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Quantity-Sensitive Foot Formation in Suzhou: Evidence from Light-Initial Tone Sandhi

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Based on a first-time acoustic analysis of the checked-tone sandhi patterns in Suzhou (Northern Wu; author's fieldwork), I argue that the tone sandhi patterns in Suzhou can best be accounted for using two types of trochaic feet, syllabic and moraic trochees (based on Kager 1993). The choice of which type of foot to use is made by mediating the quantity relationship between foot heads and dependents (cf. Head-Dependent Asymmetry; Dresher and van der Hulst 1998). Furthermore, unfooted and toneless prosodic constituents (i.e. syllables/moras) are interpreted as "defalt L" in phrase-final positions (cf. Chen 2000). This paper addresses a key debate in prosodic typology, viz. the interaction of tone, syllable quantity, and metrical structure (Kehrein et al. 2018 for overview).

1. Introduction

The relationship between metrical structure and tonal alignment has been used to account for many phonological alternations that appear to be purely tonal/paradigmatic otherwise (Duanmu 1995; 1999; de Lacy 2002; Köhnlein 2011; Iosad 2016; Köhnlein and Zhu 2019; Morrison 2019). The current paper contributes to this line of research by investigating tone sandhi in Suzhou, which shows evidence of foot structure despite not showing any *phonetic* correlates of prominence (stress). That is, the *phonological* properties of metrical structure may manifest as systematic tonal distributions on the surface *without* bearing any traditional phonetic correlates of stress (i.e. duration, intensity, pitch) – or, as Duanmu (1995) puts it, "metrical systems may exist in ... languages in which phonetic stress is not obvious" (see also Köhnlein et al. 2019 for similar arguments)

I term the specific tone sandhi patterns that is central to this paper "light-initial sandhi" – disyllabic prosodic words where the first syllable carries what is traditionally referred to as *rusheng* or "checked" tone and the second syllable carries a *shusheng* or "smooth/unchecked" tone. In addition to recent analyses that treat "checked" tones as monomoraic (e.g. Chen 2000), I also present synchronic acoustic data of Suzhou that supports the monomoraic status of checked-toned syllables. A direct result of treating "checked" tones as monomoraic is that it creates light-heavy disyllables as part of the syllabic inventory of Suzhou. The light-initial sandhi pattern has been overlooked in recent systematic documentation (Wang 2011) and theoretical analyses (Ling 2011; Shi and Jiang 2013). Furthermore, it deviates from straightforward metrical-foot-based accounts of tone sandhi, which have been immensely successful in other representative dialects of Northern Wu (see Duanmu 1993; 1995). My main claims and crucial points of departure are two-fold:

(1). Main analytical claims

a. Footed and unfooted material (cf. de Lacy 2002) plays an active role in Suzhou tone sandhi – tones can only be realized inside the domain of the foot. This is reminiscent of, but not entirely identical to, the traditional *left/right-prominent* analysis of various Chinese dialects (e.g. Duanmu 1995; Chen 2000; Zhang 2007; Shi and Jiang 2013).

b. Suzhou Chinese demonstrates two types of foot structures: syllabic trochees (built on syllables) and moraic trochees (built directly on moras, following Kager's 1993 foot inventory). The choice of the foot is regulated by the quantity relationship between the foot head and the foot dependent – the moraic trochee is chosen only when the dependent would be heavier than the head in a syllabic trochee parse (Dresher and van der Hulst 1998; Iosad 2013).

This study contributes to various ongoing debates in the literature on theoretically-informed prosodic typology in general, and the phonology of Chinese languages in particular. The approach adopted here has empirical support from other typologically diverse language families (e.g. Köhnlein 2011; 2016 for Franconian, Morén-Duolljá 2013 for Swedish, Iosad 2016 for Danish, Morrison 2019 for Scottish Gaelic, Köhnlein and Zhu 2019 for Uspanteko), but has not been proposed for any Chinese language. Moreover, the foot-based analysis explores two less well-established generalizations in phonological theory: Head-Dependent Asymmetry (despite having many empirical examples; Dresher and van der Hulst 1998) and Violable Syllable Integrity (cf. Martínez-Paricio and Kager 2016; Kager and Martínez-Paricio 2018; Breteler 2018).

The remainder of the paper is structured as follows. §2 offers some further background information on metrical prominence and tone sandhi in Chinese dialects generally. In §3 I report the empirical data on both the synchronic phonetic status of "checked tone"/light syllables and the pitch patterns of light-initial tone sandhi. A metrical analysis accounting for all light-heavy tonal combinations is given in §4. §5 concludes the paper

2. Background

2.1. Left-dominant tone sandhi

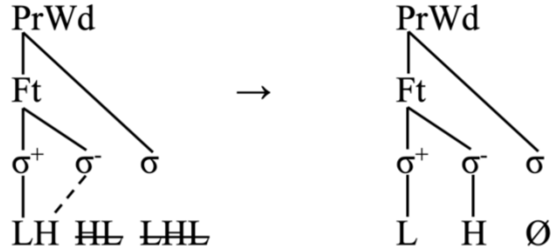
Tone sandhi broadly refers to phonological tone changes between adjacent toned morphemes/syllables (see Chen 2000; Zhang 2016 for overview). First noted by Yue-Hashimoto (1987) and Chan and Ren (1989), most varieties of Chinese languages demonstrate certain "dominance" effects in their tone sandhi patterns. The current study discusses empirical data that demonstrate *left-dominance,* similar to numerous neighboring Northern Wu dialects do. In a left-dominant or left-prominant sandhi process, the leftmost/initial syllable in a prosodic constituent (typically a prosodic word; see Zhang 2016) preserves its tonal material while the remaining non-initial syllables undergo either tonal neutralization or "pattern extension" (term coined by Chan and Ren 1989) – the displacement or redistribution of initial syllable tones to subsequent syllables. Left-dominant sandhi can be seen as a left-to-right phonological process, where the leftmost lexical tone determines the surface tonal/pitch pattern. A concise example from Suzhou Chinese is given in (2).

(2). /**LH**/ + /HL/ + /HLH/ → [**L**.**H**.L] e.g. [zoː.gøː.diː] "tea shop"

A trisyllabic word in Suzhou preserves all tonal material of the initial /LH/ syllable by redistributing the contour tone evenly across the first two syllables. The third syllable, on the other hand, undergoes tonal deletion and realizes as a phonetic L on the surface (see Chen 2000 on the status of "default L"). Noticeably, the underlying tones of the second and third syllables play no role in determining the sandhi output.

Despite the criticism that phonetic *stress* per se in Chinese languages is notoriously elusive, if not non-existant (see Chen 2000 for review), various phonological analyses rooted in autosegmental tonal representation (Leben 1973; Goldsmith 1976) and metrical stress theory (Hayes 1995) essentially argue that *phonological prominence*, a structural property, can stand independent to the presence or absence of *phonetic stress*, an acoustic property. Left-dominant sandhi patterns among Northern Wu dialects such as Shanghai (Duanmu 1993; 1995), Wuxi (Chan and Ren 1989), Danyang (Chan 1995) and Nantong (Ao 1993) have all been analyzed in ways that connect tonal behaviors to left-headed stress feet. In the context of Suzhou, previous studies such as Shi and Jiang (2013) have also provided a convincing analysis: assuming that a disyllabic trochaic foot is formed at the left edge of every prosodic word, the surface tonal pattern in (2) can be captured in three steps: (i). the initial /LH/ retains all tones by virtue of its metrically strong position; (ii). all non-initial syllable tones are deleted; (iii). the initial /LH/ contour is evenly distributed within the disyllabic foot, but does not extend to the third syllable, which is hypothesized to be toneless and phonetically L on the surface. (3) shows the autosegmental diagram of such process.

(3). A foot-based analysis of tone sandhi in Suzhou, based on Shi & Jiang (2013)



In (3), a left-aligned syllabic trochee dominates the first two syllables, retaining all tones under the metrical head (σ^+) and evenly redistribute the contour with the dependent (σ^-). The leftover third syllable is unparsed by a foot and directly dominated by the Prosodic Word (PrWd), and surfaces without any phonological tone (Ø). In essence, such an approach illustrates a three-way distinction of tonal behaviors in three types of syllables:

(4). Three types of syllables under a foot-based analysis

a. Foot head (σ^+): retains all lexical tones; redistributes/reassociates[1] tones to the foot dependent

b. Foot dependent (σ^-): deletes all lexical tones; accepts redistribution from the head

c. Unfooted/unstressed syllable (σ): deletes all lexical tones; surfaces as default L

A crucial extension of (4) is that *only* the foot head (initial syllable) can determine the tonal output of polysyllabic words in Suzhou. In the next subsection I present some preliminary data in Suzhou that contradicts with predictions listed above. These counterexamples are the primary motivation for my fieldwork and the focus of the analysis section as well.

2.2. Exceptional tone sandhi patterns in Suzhou Chinese

Suzhou has seven lexical tones, two of which are traditionally referred to as "checked" tones (Qian 1992; Ye 1993; Wang 2011). The two "checked" tones have rather short syllable nucleus duration and often end in a glottal stop in citation form (i.e. isolation). Below in Table 1 I provide minimal or near-minimal pairs[2] containing the seven lexical tones.

Table 1. Lexical tones in Suzhou

Representation	**Tone letter**	**Example**	**Gloss**
/HH/	44	[tiː]	low
/LH/	13	[diː]	carry

[1] The process where leftmost syllable "shares" tones with foot dependents are often referred to as "tonal spreading" in the tone sandhi literature (Chan 1991; Duanmu 1999; Chen 2000b). Here I use the terms "redistribution" or "reassociation" to differentiate the process in discussion from canonical examples of tonal spreading – a single tone spans over a few Tone Bearing Units (e.g. unbounded H spreading in Chinlungu: /kú-/ + /saakul/ + /-à/ → [kú-sáákúl- à], cf. Bickmore 1996).

[2] Onset voicing contrasts are partially predictable from tonal registers (Yip 2002). Therefore, for some tonal contrasts only near-minimal pairs differing in both onset voicing and lexical tone are available.

/HL/	52	[tiː]	bottom
/HLH/	412	[tiː]	emperor
/LHL/	231	[diː]	ground
/H/	5	[tɪʔ]	trickle
/LH/	23	[dɪʔ]	flute

The last two lexical tones will be the focus of this paper. They have a (C)Vʔ syllable structure in citation form and are traditionally referred to as "checked" tones (Qian 1992; Ye 1993; Wang 2011). I refer to them as *light/monomoraic* tones here, following Chen (2000). Note that there are two lexical tones with the same /LH/ underlying representation in Table 1 – [diː] "carry" and [dɪʔ] "flute". Consequently, the phonological contrast between these two morphemes is not about tones *per se*, but about syllable structure: the morpheme "carry" is represented as a *bimoraic* open syllable with a /LH/ rising tone, and the morpheme "flute" a *monomoraic* open CV syllable with a /LH/ rising tone. Importantly, despite the fact that the last two light tones are realized with a coda glottal stop *in isolation*[3], I will argue that the glottal stop, even if present, does not contribute to any moraic status in contemporary Suzhou (unlike other varieties of Chinese; see Duanmu 1999; 2007) and the "checked" vs. "unchecked" contrast has shifted from a difference of coda /ʔ/ to a difference of syllable weight – monomoraic vs. bimoraic (see §3.2).

The crucial data that provide counterevidence to the claims in (4) are concerned with lexical items with an initial checked-tone, which I will refer to as *light-initial sandhi*. Two relevant generalizations are given in (5).

(5). Exceptional sandhi patterns in Suzhou

a. Second syllable tone is able to influence tone sandhi, but *only* when the initial syllable is a light tone.

/H/ + /LH/ → [H.L] e.g. [hə.dæː] "spade"

/H/ + /HL/ → [H.HL] e.g. [hə.tsɨː] "black paper"

Compare this with:

/HH/ + /LH/ → [H.H] e.g. [foŋ.lʲãː] "cold"

/HH/ + /HL/ → [H.H] e.g. [foŋ.sʉː] "fengshui"

b. The falling contour tone /HL/ does not redistribute in initial position. Additionally, it does not undergo deletion in second position, when preceded by initial /H/ (/T/: any lexical tone).

/HL/ + /T/ → [HL.L]/*[H.L] e.g. [sɨː.nɪn] "dead people"

[3] This could potentially be due to a word minimality constraint, which regulates that a minimal word in Suzhou must be bimoraic. See Lin (1993) and Duanmu (1999) for discussion on word minimality in Chinese languages.

/H/ + /HL/ → [H.HL]/*[H.L] e.g. [hə.pɛː] "blackboard"

(5a) contradicts with the prediction that only initial tones determine the sandhi output directly: in light-initial sandhi, different underlying tones of the second syllable may contribute to different sandhi output. A consequence is that one initial syllable tone may not correspond to only one sandhi pattern anymore – in fact, light /H/-initial sandhi has *three* distinct pitch patterns instead of one: [H.L], [H.H] and [H.HL] (see §3.3). (5b) contradicts with the observation that contour tones always redistribute in initial positions, and as an effect also contributes to the alternative tonal patterns in light-initial sandhi. As I would argue later, this is due to the special tonal structure of the contour tone /HL/, but not to the exceptional behaviors of light-initial sandhi only (also see Zhu 2020). Based on the data in (5), there are two research questions I aim to address in this study:

(6). Research questions
a. What are the synchronic phonetic characteristics of syllables with "checked"/light tones? What tone sandhi patterns do light tones demonstrate?
b. Can a foot-based analysis account for all tone sandhi patterns in Suzhou? What are the relevant stress/sandhi domains?

In the next section I provide two pieces of acoustic data coming from my fieldwork in Suzhou – checked-tone/light syllables embedded in carrier sentences (§3.2), and F0 patterns of light-initial sandhi (§3.3).

3. The data

3.1. Methods

The focus of the present study is tone sandhi patterns of disyllabic prosodic words in Suzhou Chinese. I used a word reading task to elicit disyllabic lexical items. To avoid various domain-final phonetic effects (e.g. domain-final lengthening, L tone insertion), all disyllabic stimuli are embedded in a carrier phrase "講___撥我聽"("Say ___ for me") in Chinese. The elicitation word list contains 203 common disyllabic nouns in the language with various tonal combinations. Since light-initial sandhi patterns are my main focus, 168 of the words include an initial light tone – $/H/_{\mu}[5]$ or $/LH/_{\mu}[23]$, while the remaining 35 start with an initial heavy tone and partially serve as distractor items. Since there are two light tones in contemporary Suzhou and seven lexical tones in total, all light-initial disyllabic forms can be divided into 2*7 = 14 binary tonal combinations. In Table 2 I provide one example for each cell of combination.

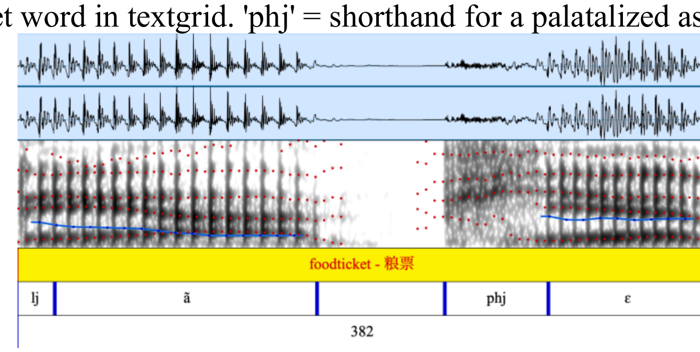
Table 2. All light-initial disyllabic combinations[4]. Columns: initial light tone. Rows: second tone. /T/$_{\mu\mu}$: bimoraic/heavy tones; /T/$_{\mu}$: monomoraic/light tones.

	/H/$_{\mu}$	/LH/$_{\mu}$
/HH/$_{\mu\mu}$	[po.foŋ] "north wind"	[bɑ.tɕɪn] "platinum"
/LH/$_{\mu\mu}$	[hə.dæː] "spade"	[bɑ.dãː] "white sugar"
/HL/$_{\mu\mu}$	[hə.tsɨː] "black paper"	[bɑ.pɛː] "whiteboard"
/HLH/$_{\mu\mu}$	[fo.tɕʰɨː] "fortune"	[bɑ.tsʰɛː] "bok choy"
/LHL/$_{\mu\mu}$	[sʲə.dɨː] "snowfield"	[bɑ.mɨː] "white rice"
/H/$_{\mu}$	[tsʰɑ.tɕʲɑ] "barefoot"	[lɑ.pʲə] "crayon"
/LH/$_{\mu}$	[sʲə.bo] "tinfoil"	[zə.lo] "sixteen"

The main acoustic data come from two male speakers who were 25 and 27 years old at the time of the recording. There are therefore 406 * 2 = 812 word tokens in carrier sentences in the data I report here. Each speaker signed an informed consent form before participating in the elicitation.

The elicitation had two parts: a sociolinguistic interview and a pseudorandomized wordlist of disyllabic items. The target disyllabic words were presented in Chinese characters in a slideshow, with one word per page. Each participant was digitally recorded in a quiet room at a sampling rate of 44100Hz using a Shure SM10A-CN head-worn microphone and a Zoom H4N PRO digital recorder. After collecting the recording data, the wave files were then submitted to Praat (Boersma and Weenink 2019) for further acoustic analysis. Each target disyllabic word was marked and segmented using Praat's textgrid function. Three tiers were used: one tier for the word token (in both Chinese and English), one for segmentation, and one for a search index. An example of textgrid segmentation is illustrated in Figure 1.

Figure 1. A target word in textgrid. 'phj' = shorthand for a palatalized aspirated stop: [pʰʲ]



[4] Note that almost all disyllabic words are bimorphemic compounds, as monomorphemic disyllabic words in Chinese are extremely rare. See (Chen 2000: 39; Lin 2007) for discussion.

Pitch-related information was also extracted from Praat using the "Draw visible pitch contour" function. Pitch duration was normalized by using the same length of Praat Picture window for each pitch contour. The pitch range for extraction was adjusted to 60-220Hz to accommodate the male pitch range. Moreover, detailed pitch settings (e.g. "voicing threshold", "silence threshold") were hand-adjusted for each word token to ensure that the entirety of the voicing period was recognized by Praat's pitch tracking function. An example of the normalized pitch data is shown in Figure 2.

Figure 2. Time-normalized pitch tracking data. The middle section without pitch tracking information is due to oral closure of coda/onset stops. The example word in the figure will be transcribed as [$L_{\mu\mu}$.H_{μ}], with a bimoraic L-toned syllable followed by a monomoraic H-toned syllable (see also §3.3)

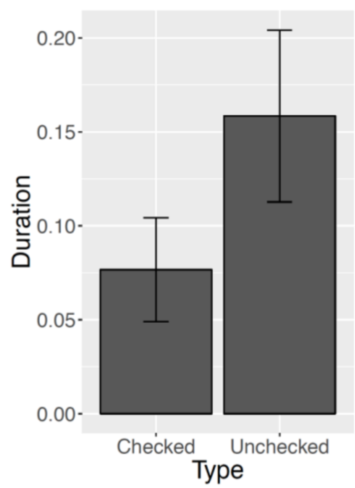
3.2. Segmental characteristics of light/"checked" tones

In this subsection I report some segmental data that lead to my characterization of "checked" tone syllables as light/monomoraic syllables. Crucially, the so-called "checked" tones in contemporary Suzhou have *extremely short vowel duration* and *no discernable coda closure* in an embedded context. They are better characterized as lexical tones with *light/monomoraic* syllable structure. The mean rhyme durations of "checked" and "unchecked" syllables are summarized in Table 3, accompanied by a bar graph in Figure 3.

Table 3. Means and standard deviations(in parentheses) of "checked" and "unchecked" syllable rhymes.

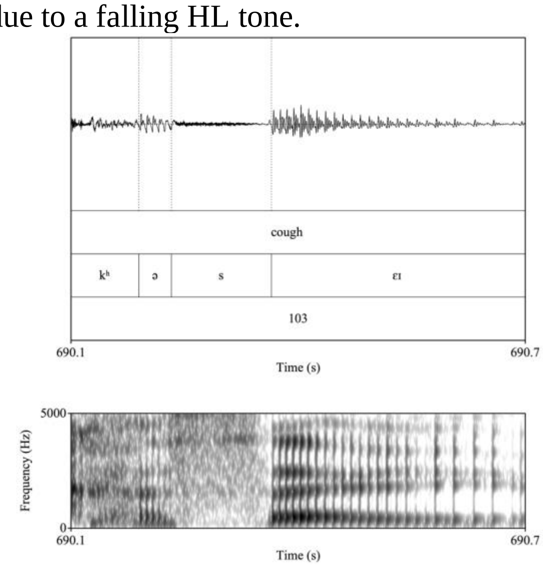
	Mean
Checked	0.1566 (0.0472)
Unchecked	0.0789 (0.0304)

Figure 3. Bar graph for mean syllable rhyme durations (in seconds) of "checked" and "unchecked" tones. Error bars represent standard error.



Both the summary table and the bar graph show that "checked" syllables in Suzhou are only have half the rhyme duration (≈ 75ms) of "unchecked" syllables (≈ 150ms). A potential interpretation of the durational data is that "checked" tone syllables are realized with a short/monomoraic vowel [V] in Suzhou, while "unchecked" tone syllables are either open syllables with long/bimoraic vowels [Vː] or closed syllables with a short vowel and a nasal coda [VN]. However, due to the fact that checked-tone syllables in Suzhou are still realized with a coda glottal stop in isolation, it is unclear if the glottal stops is associated with a mora, making the checked syllable still bimoraic. Now, consider the acoustic data in Figure 4 showing an initial checked syllable followed by another unchecked syllable in running speech.

Figure 4. Waveform and spectrogram for "cough". Visible creaky vowel production in the second syllable is due to a falling HL tone.



Clearly, there is no stop closure whatsoever between the first syllable [kʰə] and the second syllable [sɛɪ]. The initial "checked" syllable is better transcribed as a *monomoraic/light open syllable*: [kʰə] instead of [kʰəʔ]. Combining this with the extremely short vowel duration, we have ample evidence to claim that the crucial contrast between checked and unchecked syllables in contemporary Suzhou is in syllable weight: checked syllables are light, while unchecked ones are heavy. From this point on, I will refer to the contrast as light vs. heavy and use corresponding moraic transcriptions T_μ vs. $T_{\mu\mu}$ when applicable.

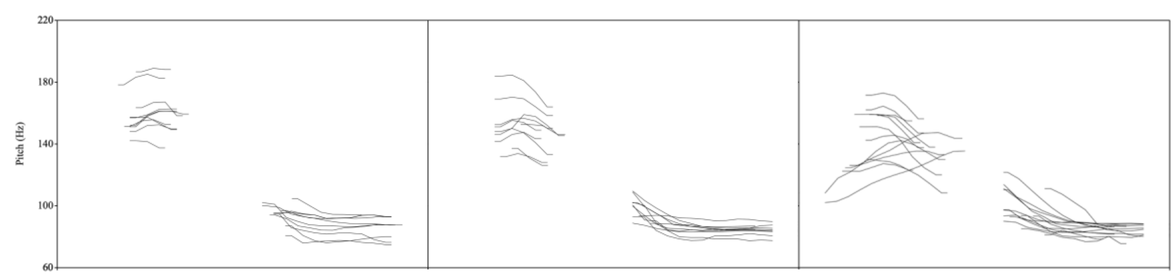
3.3. F0 patterns of light-initial sandhi

Below I present all majority pitch patterns of light-initial tone sandhi: when the light /H/ tone is initial, there are three distinct pitch forms: [$H_\mu.L_{\mu\mu}$] (Figure 5), [$H_\mu.H_\mu L_\mu$] (Figure 6) and [$H_\mu.H_\mu$] (Figure 7); when the light /LH/ tone is initial, we see two pitch patterns instead: [$L_\mu.H_\mu L_\mu$] (Figure 8) and [$L_\mu.H_\mu$] (Figure 9). All possible light-initial sandhi pitch patterns and their corresponding underlying tone combinations are summarized in Table 4, followed by respective figures.

Table 4. Light-initial sandhi patterns. Columns: initial light tone. Rows: second tone. Forms in slashes are underlying representation of different lexical tones, while those in square brackets are surface pitch patterns.

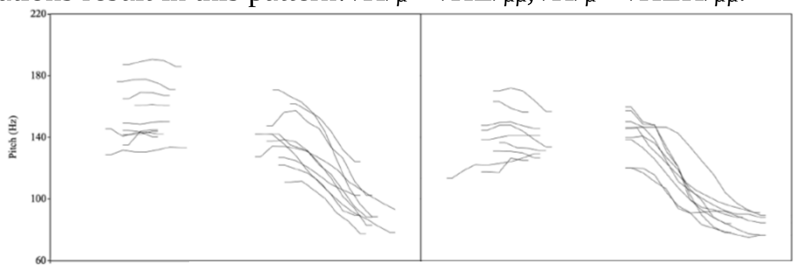
	/H/$_\mu$	/LH/$_\mu$
/HH/$_{\mu\mu}$	[$H_\mu.L_{\mu\mu}$]	[$L_\mu.H_\mu L_\mu$]
/LH/$_{\mu\mu}$		
/LHL/$_{\mu\mu}$		
/HL/$_{\mu\mu}$	[$H_\mu.H_\mu L_\mu$]	
/HLH/$_{\mu\mu}$		
/H/$_\mu$	[$H_\mu.H_\mu$]	[$L_\mu.H_\mu$]
/LH/$_\mu$		

Figure 5. [$H_\mu.L_{\mu\mu}$]: H monomoraic tone followed by a L bimoraic tone. Three tonal combinations result in this pattern: /H/$_\mu$ + /HH/$_{\mu\mu}$, /H/$_\mu$ + /LH/$_{\mu\mu}$, /H/$_\mu$ + /LHL/$_{\mu\mu}$.



a. /H/$_\mu$ + /HH/$_{\mu\mu}$ b. /H/$_\mu$ + /LH/$_{\mu\mu}$ c. /H/$_\mu$ + /LHL/$_{\mu\mu}$

Figure 6. $[H_{\mu}.H_{\mu}L_{\mu}]$: H monomoraic tone followed by a HL falling bimoraic tone. Two tonal combinations result in this pattern: /H/$_{\mu}$ + /HL/$_{\mu\mu}$, /H/$_{\mu}$ + /HLH/$_{\mu\mu}$.

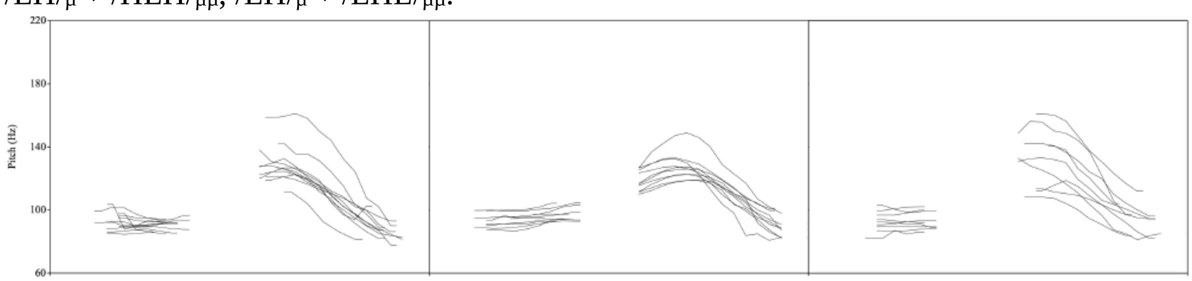


a. /H/$_{\mu}$ + /HL/$_{\mu\mu}$ b. /H/$_{\mu}$ + /HLH/$_{\mu\mu}$

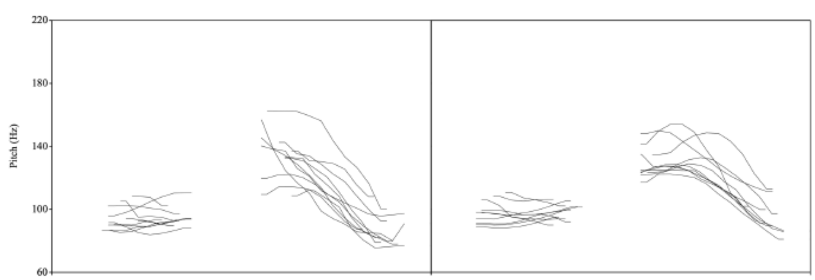
Figure 7. $[H_{\mu}.H_{\mu}]$: H monomoraic tone followed by a H monomoraic tone. Two tonal combinations result in this pattern: /H/$_{\mu}$ + /H/$_{\mu}$, /H/$_{\mu}$ + /LH/$_{\mu}$.

a. /H/$_{\mu}$ + /H/$_{\mu}$ b. /H/$_{\mu}$ + /LH/$_{\mu}$

Figure 8. $[L_{\mu}.H_{\mu}L_{\mu}]$: L monomoraic tone followed by a HL falling bimoraic tone. Five tonal combinations result in this pattern: /LH/$_{\mu}$ + /HH/$_{\mu\mu}$, /LH/$_{\mu}$ + /LH/$_{\mu\mu}$, /LH/$_{\mu}$ + /HL/$_{\mu\mu}$, /LH/$_{\mu}$ + /HLH/$_{\mu\mu}$, /LH/$_{\mu}$ + /LHL/$_{\mu\mu}$.

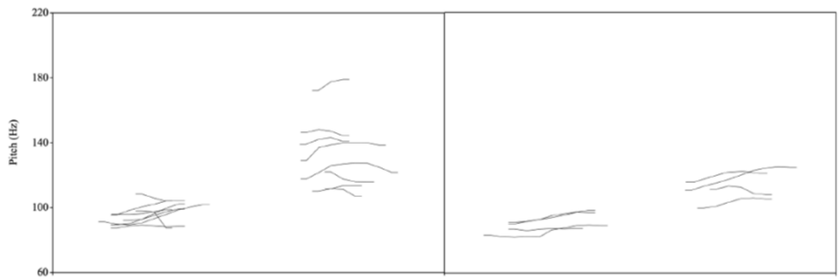


a. /LH/$_{\mu}$ + /HH/$_{\mu\mu}$ b. /LH/$_{\mu}$ + /LH/$_{\mu\mu}$ c. /LH/$_{\mu}$ + /LHL/$_{\mu\mu}$



a. /LH/$_{\mu}$ + /HLH/$_{\mu\mu}$ b. /H/$_{\mu}$ + /LHL/$_{\mu\mu}$

Figure 9. $[L_\mu.H_\mu]$: L monomoraic tone followed by a H monomoraic tone. Two tonal combinations result in this pattern: $/LH/_\mu + /H/_\mu$, $/LH/_\mu + /LH/_\mu$.



a. $/LH/_\mu + /H/_\mu$ b. $/LH/_\mu + /LH/_\mu$

For exposition reasons, this paper focuses on the 2*5=10 disyllabic patterns of the shape light-heavy, as: (i). Alternative sandhi patterns conditioned by the second syllable tone are most robustly attested here; (ii). light-light disyllables can be easily analyzed as a "cut-off" version of corresponding light-heavy pitch forms (i.e. $[H_\mu.H_\mu]$ and $[H_\mu.H_\mu L_\mu]$ only contrast in mora count, but not in tonal composition).

Three crucial observations can be drawn from the summary data in Table 4. First, all tones of the initial syllable in the input *is always preserved* – when light $/H/_\mu$ is initial, output forms always begin with $[H_\mu]$; when light is $/LH/_\mu$ initial, the L and H tones appear in different syllables $[L_\mu.H_\mu...]$ in the output but are nevertheless preserved. Second, the second syllable plays a role in determining the sandhi output only when light $/H/_\mu$ is the initial syllable. The last observation is concerned with unattested (and by inference ungrammatical) forms in light initial sandhi: whenever the disyllabic word takes the shape of light-heavy [μ.μμ], the third mora never has a H tone. That is, pitch patterns such as $[H_\mu.H_{\mu\mu}]$ (from $/H_\mu/ + /HH/_{\mu\mu}$) or $[H_\mu.L_\mu H_\mu]$ (from $/H_\mu/ + /LH/_{\mu\mu}$) are unattested. Importantly, this restriction on the third mora (or, the second mora of the second syllable) is unique to light-initial sandhi: $[L_{\mu\mu}.H_{\mu\mu}]$ is grammatical as a heavy-initial tonal pattern but $*[L_\mu.H_{\mu\mu}]$ is not. The three generalizations are summarized below.

(7). Generalizations of light-initial tone sandhi
a. Initial syllable tones are always preserved.
b. Only $/H/_\mu$-initial forms are conditioned on the second syllable tone.
c. In "light + heavy" disyllables, the third mora is never H / always L.

4. A metrical analysis of light-initial sandhi

In this section I offer a concise analysis of the light-initial sandhi patterns couched in metrical stress theory (for a full OT analysis, see Zhu in preparation). Crucially, I argue that the exceptional behavior of light-initial sandhi is rooted in the quantity contrast between initial light vs. heavy syllables: Suzhou Chinese disallows an "unbalanced" trochaic foot with a light head and a heavy dependent, and avoids such structure by opting for a bimoraic trochee.

4.1. Tonal representation

Before we proceed to the analysis, a few notes on the overall tonal structure and representation of Suzhou. First, consider the exceptional behavior of the falling tone /HL/ in (5b), repeated here for convenience:

(8). The falling contour tone /HL/$_{\mu\mu}$ does not redistribute in initial position. Additionally, it does not undergo deletion in second position, when preceded by initial /H/$_{\mu}$ (/T/: any lexical tone).

/HL/$_{\mu\mu}$ + /T/ → [HL.L]/*[H.L] e.g. [sɨː.nɪn] "dead people"
/H/$_{\mu}$ + /HL/$_{\mu\mu}$ → [H.HL]/*[H.L] e.g. [hə.pɛː] "blackboard"

Simply put, there is a certain "stability" with the /HL/$_{\mu\mu}$ tone that prevents any modification on it, regardless of its position in the disyllable. Compare this with the low rising tone /LH/$_{\mu\mu}$:

(9). The rising contour tone /LH/$_{\mu\mu}$ both redistributes in initial posistion and deletes in second position when preceded by initial /H/$_{\mu}$

/LH/$_{\mu\mu}$ + /T/ → [L.H]/*[LH.L] e.g. [hoŋ.dæ] "heart" (playing card suit)
/H/$_{\mu}$ + /LH/$_{\mu\mu}$ → [H.L]/*[H.LH] e.g. [hə.dæ] "spade" (playing card suit)

As shown, the exceptional light-initial sandhi patterns are partially due to the unique structure property of the /HL/$_{\mu\mu}$ tone (and for that matter, /HLH/$_{\mu\mu}$ tone as well; see below). Disregarding the light-initial patterns, any adequate phonological analysis still has to account for the independent fact that /HL/$_{\mu\mu}$ does not demonstrate the prototypical "deletion-redistribution" processes other Northern Wu dialects would. To account for this fact, I argue that Suzhou makes use of *associated vs. floating* underlying tones (see similar approaches in Chan 1985; Milliken 1989; Chen 2000; also see further discussion in Zhu 2020). A general dispreference against delinking autosegmental association lines accounts for the non-redistribution/non-deletion of /HL/$_{\mu\mu}$. I show the representational contrast of /LH/$_{\mu\mu}$ and /HL/$_{\mu\mu}$ and below.

(10). Underlying representations of /<LH>/$_{\mu\mu}$ and /HL/$_{\mu\mu}$

LH	HL
	| |
μ μ	μ μ

Linearly, I choose to represent floating underlying tones with angle brackets, following Chen (2000). Note that the representation assumes that moras are the TBUs in

Suzhou (cf. Duanmu 1995). This easily accounts for the observation that no contour tones (i.e. tones consisting of two tonemes) are observed in light/monomoraic syllables after tone sandhi, and no complex contours (i.e. tones with three tonemes) are observed in heavy/bimoraic syllables: many-to-one tonal association is generally prohibited in Suzhou.

4.2. Quantity-sensitive foot formation

Now we tackle the intriguing patterns of light-initial tone sandhi. Recall the three observations in (7): only $/H/_{\mu}$-initial sandhi shows alternation conditioned on second syllable tone, while the $/LH/_{\mu}$-initial sandhi output is uniformaly $[L_{\mu}.H_{\mu}L_{\mu}]$. More specifically, the only lexical tone demonstrating alternative sandhi patterns is at the same time the only lexical tone consisting of one toneme – all other lexical tones in Suzhou contain at least two tonemes (see Table 1). Suzhou Chinese seems to allow preservation of second syllable tone only when the initial morpheme does not provide "enough" tonal material. In addition, when the initial tone is a complex contour such as $/HLH/_{\mu\mu}$, only *two* of the three tonemes are preserved in sandhi: $/HLH/_{\mu\mu}$ + T → [H.H]/*[H.LH],*[HL.H]. This echoes with the observation succinctly put by Kenstowicz (1994: 597): "linguistic rules do not count beyond two". In the context of Suzhou, the optimal amount of phonological tones after sandhi seems to be *two*, reflecting the binary nature of metrical footing.

Once we have accepted that post-sandhi forms carry at most two phonological tones, we still need to explain why light-initial forms such as $[L_{\mu}.H_{\mu}L_{\mu}]$ and $[H_{\mu}.H_{\mu}L_{\mu}]$ seem to be tri-tonal. Interestingly, in the ten possible light-heavy tonal combinations, the second mora of the second heavy syllable is always L (observation 7c). Forms such as $[H_{\mu}.L_{\mu}H_{\mu}]$ or $[L_{\mu}.H_{\mu\mu}]$ in phrase final positions[5] are considered ungrammatical and rejected by native speakers. The exceptionless distribution of phonetic L pitch on the third mora in light-heavy disyllables resembles phonetic Ls in third *syllables* in heavy-initial trisyllabic tone sandhi. Recall the form in (2):

(11). /LH/ + /HL/ + /HLH/ → [L.H.Ø]   e.g. [zoː.gøː.diː] "tea shop"

It is usually assumed that trisyllabic lexical items only have one left-aligned syllabic trochee, leaving the third mora unparsed and *toneless* on the surface. Toneless syllables are assigned a "default L" in phrase final positions (cf. Chen 2000). Could the third mora in light-heavy disyllables also be toneless and interpretable as phonetic default Ls $[L_{\mu}.H_{\mu}Ø_{\mu}]/[H_{\mu}.H_{\mu}Ø_{\mu}]$?

A possible binary foot that is able to exclude the third (and later) mora is the *bimoraic trochee* (Kager 1993b; Martínez-Paricio and Kager 2016; Kager and Martínez-

[5] A third [H] mora in phonetic pitch is indeed observed in phrase-non-final positions when followed by another phonological H tone. See Zhu (2021).

Paricio 2018). That is, disyllabic trochees are the relevant foot structure in heavy-initial sandhi, while bimoraic trochees are formed when a disyllabic word starts with a light/monomoraic "checked" syllable. I show this crucial contrast between a trisyllabic heavy-initial word and a trimoraic light-initial word in (12).

(12). Comparison between a disyllabic trochee and a bimoraic trochee

a. Disyllabic trochee (heavy-initial) b. Bimoraic trochee (light-initial)

(12a) shows a trisyllabic heavy-initial lexical item (such as [zoː.gøː.diː] "tea shop"), with an unparsed and toneless third syllable. (12b), on the other hand, shows a trimoraic light-heavy disyllable, with a trochaic foot directly dominating the first two moras. The third mora (second mora of the second syllable) for the same reason is unparsed and toneless on the surface. Importantly, such a quantity-sensitive foot alternation is not only empirically adequate, but also preferred under purely structural grounds. Motivation for this comes from a cross-linguistic observation that "dependents cannot be more complex than heads" in quantity-sensitive systems (Dresher and van der Hulst 1998: 341). That is, heavy-heavy or heavy-light disyllables are compatible with a disyllabic trchaic foot, since the leftmost foot head is always heavier than or as heavy as the foot dependent on the right. If we were to use the same disyllabic foot to parse the light-heavy sequence, however, we end up with a light foot head with a heavy dependent. Such dispreference for lighter metrical heads is referred to as "Head-Dependent Asymmetry" (HDA) by Dreasher and van der Hulst. Suzhou Chinese in this case chooses to repair HDA-violating metrical structures by positing an alternative bimoraic trochee.

Once we have established that bimoraic trochees are the relevant metrical structure for the light-heavy disyllables, the alternative sandhi output follows directly from the underlying representation of heavy lexical tones and the hard requirement for the third mora to be toneless. Crucially, /<HH>/$_{\mu\mu}$, /<LH>/$_{\mu\mu}$ and /<LHL>/$_{\mu\mu}$ are all lexical tones with fully floating tonemes, allowing them to redistribute freely in initial position, and delete completely when following /H/$_{\mu}$, yielding [H$_{\mu}$.Ø$_{\mu\mu}$] (phonetically [H$_{\mu}$.L$_{\mu\mu}$]). On the other hand, /HL/$_{\mu\mu}$ has both tonemes associated, while /H<LH>/$_{\mu\mu}$ has at least the first toneme anchored, blocking them from deletion or redistribution.

5. Conclusion

To summarize, the exceptional light-initial sandhi with second syllable conditioning is caused by two facts. First, Suzhou preserves at most two phonological tones within a tone sandhi domain, directly echoing general phonological principles such as foot binarity; Second, /H/$_\mu$ being the only single-toneme lexical tone in Suzhou allows extra input from the second syllable, but only when the tonemes are underlyingly associated. These two claims connect well with the general properties of heavy-initial sandhi, the majority patterns in Suzhou. In addition, the exceptionless third mora L tone in light-heavy disyllables resembles toneless syllables unparsed by the metrical foot. This in turn leads to a quantity-sensitive footing alternation depending on the initial syllable quantity: a disyllabic trochee in heavy-initial sandhi, but a bimoraic trochee in light-initial sandhi. This footing alternation has both empirical coverage and theoretical grounding: Head-Dependent Asymmetry (Dresher and van der Hulst 1998) captures the fact that foot heads lighter in quantity are cross-linguistically dispreferred, which corresponds precisely to the condition of the syllabic-moraic footing switch – light-heavy disyllables. As a side note, the case of alternating moraic trochees in Suzhou also contributes the more recent investigation of "Violable Syllable Integrity", the fact that moraic trochees may intervene within a syllable (Martínez-Paricio and Kager 2016; Kager and Martínez-Paricio 2018; Breteler 2018)

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