Tone Sandhi in Mono/Polysyllabic Single Words in Shanghai Chinese*

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Abstract
This study examines tone sandhi in mono/polysyllabic words in Shanghai Chinese, with a specific focus on tonal redistribution domains. The goal of this study is to examine the tonal redistribution patterns in quadrisyllabic and quintesyllabic words, the results of which will bear on the metrical structure analysis for this language. There are three major findings from this study based on the analysis of tonal contours from one native speaker. First, T4 is a H level tone in monosyllabic words but surfaces as a LH contour tone in polysyllabic words. Second, only one redistribution domain has been identified for quadrisyllabic words. Third, quintesyllabic words are most reliably characterized by two tonal redistribution domains, although the mono-domain pattern has also been attested. The results of this study are discussed under the Optimality Theory framework.

Key words
Shanghai Chinese, tone sandhi, tonal redistribution, stress, foot

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1. Introduction

In Shanghai Chinese, each syllable is a tone bearing unit (TBU). When multiple syllables combine to form a word, tonal change or *tone sandhi* occurs. Previous research on this language primarily focuses on the description of citation tones (e.g., Xu et al. 1988), the property of breathiness (e.g., Sherard 1972, Cao and Maddieson 1992, Gao et al. 2019), interface of tone and syntax (e.g., Selkirk and Shen 1990), and metrical structures (e.g., Duanmu 1995, 1997), with few experimental studies on tonal patterns in polysyllabic words (but see Yasunori 2015) on which there is no consensus. The empirical goal of this paper is to characterize the tonal patterns of mono/polysyllabic single words in Shanghai Chinese. The theoretical goal is to reassess the foot structure analysis by Duanmu (1997) with new data.

2. Tone sandhi in Shanghai Chinese

There are five citation tones in Shanghai Chinese, one falling tone and four rising tones (see e.g., Xu et al. (1988) for details). However, they can be arguably reduced to two underlying tones, /HL/ and /LH/ (Selkirk and Shen 1990, Duanmu 1997, Chen 2000). The pitch value differences among the four rising tones are related to phonation types. If the onset is voiceless, the rising contour has a higher initial pitch value; if the onset is "voiced", the contour has a lower initial pitch value. Note that the "voiced" onsets are not necessarily voiced with a negative VOT, but rather produced with a breathy voice or "clear sound with a muddy aspiration" (Liu 1925, Chao 1928). Further, if the rime has a glottal stop /ʔ/, the duration of the rime is shorter. Despite these differences, I shall follow the literature by assuming that Shanghai has two phonological contour tones, /HL/ and /LH/.

In Shanghai Chinese, when several syllables combine, tone sandhi occurs. In general, there are two types of tone sandhi. *Broad tone sandhi* applies within each word category, and *narrow tone sandhi* applies across word categories. This paper only limits itself to broad tone sandhi in single words (compounds are beyond the scope of this paper). Broad tone sandhi can be characterized by a *tonal redistribution* process. When two syllables combine, the tone of the second syllable is delinked from its TBU. The contour tone of the first syllable then spreads to the entire word. An example is given in (1) where the underlying LH tone of /li/ in 'Paris' is delinked from its TBU. The HL contour tone of the first syllable /pa/ then redistributes so that /pa/ and /li/ are pronounced with a H and L tone, respectively.

(1) Tonal redistribution in disyllabic words

HL	LH	**LH**	LH
H	**L**	**L**	**H**
pa	li	zã	hɛ
'Paris'		'Shanghai'	

What happens when a word is trisyllabic where the initial contour tone does not have enough tone autosegments to redistribute? In this case, the tonal pattern depends on the initial tone (see (2)). Descriptively, if the initial tone is T2/T3/T4, the initial tone spreads till the second syllable, with the third syllable receiving a default L tone (Xu et al. 1988, Duanmu 1995, 1997). This is called "second association". If the initial tone is T1/T5, the initial tone spreads till the third (last) syllable with the second syllable getting an intermediate L tone, which is called "final association". It should be emphasized that, regardless of the association type, only the initial contour tone redistributes. Thus, in trisyllabic words, there is only one *tonal redistribution domain*.

(2) Tonal redistribution in trisyllabic words

T1-initial	T2-initial	T3-initial	T4-initial	T5-initial
HL LH LH	**LH** LH LH	**LH** LH HL	**LH** LH HL	**LH** HL HL
H L **L**	**L** **H** L	**L** **H** L	**L** **H** L	**L** L **H**
jin tɕɪʔ lɪʔ	tʰɕo kaʔ lɪʔ	ŋu lu sz̩	faʔ lɛ ɕi	loʔ sɛ tɕi
'English'	'Chocolate'	'Russia'	'French'	'Los Angeles'

As to quadrisyllabic words, there is controversy in the number of redistribution domains as Xu et al. (1988) and Duanmu (1995, 1997) disagree. First, we look at Xu et al.'s description. After converting Xu et al.'s numeric pitch values to binary H/L values, the quadrisyllabic tonal patterns are displayed in (3). For T1-initial words, the initial tone spreads till the final syllable (i.e., final association); for T2/T3/T4-initial words, tone spreading terminates on the second syllable (i.e., second association). For T5-initial words, both second and final associations are provided by Xu et al. Regardless of the association type, in Xu et al.'s analysis, there is only one redistribution domain since *only one syllable redistributes its contour tone*.

(3) Quadrisyllabic tonal pattern in Xu et al. (1988) with adaptation

T1-initial	T2-initial	T3-initial	T4-initial
HL LH HL LH	**LH** LH LH HL	**LH** LH HL LH	**LH** LH LH HL
H L L **L**	**L** **H** L L	**L** **H** L L	**L** **H** L L
ja lu sa lã	kʰa lɛ lu na	mu lɛ ɕi ja	kʰaʔ li mi ja
'Jerusalem'	'Carolina'	'Malaysia'	'Crimea'

T5-initial (second association)	T5-initial (final association)
LH LH LH LH	**LH** LH LH LH
L **H** L L	**L** L L **H**
paʔ ŋu lu sz̩	paʔ ŋu lu sz̩
'Belarus'	'Belarus'

Next, let's look at Duanmu's (1997) description of tone sandhi patterns in quadrisyllabic words. According to his description, all quadrisyllabic words have two tonal redistribution domains as there are *two syllables that redistribute their contour tones*. Thus, the same set of words in (3) would have the tonal patterns in (4).

(4) Quadrisyllabic tonal pattern in Duanmu (1997)

T1-initial	T2-initial	T3-initial	T4-initial	T5-initial
HL LH **HL** LH	**LH** LH **LH** HL	**LH** LH **HL** LH	**LH** LH **LH** HL	**LH** LH **LH** LH
H L H L	**L H L H**	**L H L H**	**L H L H**	**L H L H**
ja lu sa lã	kʰa lɛ lu na	mu lɛ ɕi ja	kʰaʔ li mi ja	paʔ ŋu lu sz̩
'Jerusalem'	'Carolina'	'Malaysia'	'Crimea'	'Belarus'

Finally, we look at quintesyllabic words. Xu et al. did not provide the tone sandhi patterns, but Duanmu claims that the pattern in (5) was attested by his informant, where the initial tone spreads till the second syllable to form the *first* redistribution domain before a *second* redistribution domain begins from the third syllable. As quintesyllabic real words with T4/T5 initial tones are quite rare, I only illustrate with T1/T2/T3-initial words.

(5) Quintesyllabic tonal pattern based on Duanmu (1997)

T1-initial	T2-initial	T3-initial
HL HL **LH** LH LH	**LH** LH **HL** LH HL	**LH** LH **HL** HL HL
H L L H L	**L H H L** L	**L H H L** L
piŋ ɕi faʔ ni ja	mu taʔ ka sz̩ ka	t^ha k^haʔ la mu kø
‘Pennsylvania’	‘Madagascar’	‘Taklamakan’

Given the above description, I summarize the broad tone sandhi patterns for polysyllabic single words in Shanghai Chinese as follows. If the single words in question are di/trisyllabic, there is only one tonal redistribution domain. If the words are quadrisyllabic, Xu et al. (1988) assumes that there is only one redistribution domain, while Duanmu (1997) assumes that there are two, similarly for quintesyllabic words. Therefore, the main difference between Xu et al. and Duanmu lies in the number of redistribution domains in quadrisyllabic and quintesyllabic words.

3. Metrical structure in Shanghai Chinese

Metrical structure is common in languages with stress. Stress is often correlated with higher pitch values and stronger intensity. A stressed syllable plus an unstressed syllable (**σ**σ) form a head-first metrical structure called *trochaic* foot (e.g., ***fa**ther*). A head-final metrical structure is called an *iambic* foot (σ**σ**) (e.g., *in**fer***). Shanghai Chinese does not have stress realized in a similar way as English, and native speakers do not have such an intuition, either (Selkirk and Shen 1990). However, Duanmu (1995) observes that there is an interesting parallel between vowel reduction in English and tone “reduction” (i.e., delinking and replacement with a default L tone) in Shanghai Chinese.

In English, a vowel in an unstressed syllable tends to undergo reduction to a schwa as in *at**o**m*. In a similar vein, in Shanghai Chinese, non-initial TBUs lose their tones in a tonal redistribution domain and are assigned a L tone, presumably because they are in unstressed positions. Therefore, this delinking process leads some linguists to argue that a redistribution domain is also a stress domain, namely, a foot. Given that initial syllables in redistribution domains always retain their citation tones, it seems that Shanghai Chinese has a trochaic (head-first) foot structure (Duanmu 1995, 1997, Chen 2000, Zhang 2014). In the following paragraphs, I will describe Duanmu’s (1997) phonological foot structure analysis for polysyllabic words, which forms the theoretical foundation for this study.

First, let us take mono/disyllabic words as a starting point to introduce some constraints under the Optimality Theory (OT) framework (Prince and Smolensky 1993) that determine the scope of tonal redistribution. For the sake of the argument, let us assume with Duanmu that (i) if a syllable is not the head of a foot, its citation tone will be lost and replaced with a default L tone, and (ii) if a syllable is left unparsed into a foot, it will similarly lose its citation tone and receive a default L tone. With these two assumptions, we turn to three OT constraints employed by Duanmu (1997), rephrased in (6).

(6) **Parse**: Every syllable must be parsed into a (trochaic) foot.
Ft-Bin: Every foot must be binary (i.e., disyllabic).
Align-Ft-L: The left edge of every foot must be aligned with the left edge of the prosodic word.

Tableaux 1 and 2 are reproduced from Duanmu (1997:486). In these tableaux, an upper-case *S* means that the syllable is stressed (keeps its citation tone); a lower-case *s* means it is unstressed (loses its citation tone). The parentheses represent foot boundaries. Thus, the winning candidate "(S)" represents that the syllable is a monosyllabic foot and that it is stressed.

With these notations explained, we can see that Parse outranks Ft-Bin in Tableau 1 because, otherwise, the citation tone of the monosyllabic word will be lost, contrary to fact. The ranking of Align-Ft-L is undetermined because it is satisfied for both the candidate "(S)" and the candidate "s" (vacuously, as the latter is not a foot at all). The ranking of Ft-Bin and Align-Ft-L cannot be determined in Tableau 2 either, as the losing candidate "(S)(S)" violates both constraints while the winning candidate "(Ss)" violates neither.

Tableau 1. OT analysis of foot structure in monosyllabic words.

Candidate	Parse	Ft-Bin	Align-Ft-L
☞ a. (S)		*	
b. s	*!		

Tableau 2. OT analysis of foot structure in disyllabic words.

Candidate	Parse	Ft-Bin	Align-Ft-L
☞ a. (Ss)			
b. (S)(S)		*!*	*

The foot structure for trisyllabic words is shown in Tableau 3. Duanmu (1997) argues that a foot can be trisyllabic in Shanghai Chinese. This is because candidate (b) "(Ss)s" with a binary foot is less optimal than candidate (a) "(Sss)" since Parse must outrank Ft-Bin, independently established in Tableau 1. Candidates c and d are harmonically bounded (i.e., always less optimal).

The ranking of Ft-Bin and Align-Ft-L can be determined with quadrisyllabic words, shown in Tableau 4. If there are indeed two redistribution domains (i.e., two feet), as Duanmu suggests, Ft-Bin must outrank Align-Ft-L. This is because the losing candidate (b) "(Ssss)" incurs a fatal violation of Ft-Bin but no violation of Align-Ft-L.

Tableau 3. OT analysis of foot structure in trisyllabic words.

Candidate	Parse	Ft-Bin	Align-Ft-L
☞ a. (Sss)		*	
b. (Ss)s	*!		
c. (Ss)(S)		*	*!*
d. (S)(Ss)		*	*!

Tableau 4. OT analysis of foot structure in quadrisyllabic words.

Candidate	Parse	Ft-Bin	Align-Ft-L
☞ a. (Ss)(Ss)			**
b. (Ssss)		*!	
c. (Sss)(S)		*!*	***
d. (Ss)ss	**!		

Finally, for quintesyllabic words, the tonal pattern suggested by Duanmu (1997) is candidate (a) in Tableau 5 where the first two syllables form a redistribution domain and the last three syllables form another. The constraint ranking proposed above can capture the tone sandhi pattern.

Tableau 5. OT analysis of foot structure in quintesyllabic words.

Candidate	Parse	Ft-Bin	Align-Ft-L
☞ a. (Ss)(Sss)		*	**
b. (Sss)(Ss)		*	***!
c. (S)(Ss)(Ss)		*	*,**!*
d. (Ss)sss	*!**		

In sum, Duanmu (1995, 1997) argues that Shanghai Chinese has a trochaic foot structure as only initial syllables can keep their citation tones and redistribute, presumably as a result of being in a stressed position. Due to the ranking of Parse >> Ft-Bin >> Align-Ft-L, the tonal patterns for polysyllabic single words as in (1), (2), (4), (5) are derived. However, given the inconsistency of judgments between Xu et al. and Duanmu in terms of tone sandhi patterns for quadrisyllabic words and due to insufficient evidence on quintesyllabic words, this study aims to assess the tone sandhi descriptions in prior work, which will bear on Duanmu's foot structure analysis.

4. Experiment

4.1 Participant

A 30-year-old male native speaker of Shanghai Chinese participated in a production experiment.

4.2 Stimuli

The stimuli are composed of both real and nonce words (see Table 1). All the mono/disyllabic words are real words. But for words with three or more syllables, a mixture of real and nonce words was used. Nonce words were created to address two issues: (i) to create segment-level minimal pairs among words that have different initial tones, and (ii) to substitute real words where polysyllabic real words with specific initial tones are rarely available. None of the mono/disyllabic words and polysyllabic nonce words have consonant onsets. Real words were also included (under the column "List 2") to see whether nonce words are pronounced with different tonal redistribution patterns than real words. As there was no substantial difference between nonce words and real words, I will not report all of them in this paper. Thus, unless indicated, tonal patterns for words with three or more syllables are based on nonce words in List 1, although tonal variation with quintesyllabic real words has been found, which will be reported separately.

4.3 Procedure

The participant read each word in the word list twice in a framing sentence 'I like_____' (IPA: [ŋu hø ɕi]) following the practice of Yasunori (2015). For each monosyllabic word, pitch values corresponding to four equally spaced time points were extracted using Praat (Boersma and Weenink 2018). To assess the pitch contour of each syllable, I follow the practice of Elfner (2015) by providing a set of diagnostics for determining the tone type (i.e., L or H) in a polysyllabic word. To extract the pitch values, Praat was used to generate a pitch list for F_0 of each word. Each list samples pitch values every 10ms. The data were then plotted in R (R core team 2018). Out of two tokens for each word, only the token with less pitch loss under the column “List 1” was plotted.

Table 1. Word lists

	Initial tone	List 1 (IPA)	Gloss	List 2 (IPA)	Gloss
	T1	ɛ	‘grief’	-	-
	T2	ɛ	‘love’	-	-
Monosyllabic	T3	ɛ	‘salty’	-	-
	T4	aʔ	‘duck’	-	-
	T5	aʔ	‘box’	-	-
	T1	ɛ.tɕin	‘sorrow’	-	-
	T2	ɛ.tɕin	‘love’	-	-
Disyllabic	T3	ɛ.tɛ	‘salted egg’	-	-
	T4	aʔ.tsz̩	‘duck’	-	-
	T5	aʔ.tsz̩	‘box’	-	-
	T1	ɛ.li.ja	nonce word	ka.na.ta	‘Canada’
	T2	ɛ.li.ja	nonce word	pɛ.lɛ.kɛn	medicine name
Trisyllabic	T3	ɛ.li.ja	nonce word	tɛ.tɕɪ.ti	company name
	T4	aʔ.li.ja	nonce word	taʔ.i.tsz̩	‘Germany’
	T5	aʔ.li.ja	nonce word	paʔ.lɛ.ti	‘brandy’
	T1	ɛ.sa.ni.ja	nonce word	ja.lu.sa.lã	‘Jerusalem’
	T2	ɛ.sa.ni.ja	"Estonia"	kʰa.lɛ.lu.na	‘Carolina’
Quadrisyllabic	T3	ɛ.sa.ni.ja	nonce word	mu.lɛ.ɕi.ja	‘Malaysia’
	T4	aʔ.sa.ni.ja	nonce word	kʰaʔ.li.mi.ja	‘Crimea’
	T5	aʔ.sa.ni.ja	nonce word	paʔ.ɲu.lu.sz̩	‘Belarus’
	T1	ɛ.sɛ.ɲu.pi.ja	"Ethiopia"	piŋ.ɕi.faʔ.ni.ja	‘Pennsylvania’
	T2	ɛ.sɛ.ɲu.pi.ja	nonce word	mu.taʔ.ka.sz̩.ka	‘Madagascar’
Quintesyllabic	T3	ɛ.sɛ.ɲu.pi.ja	nonce word	tʰa.kʰaʔ.la.mu.kø	‘Taklamakan’
	T4	aʔ.sɛ.ɲu.pi.ja	nonce word	-	-
	T5	aʔ.sɛ.ɲu.pi.ja	nonce word	-	-

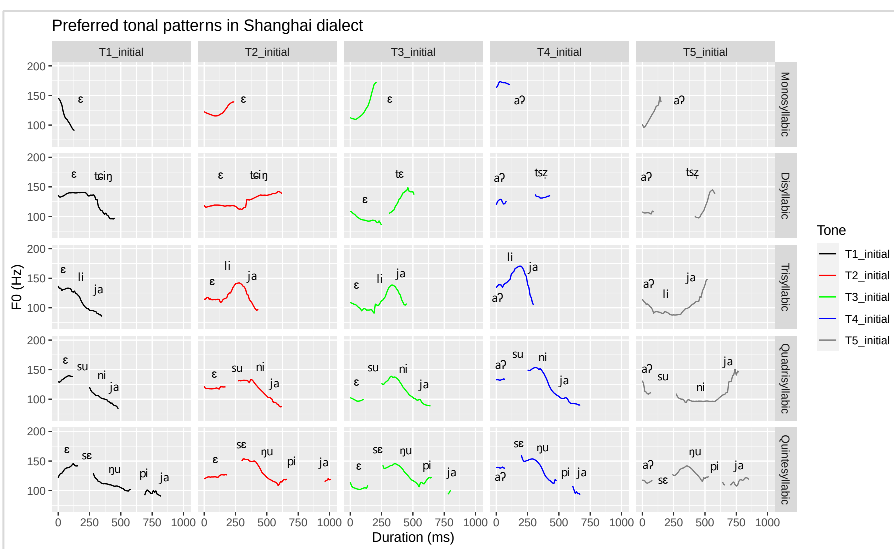

Figure 1: Preferred tonal patterns for single words under the “List 1” column in Table 1.

4.4 Results

Figure 1 displays the tonal contours produced by the participant for all the words under List 1. For quintesyllabic words, only the preferred pattern is displayed in the figure. The attested contrast between the preferred and the alternative pattern is shown in Figure 2. The alternative pattern was added by the participant himself, but it was not the pattern normally used by the participant.

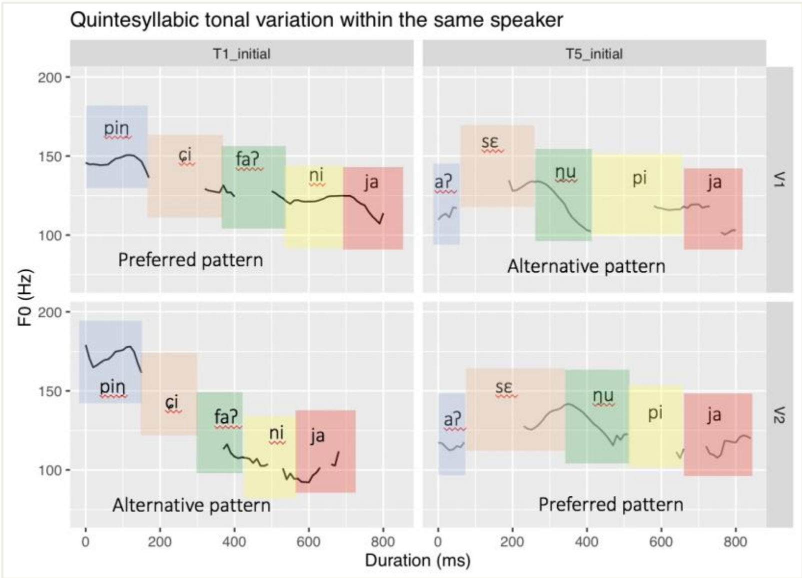

Figure 2: Quintesyllabic tonal variation (left: 'Pennsylvania'; right: /aʔ.sɛ.ŋu.pi.ja/)

To assess the tonal pattern, I provide a set of diagnostics to determine whether a TBU has a H or L tone in mono/polysyllabic words. See (7) below.

(7) Diagnostics for assessing the pitch contours based on visual inspection
  a. A tone with a positive slope is a H tone.
  b. A tone with a negative slope is a L tone.
  c. The tone type for a level tone depends on its adjacent "sloping" tone:
    (i) if the tone to its left is falling, it is a L tone.
    (ii) if the tone to its left is rising, it is a H tone (this is not observed).
    (iii) if the tone to its right is falling, it is a H tone; but if (i) also obtains, it is a L tone.
    (iv) if the tone to its right is rising, it is a L tone.

Based on the diagnostics in (7), the tonal patterns of single words are summarized in Table 2. And the number of tonal redistribution domains is shown in Table 3 based on our knowledge about tonal redistribution behaviors. However, note that Figure 2 shows that the participant produced two different patterns for T1-initial and T5-initial quintesyllabic words. Therefore, for these two subtypes, (Ss)(Sss) and (Sssss) are both attested. Also note that L tones in final positions can have a rise probably because the voice is returning to a normal register (e.g., lower left panel Figure 2), but is treated as a L tone in this paper.

Table 2. Pitch contours for mono/polysyllabic words

Initial Tone	Monosyllabic	Disyllabic	Trisyllabic	Quadrisyllabic	Quintesyllabic
T1	HL	H-L	H-L-L	H-L-L-L	H-L-L-H-L/H-L-L-L-L
T2	LH	L-H	L-H-L	L-H-L-L	L-H-L-H-L
T3	LH	L-H	L-H-L	L-H-L-L	L-H-L-H-L
T4	H	L-H	L-H-L	L-H-L-L	L-H-L-H-L
T5	LH	L-H	L-L-H	L-L-L-H	L-H-L-H-L/L-H-L-L-L

Table 3. Tonal domains for mono/polysyllabic words with different initial tones

Initial Tone	Monosyllabic	Disyllabic	Trisyllabic	Quadrisyllabic	Quintesyllabic
T1	S	(Ss)	(Sss)	(Ssss)	(Ss)(Sss)/(Sssss)
T2	S	(Ss)	(Sss)	(Ssss)	(Ss)(Sss)
T3	S	(Ss)	(Sss)	(Ssss)	(Ss)(Sss)
T4	S	(Ss)	(Sss)	(Ssss)	(Ss)(Sss)
T5	S	(Ss)	(Sss)	(Ssss)	(Ss)(Sss)/(Sssss)

Generally, based on Table 3, we can see that the data for quadrisyllabic words fit better with Xu et al.'s (1988) description, although Duanmu's (1997) judgment for quintesyllabic words – there are two tonal redistribution domains –is largely accurate.

5. Discussion and conclusion

This study aims to empirically examine prior claims about tone sandhi in mono/polysyllabic single words in Shanghai Chinese. The first goal of this paper is to evaluate the different judgments offered by Xu et al. (1988) and Duanmu (1997). The second goal is to assess the foot structure analysis proposed by Duanmu (1997). There are three main findings from this study.

First, the acoustic analysis supports the phonological analysis of T4 as a LH tone. We see that T4 in monosyllabic words surfaces as a H level tone with minimal contour, consistent with prior observations (e.g., Gao and Hallé 2017). However, in polysyllabic words, T4 behaves as a LH tone since it redistributes its H "segment" tone to the second syllable. Therefore, T4 has two "allotones". This "paradox" (i.e., T4 is both H and LH) could be related to the property of the rime in T4-initial monosyllabic words: (i) as T4-initial monosyllabic words with glottal stops are shorter compared to monosyllabic words with other initial tones (see Figure 1), it could be that the rising contour is "hidden" due to the short duration of the word; (ii) the fast and early onset of the glottal stop with high F_0 may impact the F_0 of T4-initial monosyllabic words. I leave this to future research.

Second, the acoustic data is consistent with the judgment of Xu et al. (1988), but not with the judgment of Duanmu (1997), on tonal redistribution domains for quadrisyllabic words. According to Duanmu, the redistribution domain pattern should be (Ss)(Ss) rather than (Ssss). In contrast, what this study has found is the latter, supporting the judgment of Xu et al. It is important to note that the production pattern identified in this study is not conclusive evidence against Duanmu (1997). Rather, it is possible that there is variation among native speaker's preferences, presumably due to the different ranking of constraints (or different weights assigned to them) in their individual grammars. In what follows, instead of stopping at a description of the tonal pattern, I will offer an OT analysis, based on the insights of Duanmu (1997), to derive the optimal candidate (Ssss).

To derive the correct pattern, one could reverse the ranking of Align-Ft-L and Ft-Bin, shown in Tableau 6. Now, the losing candidate "(Ss)(Ss)" incurs two fatal violations of Align-Ft-L. The winning candidate (b) "(Ssss)" is also more optimal than candicate (c) "(Ss)ss" by virtue of respecting the Parse constraint which is ranked higher based on the analysis provided in Tableau 1. Candidate d is harmonically bounded. However, there is one complication. If we follow Duanmu (1997) by assuming that a tonal redistribution domain is also a foot domain, we might conclude that the winning candidate "(Ssss)" is a quadrisyllabic foot. This would force us to accept the existence of quadrisyllabic feet, which is debatable (see, for instance, Kager (2012)). I will not delve deeper into this issue, as this is beyond the scope of this paper.

Tableau 6. Reranking of constraints for quadrisyllabic words.

Candidate	Parse	Align-Ft-L	Ft-Bin
a. (Ss)(Ss)		*!*	
☞ b. (Ssss)			*
c. (Ss)ss	*!*		
d. (Sss)(S)		*!**	**

Lastly, the production data on quintesyllabic words is largely in line with Duanmu's judgment as the most reliable pattern is the two-domain pattern (Ss)(Sss). However, even setting aside the issue of intraspeaker variation,[1] we still face one problem. The ranking in Tableau 6 will not produce (Ss)(Sss) as the optimal candidate since Align-F-L outranks Ft-Bin. This is shown in Tableau 7, where the unexpected winner is candidate (b) "(Sssss)".

Tableau 7. Unpredicted output in quintesyllabic words.

Candidate	Parse	Align-Ft-L	Ft-Bin
💣 a. (Ss)(Sss)		*!*	*
☞ b. (Sssss)			*
c. (Sss)(Ss)		*!**	*

One solution to address this issue is to make use of a constraint higher ranked than Align-Ft-L. I suggest that a constraint which limits the scope of the redistribution domain may be at play, which is the same as restricting the size of the foot to at most four syllables. I define this constraint in (7). With this constraint, "(Ss)(Sss)" will now be the optimal candidate, shown in Tableau 8.

(7) Ft-Size: A foot must not comprise more than four syllables.

Tableau 8. Updated OT analysis of foot structure in quintesyllabic words.

Candidate	Parse	Ft-Size	Align-Ft-L	Ft-Bin
☞ a. (Ss)(Sss)			**	*
b. (Sssss)		*!		*
c. (Sss)(Ss)			***!	*

[1] Intraspeaker variation suggests that other OT-based models such as Harmonic Grammar (e.g., Pater 2009) and Stochastic OT (e.g., Boersma 1997, Boersma and Hayes 2001) may be more appropriate for modeling the results in this study. However, given the very limited data, I will only focus on this direction in the future.

Before I conclude, I'd like to point out one potential contributor to the variation we see with quintesyllabic words, T1-initial 'Pennsylvania' and T5-initial /aʔ.sɛ.ŋu.pi.ja/ (based on 'Ethiopia'). In English, the stress of 'Pennsylvania' falls on the third syllable, matching the participant's preferred tonal pattern which also has stress on the third syllable. In fact, it is possible that the participant is generalizing the English stress of 'Ethiopia' to all quintesyllabic nonce words, which gave rise to the predominant (Ss)(Sss) pattern. I will address this issue in future work.

To conclude, the data on quadrisyllabic words are consistent with the description of Xu et al. (1988), but not with that of Duanmu (1997). This is presumably because Align-Ft-L outranks Ft-Bin, at least for the participant on this study. Furthermore, it is discovered that even within the same speaker, there is variation for T5-initial words.

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