Developing structural sensitivity in tonal alternations: Tone 3 sandhi production and directionality in L1 and L2 Mandarin

Introduction: Phonological alternations are prevalent in language yet challenging to process as they involve the application of different types of information and their interactions. This study investigates how second language (L2) learners produce Mandarin Tone 3 sandhi (T3S), a phonological process that involves (a) identifying the domain of rule application based on morphosyntactic and prosodic structures and (b) phonologically changing the first of two neighboring low tones (T3) to a rising tone (T2) (T3T3→T2T3). This rule is consistently applied by native adults in disyllabic sequences [1, 2]. In trisyllabic T3 sequences (i.e., T3T3T3), its realization interacts with prosodic/morphosyntactic domains: left-branching structures (LB) involve left-to-right application of T3S and yield T2T2T3, and right-branching structures (RB) involve right-to-left application and produce T3T2T3 (see 1&2). While L1 Mandarin speakers can accurately produce disyllabic and LB trisyllabic sandhi by age 3 [3, 4], they face challenges with RB trisyllabic sequences until age 5 [4]. This suggest that processing RB structures may involve greater cognitive effort and complexity and take longer to learn. However, little is known about how L2 learners produce T3S especially in trisyllabic T3 sequences.

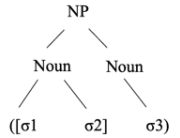
Research questions: (1) How do L2 learners produce T3S in disyllabic expressions? **(2)** How do L2 learners apply T3S in complex trisyllabic sequences, which involve opposite branching directions? **(3)** How does the production of T3S change as L2 proficiency improves?

Method. Exp.1 recruited 15 native speakers (NSs), 14 intermediate-low (IL), and 16 intermediate-high (IH) English-L1 learners in a production task for disyllabic sandhi words. Test materials included 12 T2T3 and T3T3 minimal pairs (6 real word pairs and 6 pseudowords). Participants heard two monosyllables separately and produced them as a disyllabic word/sequence. **Exp.2**, a read-out task, elicited the production of trisyllabic sandhi sequences (6 NSs, 5 IL, 7 IH participants, data collection ongoing). Test materials comprised 36 trisyllabic sandhi phrases, varying in two branching directions (LB vs. RB determined by semantics of the sequence) and two sequence types (real vs. novel phrases). Word/phrase meaning tasks were conducted to ensure all learner participants were familiar with the existing words and phrases.

Results. Exp.1 found that all three groups were able to apply T3S to disyllabic sequences, though with differing rates (Table 1). Acoustic analyses revealed a significant slope difference only between NSs and IL learners, but not between NSs and IH learners, suggesting progression towards native-like sandhi productions (Fig. 1). In **Exp.2**, NSs accurately applied T3S to both LB and RB structures (Fig. 2). IH learners showed lower accuracy than NSs, especially in right-branching structures, but exhibited sensitivity to the morphosyntactic structures (Fig. 3, $p<0.01$). In addition, they had more left-to-right realizations (i.e., T2T2T3) in novel phrases ($p<0.05$). IL learners demonstrated even lower application rates and predominantly applied sandhi from left to right, favoring T2T2T3 overall (Fig. 4).

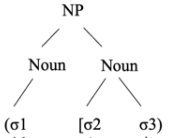
Discussion. First, intermediate-level learners can productively apply T3S to disyllabic pseudowords, providing empirical evidence that L2 learners generalize phonological rules to novel contexts. **Second**, higher proficiency learners showed more native-like T3S application, highlighting the role of proficiency. **Moreover**, learners encounter challenges with trisyllabic sequences. IL learners predominantly realize T3S linearly from left to right; IH learners start to develop sensitivity to branching directions and prosodic domains, likely reflecting a deeper understanding of prosody-syntax interaction or the availability of greater cognitive resources associated with improved proficiency.

(1) A left-branching trisyllabic prosodic word ([T3T3] T3)



([σ1	σ2]	σ3)	
([演	讲]	稿)	Chinese characters: 演讲 *speech*, 稿 *script*
([yan3	jiang3]	gao3)	Chinese pinyin
([T3	T3]	T3)	Underlying tone
([**T2**	T3]	T3)	Tone sandhi applies within the disyllabic word
(T2	**T2**	T3)	Boundary erased; tone sandhi applies again; surface tone

(2) A right-branching trisyllabic prosodic word (T3 [T3T3])



(σ1	[σ2	σ3)	
(纸	[老	虎])	Chinese characters: 纸 *paper*, 老虎 *tiger*
(zhi3	[lao3	hu3])	Chinese pinyin
(T3	[T3	T3])	Underlying tone
(T3	[**T2**	T3])	Tone sandhi applies within the disyllabic word
(T3	T2	T3])	Boundary erased; no additional process; surface tone

group	word condition	percentage
NSs	real	100%
	pseudo	100%
IH learners	real	91%
	pseudo	83%
IL learners	real	85%
	pseudo	80%

Table 1. Percentage of sandhi application in disyllabic words across groups

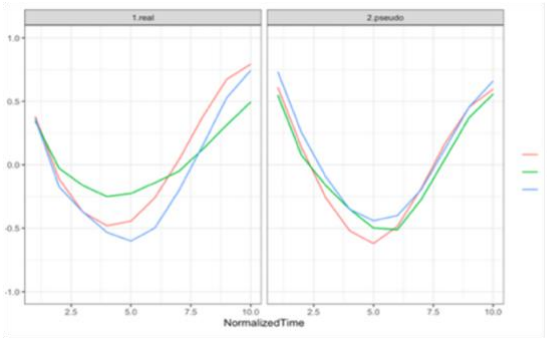


Fig. 1. Acoustic realization of sandhi T3 in disyllabic words across groups

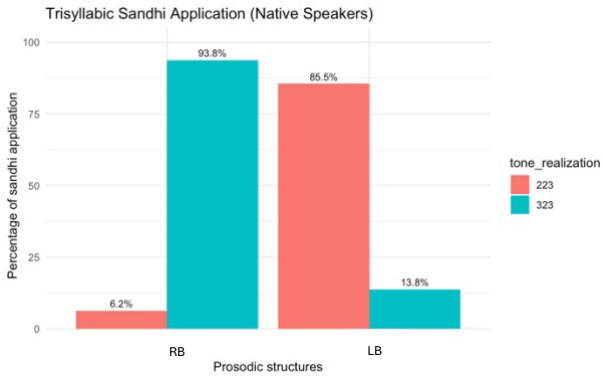


Fig. 2. Sandhi realizations of trisyllabic sequences across prosodic structures (NS)

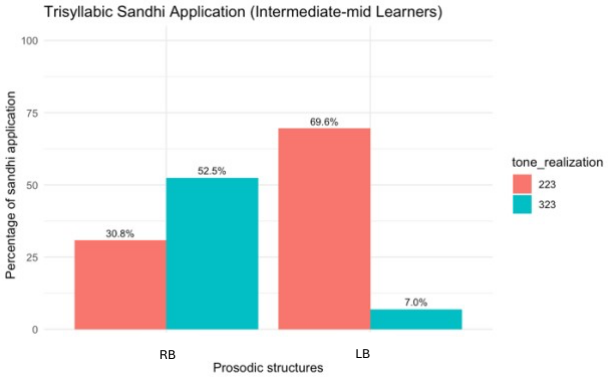


Fig. 3. Sandhi realizations of trisyllabic sequences across prosodic structures (IH)

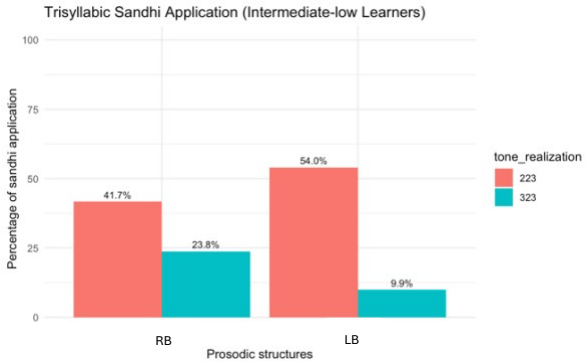


Fig. 4. Sandhi realizations of trisyllabic sequences across prosodic conditions (IL)

References

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[4] Tang, P., Yuen, I., Rattanasone, N. X., Gao, L., & Demuth, K. (2019). *Applied Psycholinguistics, 40*(6), 1495–1526.