L2 Acquisition of Chinese Tone

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Summary

L2 acquisition of Chinese tone involves coordinated encoding of pitch information across sensory-acoustic and cognitive domains, and is shaped by linguistic and non-linguistic experiences with pitch.

Autobiography

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Key words

L2 tone acquisition, linguistic experience, music experience, pitch processing, neural plasticity

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Chinese languages including Cantonese, Mandarin and Taiwanese use tones to distinguish word meaning. Tones are acoustically manifested by changes primarily in fundamental frequency (F0) as well as amplitude and duration. Native Chinese speakers process these acoustic correlates as linguistic entities in their perception and production of tonal categories. For learners whose native language (L1) is non-tonal, tones may present great difficulty, since the functional association between the acoustic characteristics and the specific linguistic tonal domain is unfamiliar to them. Research on second language (L2) tone acquisition thus focuses on the extent to which L2 tone learning involves encoding of lower-level sensory-acoustic information and how it is shaped by higher-domain linguistic experience. These issues can be addressed from three perspectives: how does L2 Chinese tone processing differ from native patterns, what factors affect tone learning, and what are the behavioral and neural manifestations of increased proficiency and training on the tone learning process.

1. Native and non-native differences

Cross-linguistic research on Chinese tone perception generally reveals that while native listeners perceive tones using linguistically relevant categorical cues, non-native listeners without a tone language background mostly rely on the acoustic properties of tone. Specifically, compared to native listeners, non-natives are more sensitive to within-category F0 differences, but less accurate in discriminating Chinese tones or classifying tonal exemplars into categories (Hallé *et al*. 2004; Peng *et al*. 2010; Xu *et al*.

2006). Native and non-native perception also differs in the perceptual weighting of tonal features. While native Mandarin listeners attach more importance to F0 contour (the primary tonal cue in Mandarin), non-native listeners (e.g., English, Japanese) rely more on F0 height (assumed to involve calibrating acoustic input based on internally stored F0 templates) (Gandour 1983; Huang and Johnson 2011; Lee *et al*. 2014), or they rely more on general temporal information (Cabrera *et al*. 2014; Xu and Pfingst 2003). These findings demonstrate that non-native listeners are inexperienced in perceiving Chinese tones as discrete phonological categories bearing contrastive linguistic significance, as their tone perception is acoustic-based with linguistically inappropriate perceptual weighting (Francis *et al*. 2008; Hallé *et al*. 2004). Moreover, for the perception of tones in linguistic contexts, non-native listeners, as compared to natives, are also less sensitive to surrounding phonetic and prosodic environments. For example, while native Mandarin listeners show normalization for F0 variations in sentential contexts, due to speaker F0 range or speaking rate, English listeners cannot efficiently incorporate such extrinsic information but rather rely on intrinsic acoustic differences of tone (Jongman and Moore 2000; Luo and Ashmore 2014). Similarly, non-native listeners fail to accurately identify Mandarin tones without tone-bearing components (vowels), as they are unable to use coarticulatory information from the consonantal contexts (Gottfried and Suiter 1997; Lee *et al*. 2009, 2010a). These results suggest that context-dependent tone perception requires long-term linguistic experience integrating global and localized F0 cues.

In terms of cortical involvement, research has established that native and non-native Chinese tone processing involve different neural mechanisms at both the acoustic and linguistic level. Behavioral and neuroimaging studies show that such differences engage a large-scale spatial brain network. While native tone processing primarily employs language-dominant left-hemisphere areas including prefrontal, frontal, temporal, and parietal regions, non-native processing involves more right-hemisphere or bilateral participation, similar to the processing of L1 prosodic or non-speech F0 information (Gandour *et al.* 2003, 2004; Hsieh *et al*. 2000; Klein *et al*. 2001; Wang *et al.* 2001, 2004). Electro-physiological research with time-sensitive event-related brain potential (ERP) data corroborates that these differences may arise from multi-stage processing mechanisms at sensory-acoustic and linguistic levels. For instance, differences in early-evoked ERP responses to Mandarin tones primarily reflect sensitivity to F0 contour for native Mandarin listeners but to F0 height for English listeners (Chandrasekran *et al*. 2007), echoing the behavioral findings of experience-driven cue-weighting patterns (e.g., Gandour 1983). Further research agrees that the experience-dependent modulation of tonal information occurs at both early and late stages of processing. For Mandarin tonal contrasts and within-category F0 changes, English listeners exhibit smaller and more delayed ERP differences at the pre-attentive stage, but are more accurate than Mandarin listeners in discriminating the within-category F0 differences at the attentive stage (Chandrasekaran *et al*. 2009b). Thus, while native tone experience results in enhanced F0 sensitivity at an early processing stage and enhanced tonal categorization ability at a later stage, non-native tone processing appears to be uniformly acoustic-driven. Consistently, some recent research has observed that experience-dependent neural responses to F0 occur as early as the sub-cortical brainstem level (Krishnan *et al*. 2005, 2012; Song *et al*. 2008; Wong *et al*. 2007b).

The native and non-native differences revealed in these behavioral and neural studies demonstrate language-specific processing of Chinese tone where non-natives' prior experience with acoustic F0 properties may not be directly generalized to higher-domain linguistic processing of tone.

2. Factors affecting tone learning

While non-native Chinese tone processing appears to be mediated by lower-level sensory-acoustic systems, higher-order experiential factors also affect how L2 tones are processed, particularly experience with pitch modulations both in the linguistic domain (e.g., L1 prosody) and in broader cognitive domains (e.g., musical experience).

The contribution of L1 prosody may involve enhanced sensitivity to F0 information based on the functional use of F0 in the L1. While non-tonal L1 listeners (e.g., Dutch, Uyghur) have been shown to be more attentive to F0 movements signaling intonational variations rather than to Mandarin tonal contrasts, tonal L1 listeners (Changsha/Nantong Chinese) are more sensitive to Mandarin tonal contrasts (Braun and Johnson 2011; Liang and Van Heuven 2007). Furthermore, tonal L1 listeners (Cantonese, Taiwanese) are better at differentiating Mandarin tonal stimuli across categories than detecting within-category differences (Hallé *et al*. 2004; Peng *et al.* 2010). These results indicate that L1 experience with classifying F0 into categories at the phonemic level can be generalized to identifying linguistic tone boundaries in an L2. The influence of L1 prosody may also arise from acoustic similarities. Particularly, non-tonal L1 listeners categorize Mandarin tones into their L1 prosodic categories based on the perceived acoustic similarities in F0 information between Mandarin tones and their native tonal, stress, rhythmic, and intonational systems

(Broselow *et al*. 1987; So and Best 2010, 2011; White 1981). While these findings imply that L1 prosodic experience may enhance tonal categorization and acoustic sensitivity, it should be noted that L1 prosodic experience might not always be facilitative. For instance, competing F0 adjustments in tone and intonation, resulting in tone-intonation clashes (e.g., a rising tone with falling intonation), pose great difficulty for non-native listeners (Yang and Chan, 2010). Additionally, L1 tone experience may also be inhibitory when L1 and L2 tonal properties do not match (So and Best 2010; Wu *et al.* 2014). In sum, non-native listeners may apply higher-domain linguistic or acoustic-phonetic strategies in their Chinese tone perception based on the functional use of prosody in their native language.

In addition to linguistic background, musical experience with pitch provides an advantage as well (Delogu *et al*. 2006, 2010; Gottfried 2007). Research reveals that native English musicians outperform non-musicians in identifying Mandarin tones, even in F0-degraded conditions, demonstrating musicians' enhanced sensitivity to pitch (Lee and Hung 2008). Furthermore, musical expertise may facilitate the perception of more linguistically-relevant acoustic dimensions of tone. While both American musicians and non-musicians perceive (acoustic) tone height in Taiwanese equally well, musicians can better track the (experience-dependent) F0 contours (Lee *et al*. 2014). Consistently, musicality effects are associated with the more efficient neural encoding of L2 Chinese tone. Musicians, relative to non-musicians, exhibit larger ERP responses in discriminating tonal differences and shorter latencies in categorizing tonal variations, as well as more robust F0 encoding in the auditory brainstem (Chandrasekaran *et al*. 2009a; Chobert and Besson 2013; Marie *et al*. 2011; Wong *et al*. 2007b). These findings implicate common behavioral and neural manifestations for music and linguistic pitch functions, suggesting that long-term pitch exposure may shape fundamental sensory circuitry in a domain-general manner.

Furthermore, pitch experiences from linguistic and musical backgrounds interact to affect L2 tone processing. While musical training provides a greater advantage than L1 tone background for L2 tone identification, both experiential factors equally facilitate learning tone-words in lexico-semantic contexts. However, the combination of these factors does not lead to cumulative facilitatory effects for musicians with an L1 tone background (Cooper and Wang 2012; Mok and Zuo 2012). These results reveal that general auditory processing mechanisms for lower-level linguistic information such as musical experience positively transfer to aid L2 tone identification. Meanwhile, while L1-specific tone features may interfere with lower-level L2 tone identification, the general L1 tone experience of utilizing F0 lexically to map phonetic features to meaning appears to facilitate tone-word learning. Together, these findings point to a dynamic influence of musical and linguistic experience, involving integrated domain-general and domain-specific mechanisms at different levels of tone processing.

3. Learning patterns

Given the contributions of these pre-existing experiential factors, the subsequent question concerns the acquisition of Chinese as a function of L2 experience. Research involving non-natives with different levels of Chinese proficiency reveals that learners shift their attention to more linguistically-relevant tonal aspects as they gain experience in Chinese. For example, experienced but not naïve non-native Mandarin listeners can efficiently use the critical F0 contour cue (rather than F0 height) in Mandarin tone discrimination (Guion and Pederson 2007). Likewise, while naïve (Cantonese-L1) listeners exhibit phonetic-level assimilation for Mandarin tones into the allophonic variants in their L1 (So 2012), more advanced learners are additionally influenced by phonological tone changes (Wu *et al*. 2014). These findings point to a progressive process of L2 tone learning, shifting from lower-level acoustic to higher-level phonemic representations in establishing new tonal categories.

Research to empirically assess how such learning occurs employs the well-established laboratory-based training paradigm aimed at assisting learners to establish L2 phonetic categories (Logan *et al*. 1991). Tone perception and production training studies show that non-native tone speakers (e.g., Dutch, English, Hmong, Japanese) can better perceive and produce Chinese tones after training, with the improvements extended to new linguistic contexts and retained in long-term memory (Leather 1990; Wang *et al*. 1999, 2003a; Wang 2012). These studies show that training yields highly generalized learning and long-term modifications of L2 tone perception and production. Further training research demonstrates that successful learning involves redistribution of acoustic cue weighting, focusing on the primary F0 cues (e.g., contour) used in the L2 rather than the properties (e.g., height) that function more prominently in the L1 (Chandrasekran *et al.* 2010; Francis *et al.* 2008). Moreover, learning at the acoustic level may predict success in higher linguistic domains. Native English or Thai learners who are better at identifying Mandarin or Cantonese tones in non-lexical contexts can more successfully learn tone-words, suggesting a phonetic-phonological-lexical continuity for tone learning in that higher-order linguistic learning may be mediated by lower-level auditory-acoustic processing (Cooper and Wang 2012; Wong and Perrachione 2007). Furthermore, training enhances tone identification in broader linguistic environments when target tones appear in sentential contexts (Wang 2012, 2013). These data indicate that training-induced learning involves reweighting of acoustic cues as well as integrating higher-domain linguistic information to develop L2 tonal categories.

The effects of multi-level experiential factors may also affect how Chinese tones are learned during training. At the auditory level, learners' perceptual aptitude appears to influence their tone learning abilities. The high-variability training paradigm, designed to expose learners to a high variety of tonal variants, turns out to be effective only for learners with strong perceptual abilities, whereas those with weaker perceptual abilities benefit more from low-variability training (Perrachione *et al.*, 2011), indicating that lower-domain perceptual abilities may predict successful category learning. Similarly, musical training and non-linguistic-context pitch training both lead to improved tone-word learning proficiency, suggesting that enhanced perception of lower-level tonal information may contribute to success in a higher-level linguistic task (Cooper and Wang 2013; Wong and Perrachione 2007). In the linguistic domain, learners' L1 prosodic experience influences tone learning. Learners with tonal (Mandarin) and non-tonal (English) L1s reveal different training-induced changes in their perception of Cantonese tones depending on their L1 experience with tonal and intonational categories (Francis *et al.* 2008). Moreover, tonal-L1 (Thai) learners exhibit higher post-training proficiency in Cantonese tone-words than do non-tonal (English) learners, despite the two groups' comparable performance in tone identification, indicating that Thai learners' L1 experience with pitch-to-meaning associations beneficially transfers to their L2 (Cooper and Wang 2012).

Brain research further reveals neuroplasticity associated with tone learning, involving recruitment of new brain resources and a shift to more efficient, native-like neural circuitry. For example, cortical effects of Mandarin tone learning by American learners involve both the expansion of language-related areas (Brodmann's area 22) and employment of adjacent cortical regions (Brodman's area 42) in the superior temporal gyrus (Wang *et al*. 2003b). Further research also identifies the participation of primary auditory cortex and sub-cortical brainstem in encoding pitch cues for linguistic-level learning, with increased left Heschl's Gyrus volume and enhanced brainstem pitch responses post-training (Song *et al*. 2008; Wong *et al*. 2008). Moreover, effective training is associated with a shift to native-like cortical representation of tones. Particularly, successful tone learners exhibit increased activation in the left-hemisphere regions involved in L1 pitch processing, whereas learners with limited improvement show increased activation in the right auditory cortex responsible for non-linguistic pitch processing (Wong *et al*. 2007a).

These learning patterns indicate progressive changes in behavioral performance and neural representations with training and increased proficiency, suggesting that L2 tone processing is continuously shaped by experience and learning.

4. Summary and future directions

Taken together, research cumulatively points to a multi-facet model of L2 tone acquisition in Chinese, encapsulating experience-dependent and domain-general factors. Specifically, Chinese tone learning appears to be modulated by multiple levels of processing across sensory-motor and cognitive domains, under the influence of linguistic, pitch, and musical experience. Furthermore, learning involves a dynamic process, as different aspects of these experiential factors are utilized at different stages of learning. The long-term experiences with pitch across domains result in neuroplasticity with respect to tone learning, reflected by changes in the temporal dynamics and cortical/sub-cortical organization of L2 tone in the brain. These findings provide support for a general theoretical account of pitch processing with integrated bottom-up and top-down processes (Zatorre and Gandour 2008).

However, it is still unclear how behavioral and neural representations are continuously shaped as learning progresses. Longitudinal research tracking tone learning trajectories is needed to define the agents of neuroplasticity at different learning stages. Additionally, further research must examine the relationship between the production and perception of tone (evidenced by the training studies) in order to determine if the coordination of the articulatory-orosensory and auditory-acoustic neural pathways observed in L2 segmental learning (Callan *et al*. 2004) is also employed in L2 tone learning. A related future direction is to also explore how visual speech input, which has been shown to facilitate L2 segmental learning (Hazan *et al*. 2005) and L1 tone perception (Chen and Massaro 2008), contributes to L2 tone learning. Collectively, research along these avenues will present a more complete understanding of the way in which multiple sensory-motor and higher-order cognitive systems cooperate functionally in L2 tone learning.

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