2006; Singh & Foong, 2012). By contrast, approximately 60–70% of the world's languages are tone languages, relying on both segments (vowels, consonants) and lexical tones (hereafter, tones) to distinguish word identity (Yip, 2002) or using tones to indicate grammatical features such as tense, aspect, and case (e.g., Demuth, 1993). Furthermore, at least half of the world's population speaks a tone language natively (Fromkin, 1978). Thus, extant evidence and theories on early language development are based on a minority of languages and language learners. A major theoretical gap therefore exists in our understanding of children's sensitivity to tones in relation to segments. This study examines children's sensitivity to tone and segment variation in spoken word recognition in tone languages.

Mandarin, the most widely spoken tone language, distinguishes words using four basic tones (in addition to a fifth, "neutral" tone, which is typically used on weak syllables) (Liu & Samuel, 2004). Thus, *ma* can mean mother (T1: high level), hemp (T2: rising), horse (T3: dipping), and curse (T4: falling). Although several acoustic attributes, such as vowel duration (Gandour & Harshman, 1978), amplitude (Garding, Kratochvil, & Svantesson, 1986), and voice quality (Gottfried & Suiter, 1997) may define changes in tone, the primary cue to tone perception is the fundamental frequency

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contour (Khouw & Ciocca, 2007). At the outset, we review past studies on the acquisition of lexical tones (see Table 1 for a summary of research on tone acquisition in Chinese-reared young children).

Tone sensitivity is evident very early in development. Recent research has evinced tone sensitivity in Mandarin- and Cantonese-reared infants as early as 4 months of age (Yeung, Chen, & Werker, 2013). Even earlier than that, neural responses to tone distinctions have been observed even in newborns (Cheng et al., 2013). Furthermore, both English- and Mandarin-reared 6-month-olds are able to discriminate Thai tones, but later in infancy, tone discrimination was only observed in Mandarin-reared infants (Mattock & Burnham, 2006). A similar pattern of narrowing for tones in non-tone language-exposed infants was found in French-reared infants (Mattock, Molnar, Polka, & Burnham, 2008, but see Liu & Kager, 2014 on Dutch-reared infants). In a study of spoken word recognition of tone-bearing words, Singh and Foong (2012) demonstrated that bilingual Mandarin-English infants integrated lexical tones in Mandarin but not in English at 11 months of age. These findings are aligned with a widely reported development – perceptual narrowing – where young infants initially perceive differences between a wide range of phonetic contrasts, then selectively narrow down their sensitivity to native contrasts (e.g., Gervain & Mehler, 2010; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Polka & Werker, 1994). However, in a study of tone discrimination between 5 and 18 months, Liu and Kager (2014) reported a different pattern of attunement not previously observed for segments: Dutch learning infants showed a transient decline in tone sensitivity between 5 and 9 months, followed by an increase in sensitivity to tone contrasts between 9 and 18 months. This suggests that the decline in tone sensitivity observed at 9 months (e.g. Mattock & Burnham, 2006; Yeung et al., 2013) may reflect a transient process that may later reverse. These findings suggest that normative developmental processes, such as perceptual narrowing, predominantly drawn from segments may not apply to lexical tones.

Do Mandarin-learning children integrate tones in word learning and word recognition? One approach to understanding monolingual Mandarin-learning children's knowledge of tone contrasts has been to scrutinize their production of tones. Based on adults' coding of children's tone production, Hua and Dodd (2000) reported early mastery of tone contrasts in Mandarin-learning 1.5- to 4.5-year-olds. Furthermore, according to parental reports of their children's productive vocabulary using a word checklist that contains common words children may produce, monolingual Mandarin learners produced minimal pairs of words differing by tones in their vocabularies before the age of 3 (Tardif, Fletcher, Zhang, Liang, & Zuo, 2008). However, adult listeners' interpretations (Hua & Dodd, 2000) and parental reports (Tardif et al., 2008) of tone production may have been influenced by their use of semantic, syntactic, and contextual cues in identifying children's tone production.

Research in the production of tones suggests that while Mandarin tones emerge early in production, the maturation of tone

Table 1
A summary of research on tone acquisition in Chinese-reared young children.

Study	Participants	Stimuli	Tasks	Major findings
Burnham et al. (2011)	5-, 7-, and 11-month-olds (Cantonese learners)[a]	Phone block (e.g., /jok3/, /jot3/, /jap3/), Tone block (e.g., /p^{h}ak3/, /sak3/, /kak1/)	Odd-one-out task (aurally presented; the odd one is underlined)	Children were more sensitive to segment variation than tone variation
Cheng et al. (2013)	Newborns, 6-month-olds	T1/3 (highly distinctive), T2/3 (less distinctive)	Mismatch responses[b]	The T1/3 pair elicited mismatches response in both age groups, while the T2/3 pair did so only in the 6-month-olds
Ciocca and Lui (2003)	4-, 6-, and 10 years old (Cantonese learners)	Tone minimal pair contrasts	Picture-image matching task	Performance improved with age. Children's performance reached adult levels at 10 years of age
Hua and Dodd (2000)	1.5- to 4.5-year-olds	Elicited speech production	Picture naming and description tasks	Tones were acquired before segments
Li and Thompson (1977)	1.5- to 3-year-olds	Elicited speech production (longitudinal)	Picture naming and description tasks	Tones were acquired before segments. Rising and dipping tones were acquired later
Mattock and Burnham (2006)	6- and 9-month-olds	/ba-rising/, /ba-falling/ (Thai tones)	Conditioned head-turn procedure[c]	Both 6- and 9-month-olds were sensitive to the tone contrasts
Singh and Foong (2012)	7.5-, 9-, and 11-month-olds (bilinguals)	Familiar words (e.g., /bei1/, /tou2/) and tone changes	Conditioned head-turn procedure[b]	Children started to use tones in distinguish word identity in Mandarin at 11 months of age
Singh et al. (2014)	18- and 24-month-olds (bilinguals)	Novel words (e.g., /leng2/), tone and vowel changes	Mispronunciation paradigm in IPLP	Both age groups were highly, equivalently sensitive to vowel and tone variation
Singh et al. (2015)	2.5- to 4.5-year-olds (bilinguals)	Familiar words and tone and segment changes	Mispronunciation paradigm in IPLP	Older children were more sensitive to segments than tones
Wong (2012a, 2012b, 2013); Wong et al. (2005)	3-, 4, and 5-year-olds	Elicited speech production in a picture naming task	Analysis of the low-pass filtered speech production	Children did not produce adult-like tones. The ease of tone acquisition differed across tones based on both perception and production data
Yeung, Chen, and Werker (2013)	4- and 9-month-old Mandarin and Cantonese learners	/tɕ^{h}i/-rising tone, /tɕ^{h}i/-mid-level tone (Cantonese tones)	Children were first familiarized with a tone, and then were exposed to tone changes in the test	Sensitivity emerged first for tones then vowels and consonants

[a] Unless otherwise indicated, the children are Mandarin learners.
[b] A component of the ERP to an odd stimulus in a sequence of stimuli.
[c] This procedure makes use of an infant's differential preference for a given side as an indication of a preference for, or a familiarity with, the input or speech associated with that side.

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