# The phonological status of Low tones in Shanghai tone sandhi

## Default tones or boundary tones?

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In Shanghai tone sandhi, with the exception of T5 (*yangru*) sandhi, a pitch-fall occurs at the second or third syllable of a phonological word (or a sandhi domain). Previous analyses argue that this is invoked by the insertion of a default Low tone to satisfy the Well-formedness Condition of the autosegmental theory. However, in the framework of the present autosegmental theory, that condition is no longer necessarily satisfied, and an alternative interpretation, adopting a boundary Low tone, has been suggested. To evaluate the appropriateness of the default and boundary interpretations, we compared pitch contours among di- to tetrasyllabic words in greater detail. The results show that, in T1 to T4 sandhi, disyllabic words tend to have lower pitch contours than tri- and tetrasyllabic words at the first and second syllables, and that, in tetrasyllables, minimum pitch values were constantly attested at the third syllable. These results indicate that in Shanghai tone sandhi, a boundary Low tone is assigned at the right edge of a phonological word, and it is further associated with the third syllable in tetrasyllables. This boundary interpretation further gives an appropriate explanation of the difference of the pitch-fall between Middle and New Shanghai.

**Keywords:** Shanghai Chinese, tone sandhi, default tone, boundary tone, intonation

## 1. Introduction

### 1.1 Phonetic realization of pitch-fall of Shanghai tone sandhi

Shanghai Chinese is a regional Chinese dialect spoken in Shanghai. It has five citation tones: high falling (T1: *yinping*), high rising (T2: *yinqu*), low rising (T3: *yangqu*), short high (T4: *yinru*), and short low rising (T5: *yangru*). In polysyllabic

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words, broad tone sandhi (or left-dominant tone sandhi) occurs, in which the pitch shape of the words or phrases, especially in the first two syllables, is significantly influenced by the tone of the initial syllable, and pitch-fall occurs in the third and fourth syllables. Previous work (Zee & Maddieson 1979; Xu et al. 1981, 1988; Chen 2008) reported that in Middle Shanghai used by middle-aged speakers, a gradual pitch-fall consistently occurs in the third and fourth syllables, with the exception of T5 sandhi (see Table 1). Takahashi (2013) showed that in New Shanghai used by younger speakers, the rate of the fall is very fast at first, but rapidly decreases as time goes on (see Figure 1), which indicates that the pitch-falling pattern of Shanghai tone sandhi has changed from Middle to New Shanghai.[1]

**Table 1.** Pitch values of tone sandhi in Middle Shanghai (Xu et al. 1988: 24)[2]

| Initial tone | Disyllables | Trisyllables | Tetrasyllables |
|---|---|---|---|
| T1: 53 | 55-31 | 55-33-21 | 55-33-33-21 |
| T2: 34 | 33-44 | 33-55-21 | 33-55-33-21 |
| T3: 23 | 22-44 | 22-55-21 | 22-55-33-21 |
| T4: 55 | 33-44 | 33-55-21 | 33-55-33-21 |
| T5: 12 | 11-23 | 11-22-23 | A. 11-22-22-23 |
| | | | B. 22-55-33-21 |

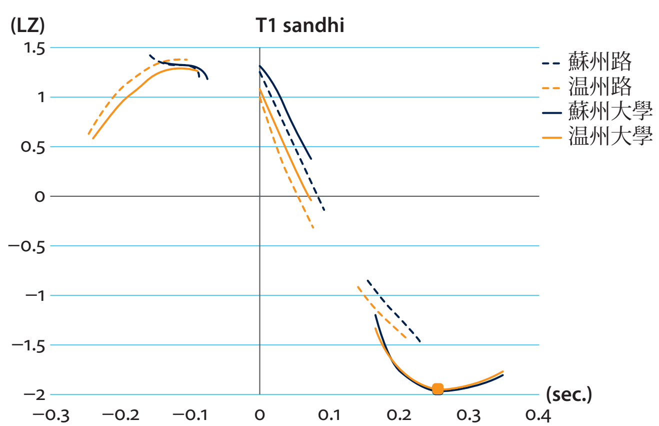



**Figure 1.** Pitch contours of New Shanghai tone sandhi in trisyllables (dotted line) and tetrasyllables (solid line) (Takahashi 2013: 141)

1. Chen (2008: 255) also points out the possibility of the occurrence of this change. In her experiment, three younger speakers of Middle Shanghai produced the sharp falling pattern in tetrasyllabic words. She attributes this to the influence of the younger generation.

2. The tonal notation divides a speaker's pitch range into five levels, with 1 as the lowest and 5 as the highest. Underlining of values indicates a checked tone.

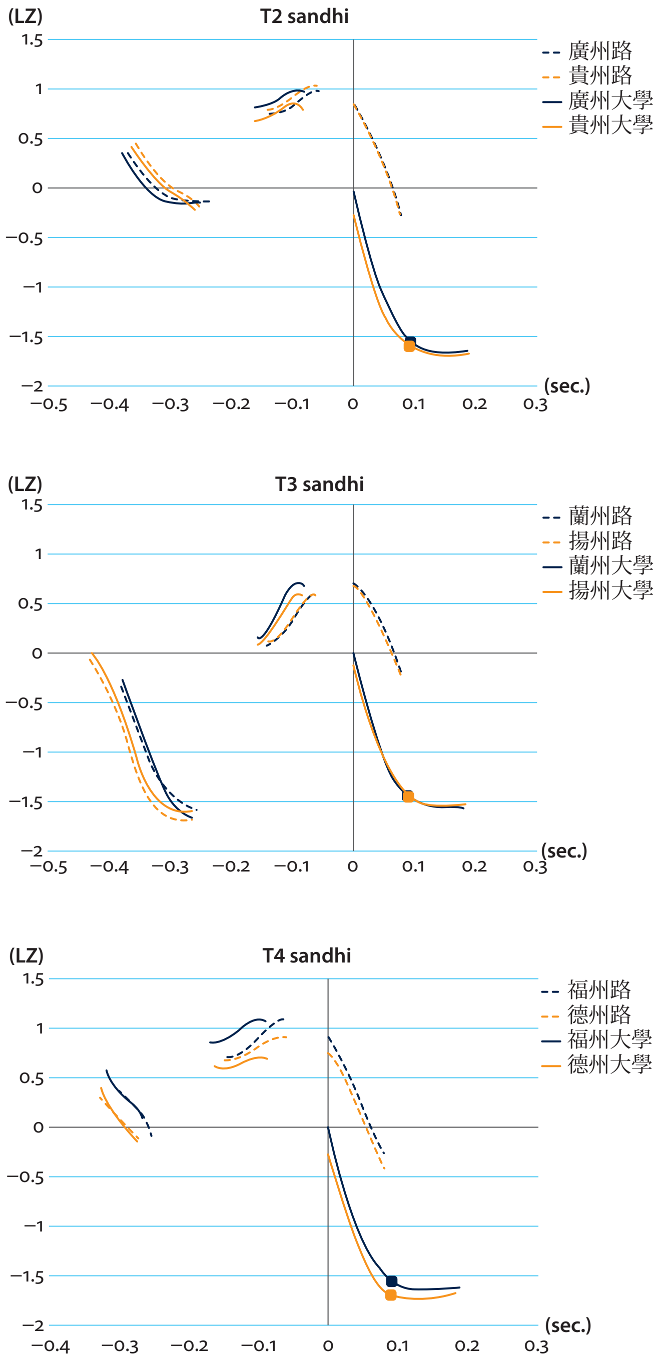


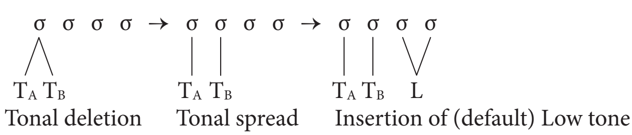

**Figure 1.** (*continued*)

## 1.2 Phonological problems of the pitch-fall pattern of Shanghai tone sandhi

Zee & Maddieson (1979) conducted the first autosegmental analysis of Shanghai tone sandhi, which consists of the following phonological operations: all tonal features except for those of the initial syllable are deleted (tonal deletion); the remaining tonal features are associated with the first and second syllables in T1 to T4 sandhi, while they are spread with the overall sandhi domain in T5 sandhi (tonal spread). This analysis has been widely supported by a number of previous studies of Shanghai tone sandhi (Yip 1980; Selkirk & Shen 1990, among others).

As for the phonological representation of the third and fourth syllables in T1 to T4 sandhi, Zee & Maddieson (1979: 120) argue that a Low tone is inserted and associated with them. Zee (1988: 341) called this inserted Low tone the "default tone." The whole analysis of T1 to T4 sandhi can be summarized as in (1):

(1) Phonological analysis of T1 to T4 sandhi proposed by Zee & Maddieson (1979) ($T_A$, $T_B$: Tonal features of the initial syllable)




Zee & Maddieson believe that the reason for the insertion of a Low tone is to satisfy the Well-formedness Condition, that "every syllable is associated with some tone" (Goldsmith 1976). However, this condition is not necessarily universally satisfied in tonal analyses of various languages. For example, Pierrehumbert & Beckman (1988) propose that in Tokyo Japanese, a word in an accentual phrase has, at most, an accented tone and some boundary tones, and pitch values of morae without these tones are determined by interpolation. Compared with a full specification analysis such as the one by Haraguchi (1977), Pierrehumbert & Beckman argue that their sparse specification analysis is more consistent with the attested pitch contours of Tokyo Japanese.[3] Referring to Chichewa, Myers (1998) argues that only the high tone is phonologically active and the low tone is absent from surface representation. Yip (2002: 70–72, 76–77) also accepts that Well-formedness Conditions are too strong, and that some languages leave syllables toneless. Following these analyses, when looking at Shanghai Chinese, it is not necessary to insert a default Low tone for satisfying the Well-formedness Condition, and we must rethink its phonological status.

What types of representation can a syllable take when it has low pitch in phonetic realization? Yip (2002: 63–64) suggests three possible answers to this question, which are shown in Table 2.

3. The differences between full and sparse analyses are summarized by Beckman & Venditti (2014).

**Table 2.** Three types of representations of a syllable with low pitch (Yip 2002: 63)

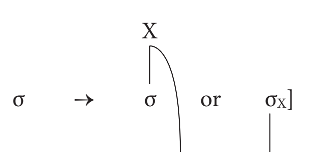
| | Phonological level | Phonetic level |
|---|---|---|
| Type (a) | L | L |
| Type (b) | Toneless | Toneless |
| Type (c) | Toneless | L |

In type (a), Low tones are active in phonology and act as low pitch targets in phonetics. In type (b), in contrast, syllables are tonally inert in both phonology and phonetics, and their pitch values are determined by their surrounding syllables. In type (c), while syllables do not have Low tones during the phonology, they surface as phonetically low. As for the last type, Yip (2002: 64) indicates that the insertion of a Low tone is an interface operation happening at the point of transition from phonology to phonetics. However, she does not pinpoint the exact level where the insertion occurs, leaving the question open.

Let us consider which type can account for the pitch-fall of Shanghai tone sandhi. First, it is obvious that type (b) is not correct, because the pitch-fall in the third and fourth syllables consistently occurs despite pitch values of the surrounding syllables. It can be said that type (a) corresponds to the default tone in the framework of Zee & Maddieson (1979) because the Well-formedness Condition should be applied at the phonological level. The appropriateness of type (c) is difficult to evaluate since the nature of the Low tone has not been clear. Thus, we must address this problem before comparing type (a) and (c).

The author proposes that type (c) can reflect the assignment of boundary tones. In intonation phonology (Pierrehumbert 1980; Pierrehumbert & Beckman 1988; Ladd 1996; Gussenhoven 2004, among others), pitch values of syllables are determined not only by lexical tones (or pitch accent), but also by boundary tones assigned at the periphery of various prosodic constituents. The former is specified at the lexical level (corresponding to "phonological level" in Table 2), and the latter at the post lexical level, located after the lexical level and before phonetic realization. The assignment of a boundary Low tone can be illustrated as (2).

(2) Assignment of a boundary Low tone (X: Prosodic constituent higher than the syllable tier, $L_X$: Boundary Low tone assigned at the right edge of the prosodic constituent X)




Intonation phonology: Lexical level — Post lexical level
Yip (2002: 63): Phonological level — Phonetic level

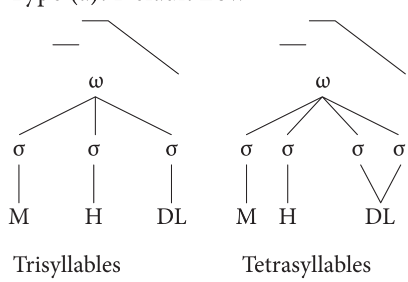
In the framework of Pierrehumbert & Beckman (1988: 127), boundary tones that are realized right at the boundary have no additional link between tones and TBUs. In (2), therefore, a syllable without a lexical tone gets its low pitch target from the boundary Low tone at the post lexical level, although there is no association line between them. The author believes that the post lexical characteristics of the assignment of a boundary tone can be captured by type (c) in Table 2.

In actuality, Zhang (2007: 261–262) assumes that in Shanghai tone sandhi, a boundary Low tone is assigned at the right edge of a (phonological) word and the pitch value of a toneless third syllable is determined by interpolation between the tonal features of the second syllable and the boundary Low in a tetrasyllabic word. The difference of the phonological representations of tri- and tetrasyllabic words between type (a) and (c) can be illustrated as in (3).

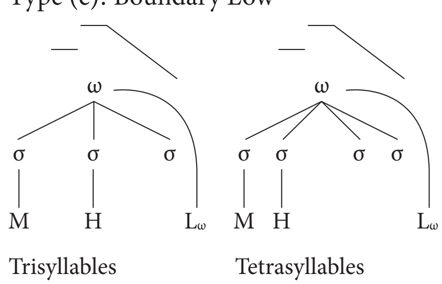
(3) Surface representations of tri- and tetrasyllabic T2 sandhi
(T2 = /MH/; DL: Default Low, ω: Phonological word, $L_{\omega}$: Boundary Low)

A. Middle Shanghai (Xu et al. 1988; Chen 2008)

a. Type (a): Default Low

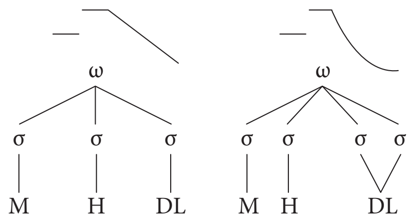



b. Type (c): Boundary Low



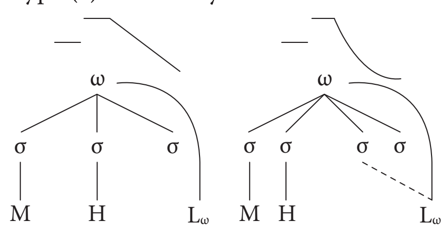
B. New Shanghai (Takahashi 2013)

c. Type (a): Default Low




Trisyllables Tetrasyllables

d. Type (c): Boundary Low[4]




Trisyllables Tetrasyllables

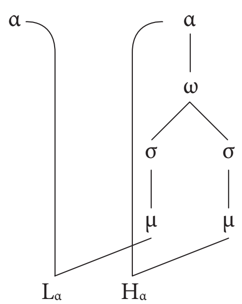
In the default interpretation, all syllables must be associated with some tone because the Well-formedness Condition still works. In the boundary interpretation, on the other hand, toneless syllables can be allowed and their pitch values may be determined by a boundary tone. As shown in § 1.1, the pitch falling patterns of Shanghai tone sandhi are different between middle and young generations. In Middle Shanghai with a gradual pitch-fall, the boundary interpretation (3b) can straightforwardly account for the pitch contour of tri- and tetrasyllabic words, while the default interpretation (3a) must explain why the default Low associated with the third syllable does not reach its low pitch target in phonetic realization. Zee & Maddieson (1979: 125) suggest that the pitch of the third syllable is closer to a phonetic mid-level due to co-articulation effects between the second High and the following Low. Alternatively, Chen (2008: 256) proposes that, compared to lexical tones, the Low tone is "weak" in that it takes longer to attain its low target.

In New Shanghai with a sharp pitch-fall, the default interpretation (3c) can straightforwardly account for the pitch contours of tri- and tetrasyllables: the default Low tone can achieve its low pitch target at the third syllable, which may indicate that, on the basis of Chen (2008), the default Low tone has been reinforced (or become "strong"). In contrast, the boundary interpretation (3d) must explain why the sharp pitch-fall occurs at the third syllable in tetrasyllabic words even though the boundary Low tone is originally assigned at the right edge of a phonological word.

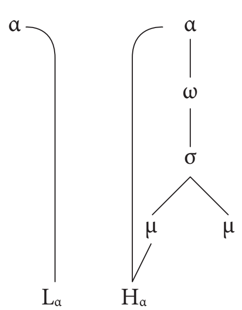
4. The dotted line indicates "secondary association of $L_{\omega}$," which will be explained below.

In intonation studies, obvious pitch movements not induced by lexical items are sometimes observed at near peripheral positions. To account for this kind of phenomenon found in Tokyo Japanese, Pierrehumbert & Beckman (1988) propose a concept "secondary association of boundary tones". In Tokyo Japanese, a phrase beginning with a short unaccented syllable has Low-High pitch values in the first two morae while a phrase beginning with a long unaccented syllable keeps High pitch during the syllable. Pierrehumbert & Beckman suggest that in the former condition (4a), a phrasal initial High tone is associated with the second mora and the phrasal final Low tone is associated with the first mora of the following phrase, while, in the latter condition (4b), the phrase initial High tone is associated with the first mora and the final Low tone assigned at the preceding phrase is not associated with the phrase.

(4) Second association of boundary tones in Tokyo Japanese
(Pierrehumbert & Beckman 1988: 126–130, α: Accentual phrase, μ: mora, ω: Phonological word, $L_{\alpha}$: Final accentual Low tone, $H_{\alpha}$: Initial accentual High tone)
a. α phrase beginning with two short syllables




b. α phrase beginning with a long syllable




Pierrehumbert & Beckman argue that a tone is associated with a mora when it occurs simultaneously with any phoneme segments associated to that mora (1988: 119);[5]

5. Similarly, Bruce (1977) suggests that tones are identified with "turning points" in the F0 contour, although Ladd (2008: 135) considers that this is too restrictive to serve as a universally valid principle of tonal realization.

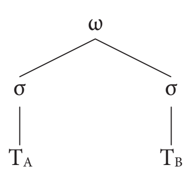
therefore, the second association of the phrasal tones of Tokyo Japanese is also motivated by the actual pitch realization of the phrases.

Returning to Shanghai Chinese, the phonological status of the third and fourth syllables in tri- and tetrasyllables is similar with the initial morae of Tokyo Japanese: their pitch information is not directly registered lexically but is automatically determined according to their position in a phonological word.[6] Thus, it is possible to adopt the boundary interpretation to account for the pitch values of the third and fourth syllables and, in New Shanghai, the boundary Low tone may be associated with the third syllable as well as the right edge of the phonological word if, following the Pierrehumbert & Beckman's definition of tonal association, the timing of the pitch-fall at the third syllable is consistent. However, the timing has not been investigated in detail.

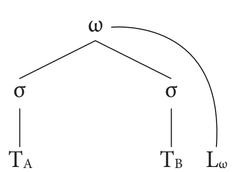
As a result, both default and boundary interpretations have problems in dealing with pitch realization of tri- and tetrasyllables in Middle and New Shanghai, and it is difficult to determine which interpretation is better. To resolve this problem, we have to investigate the pitch realization of tri- and tetrasyllables in greater detail, especially the timing of the pitch-fall in tetrasyllables.

In addition, the author wants to focus on disyllables because different surface representations are predicted in this condition, as shown in (5).

(5) Surface representations of disyllabic sandhi
($T_A$, $T_B$: Tonal features of the initial syllable, $L_\omega$: Boundary Low)
a. Default interpretation




b. Boundary interpretation




In the default interpretation (5a), it is impossible to insert a default tone since the Well-formedness Condition is already satisfied. In the boundary interpretation (5b), however, a boundary Low is always assigned at the right edge of a phonological word. Table 3 summarizes the surface representations of the first two syllables of di- to tetrasyllabic words.

6. In Tokyo Japanese, only pitch accents HL are registered at the lexical level.

**Table 3.** Surface representations of the first two syllables in di- to tetrasyllables ($T_A$, $T_B$:Tonal features of the initial syllable, $_{\omega}]$: Right edge of a phonological word, $L_{\omega}$: Boundary Low)

| | Default interpretation | | Boundary interpretation[7] | | |
|---|---|---|---|---|---|
| Disyllables | σ | σ | σ | σ | $_{\omega}]$ |
| | $T_A$ | $T_B$ | $T_A$ | $T_B$ | $L_{\omega}$ |
| Tri- and tetrasyllables | σ | σ | σ | σ | |
| | $T_A$ | $T_B$ | $T_A$ | $T_B$ | |

In the default interpretation, the first and second syllables have the same representation among di- to tetrasyllables, while, in the boundary interpretation, a boundary Low tone is adjacent with the second syllable only in disyllables. The former predicts that the pitch values of the first and second syllables are basically the same among di- to tetrasyllables; in contrast, the latter predicts that disyllables may have different pitch values with tri- and tetrasyllables. Although some previous work (Xu et al. 1981; 1988) reported that the second syllable has a pitch value of [44] in disyllables but [55] in tri- and tetrasyllables, which seems to support the boundary interpretation, a detailed acoustic comparison of the pitch contours of multisyllabic words has not been conducted. Hence, this study acoustically investigates the pitch contours of di- to tetrasyllables then compares the pitch values among them and finally attempts to determine the correct interpretation for the pitch-fall of Shanghai tone sandhi.

## 2. Methods

### 2.1 Speech materials

The targets of the experiment are di- to tetrasyllabic noun words with T1 to T5 as their initial tones. A frame sentence (6) was employed to elicit F0 values of target words, as shown in Table 4. They were inserted in the X position of the frame sentence. Each target word can form a sandhi domain by itself.

(6) Frame sentence of the experiment (LOC: Locative, ACH: Achievement)

| | | | | | |
|---|---|---|---|---|---|
| 我 | 辣 | X | 看 | 到 | 阿四 |
| I | LOC | | see | ACH | A-si |
| [(ŋ)u. | ləʔ. | | kʰø. | tɔ | a. sɿ] |

‘I saw A-si at X’

7. In Table 3, only the edge with a boundary tone is illustrated as “$_{\omega}]$”

**Table 4.** Target words of the experiment

| Initial tone | Disyllables | Trisyllables | Tetrasyllables[8] |
|---|---|---|---|
| T1 | 蘇州 [su. tsɤ] | 蘇州路 [su. tsɤ. lu] | 蘇州大學 [su. tsɤ. da. oʔ] |
| Falling | 'Suzhou' | 'Suzhou Road' | 'Suzhou Univ.' |
| | 溫州 [uən. tsɤ] | 溫州路 [uən. tsɤ. lu] | 溫州大學 [uən. tsɤ. da. oʔ] |
| | 'Wenzhou' | 'Wenzhou Road' | 'Wenzhou Univ.' |
| T2 | 廣州 [kuã. tsɤ] | 廣州路 [kuã. tsɤ. lu] | 廣州大學 [kuã. tsɤ. da. oʔ] |
| High rising | 'Guangzhou' | 'Guangzhou Road' | 'Guangzhou Univ.' |
| | 貴州 [kuɛ. tsɤ] | 貴州路 [kuɛ. tsɤ. lu] | 貴州大學 [kuɛ. tsɤ. da. oʔ] |
| | 'Guizhou' | 'Guizhou Road' | 'Guizhou Univ.' |
| T3 | 蘭州 [lɛ. tsɤ] | 蘭州路 [lɛ. tsɤ. lu] | 蘭州大學 [lɛ. tsɤ. da. oʔ] |
| Low rising | 'Lanzhou' | 'Lanzhou Road' | 'Lanzhou Univ.' |
| | 揚州 [jã. tsɤ] | 揚州路 [jã. tsɤ. lu] | 揚州大學 [jã. tsɤ. da. oʔ] |
| | 'Yangzhou' | 'Yangzhou Road' | 'Yangzhou Univ.' |
| T4 | 福州 [fəʔ. tsɤ] | 福州路 [fəʔ. tsɤ. lu] | 福州大學 [fəʔ. tsɤ. da. oʔ] |
| Short high | 'Fuzhou' | 'Fuzhou Road' | 'Fuzhou Univ.' |
| | 德州 [təʔ. tsɤ] | 德州路 [təʔ. tsɤ. lu] | 德州大學 [təʔ. tsɤ. da. oʔ] |
| | 'Dezhou' | 'Dezhou Road' | 'Dezhou Univ.' |
| T5 | 岳州 [ŋoʔ. tsɤ] | 岳州路 [ŋoʔ. tsɤ. lu] | 岳州大學 [ŋoʔ. tsɤ. da. oʔ] |
| Short rising | 'Yuezhou' | 'Yuezhou Road' | 'Yuezhou Univ.' |
| | 達州 [daʔ. tsɤ] | 達州路 [daʔ. tsɤ. lu] | 達州大學 [daʔ. tsɤ. da. oʔ] |
| | 'Dazhou' | 'Dazhou Road' | 'Dazhou Univ.' |

## 2.2 Subjects

Six native speakers of Shanghai Chinese, three males and three females, participated. All speakers had lived in an urban area of Shanghai since childhood and were studying in universities in Tokyo at the time of the experiment. Table 5 shows detailed information on the subjects. They were paid a nominal fee for the experiment.

**Table 5.** Subject information

| Subject ID (M: male, F: female) | Year of birth | District |
|---|---|---|
| F1 | 1984 | Changning 長寧區 |
| F2 | 1984 | Huangpu 黃浦區 |
| F3 | 1988 | Xuhui 徐匯區 |
| M4 | 1983 | Hongkou 虹口區 |
| M5 | 1984 | Huangpu黃浦區 |
| M6 | 1986 | Yangpu 楊浦區 |

8. Though "學" is read [ɦoʔ] in Xu et al. (1988: 98), the onset voiced glottal fricative is usually deleted in word-medial position.

After recording, we found that Speaker M6 frequently produced an unusual sandhi pattern at disyllables, in which a clear pitch-fall occurs at the second syllable. This pattern had not been reported by previous studies other than Qian (1992), and an anonymous reviewer pointed out the possibility that M6 might be not a typical speaker of Shanghai Chinese.[9] Therefore, this study excludes the data of M6, only analyzing the results produced by the remaining five speakers.

### 2.3 Procedures

Recording was conducted in a sound-treated booth. The target sentences were presented in Simplified Chinese at random, and the subjects read them five times at their normal speech rate. The experiment was preceded by an instruction and practice session, and all speakers indicated that they comprehended their task before the experiment. Recording was done with a 44.1 kHz sampling rate using a Marantz PMD660 recorder and AKG C444 microphone.

### 2.4 Measurements and normalization

All recorded materials were analyzed using Praat (Boersma & Weenink 1992–2016, version 6.0.21). Nine F0 points were measured at 10% to 90% of the vowel duration of the target words using ProsodyPro script (Xu 2013, version 5.7.0). In tetrasyllables (i.e. σ σ大學 [da. oʔ]), however, it was quite difficult to separate the third syllable [da] from the fourth syllable [oʔ], because they overlapped in the waveform and spectrogram. Thus, the author did not segment them, and nine F0 points were measured there. Each speaker's measured F0 values were transformed into an LZ-score (Zhu 2005: 54–55). This score was calculated as the difference between the logarithmic F0 and the logarithmic mean F0 of each subject, divided by the logarithmic standard deviation of the overall F0 of the same speaker. All times of 10% to 90% points of the vowel duration of the target syllables were measured, and the average times for all speakers were calculated.

9. An additional speaker of Shanghai Chinese who is studying linguistics at the Tokyo University of Foreign Studies agreed with this opinion.

## 3. Results and analysis

We shall show the results of T1 to T4 sandhi in § 3.1 and those of T5 sandhi in § 3.2. As explained in § 2.2, the data produced by F1 to M5 are analyzed here (with the exclusion of Speaker M6, as it is not clear whether he is a typical speaker of Shanghai Chinese).

### 3.1 T1–T4 sandhi

Figure 2 illustrates the speaker-normalized pitch contours of T1 to T4 sandhi. Each contour is an average of 50 tokens (2 words*5 repetitions*5 speakers). From Figure 2, we can see that steep pitch-fall starts from the second syllable in T1 sandhi and from the third syllable in T2 to T4 sandhi. It appears that pitch values of disyllables may be lower than those of tri- and tetrasyllables in the second syllable in all sandhi. As for the first syllable, the same tendency can be clearly found only in T4 sandhi while three contours tend to overlap in T1 to T3 sandhi. Detailed LZ-scores of the first and second syllables are given in Appendix.

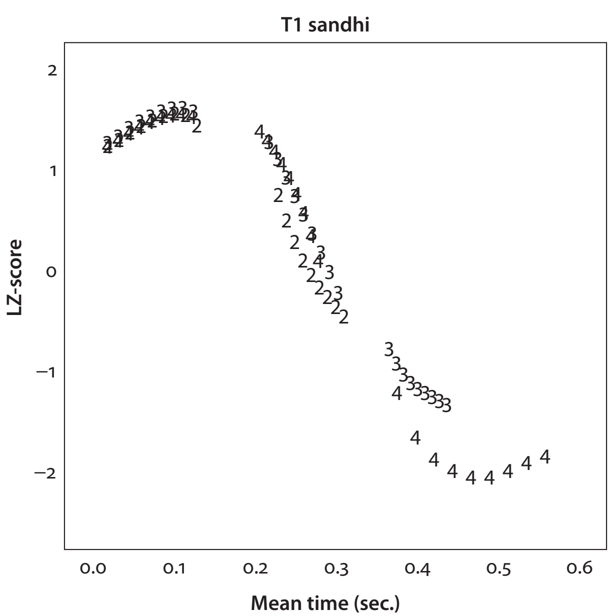
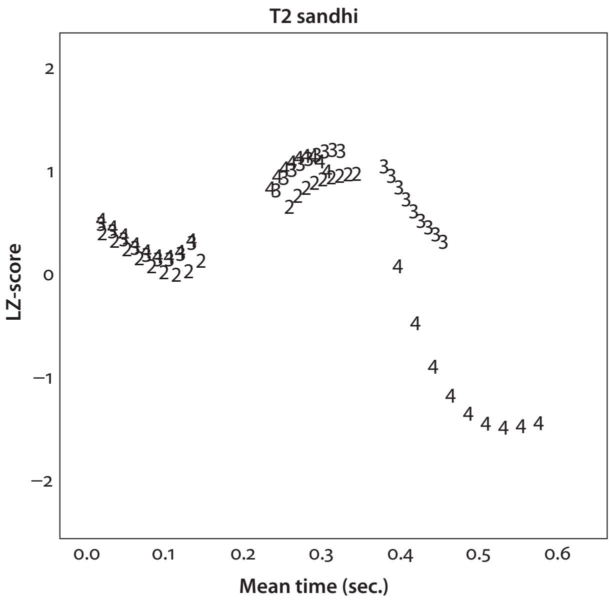



**Figure 2.** Pitch contours of di- to tetrasyllabic words in T1 to T4 sandhi (2: Disyllables, 3: Trisyllables, 4: Tetrasyllables)



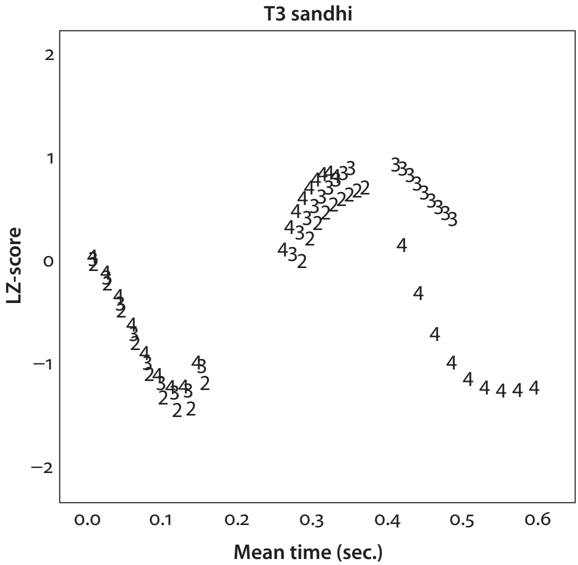




**Figure 2.** (*continued*)

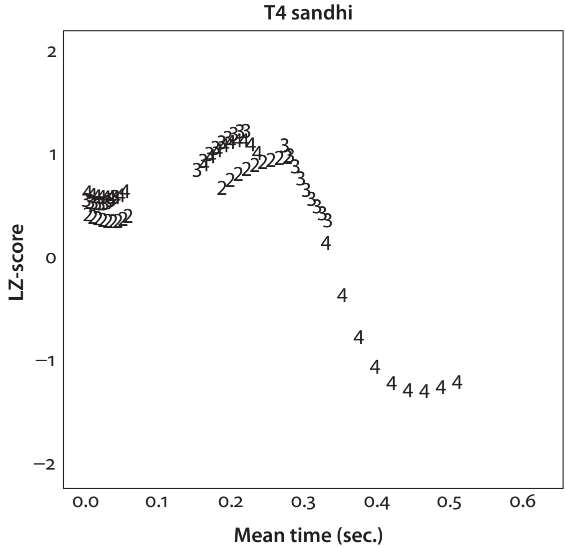



**Figure 2.** (*continued*)

To evaluate the significance of difference in pitch contours of the first and second syllables between di- to tetrasyllables, a smoothing spline analysis of variance (SS ANOVA) was conducted with R (version 3.3.3). SS ANOVA is a statistical technque to estimate the difference of the shapes of multiple curves (Gu 2002, 2013). It has been used for comparing tongue shapes on ultrasound pictures (Davidson 2006; Chen & Lin 2011) and for pitch contours (Chuang et al. 2013; Yiu 2015, among others). In this study, the smoothing splines representing pitch contours of the first and second syllables of di- to tetrasyllables were compared with each other, and if the resulting splines do not overlap with 95% confidence intervals, there is a statistical difference among them.

Figure 3 shows the SS ANOVA plots of the first and second syllables in T1 to T4 sandhi. In the first syllable, while all contours are almost overlapped in T1 sandhi, disyllables are different from tri- and tetrasyllables at least in the latter part of the contours in T2 to T4 sandhi. In the second syllable, we can see that no contours in T1 sandhi overlap, and that disyllables are different from the remaining words both in the major part of the contours in T2 and T4 sandhi and in the latter part in T3 sandhi. These results indicate that disyllables are different from tri- and tetrasyllables, at least in either the first or second syllable in T1 to T4 sandhi.

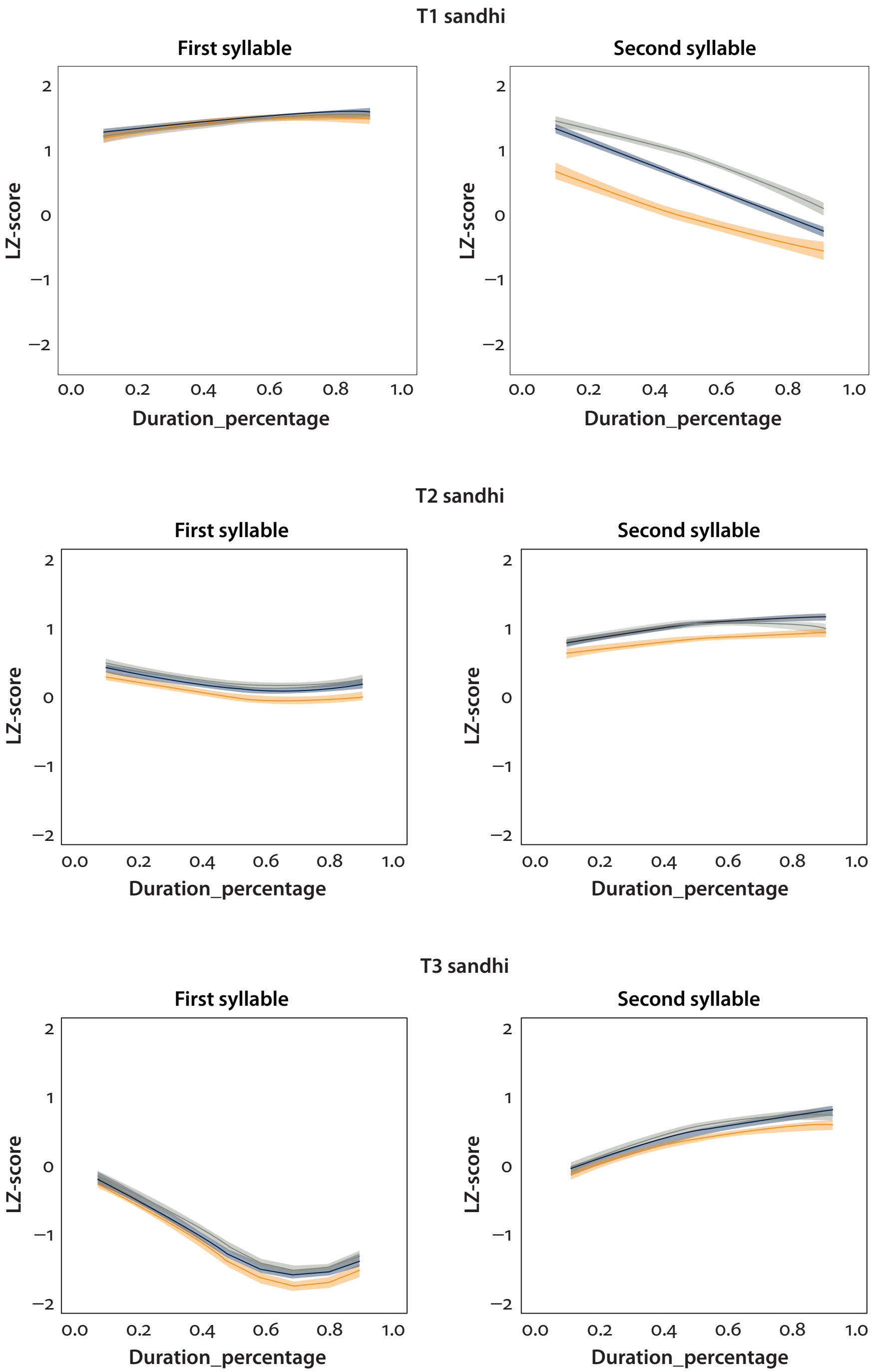



**Figure 3.** SS ANOVA results of the first and second syllables of T1 to T4 sandhi (Yellow: Disyllables, Blue: Trisyllables, Gray: Tetrasyllables)

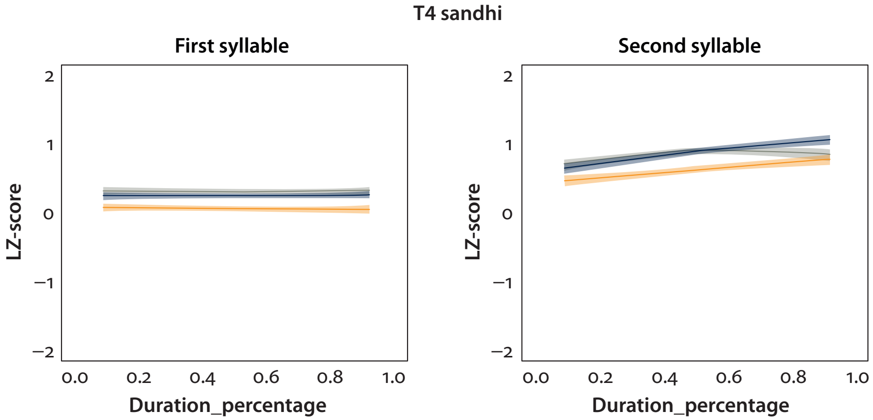



**Figure 3.** (*continued*)

## 3.2 T5 sandhi

As explained in § 1.1, T5 sandhi has a different pitch pattern from T1 to T4 sandhi: it has no pitch-fall, with the exception of variant B [22-55-33-21] of tetrasyllabic sandhi in Table 1; instead, a continuous pitch-rise occurs across the entire sandhi domain. The speaker-normalized pitch contours of T5 sandhi are shown in Figure 4. In the experiment, all five speakers of Shanghai Chinese consistently produced variant B in tetrasyllabic words.

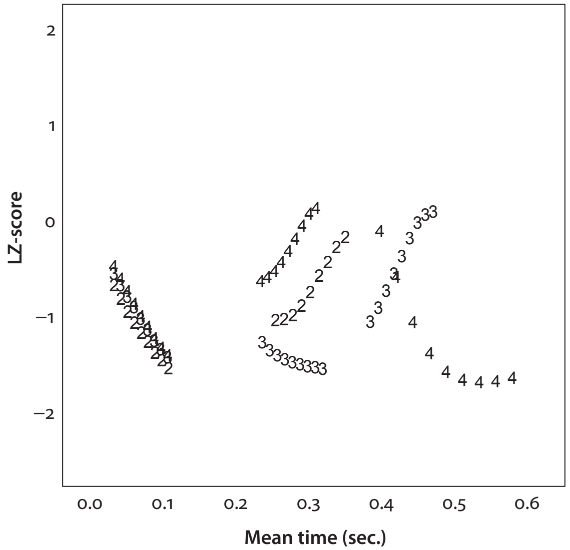



**Figure 4.** Pitch contours of di- to tetrasyllabic words in T5 sandhi (2: Disyllables, 3: Trisyllables, 4: Tetrasyllables)

The same SS ANOVA was conducted in the first and second syllables of di- to tetrasyllables, and the results are shown in Figure 5. In the first syllable, disyllables are different from tri- and tetrasyllables except at the last part of the contour. In the second syllable, on the other hand, none of the three curves overlap.

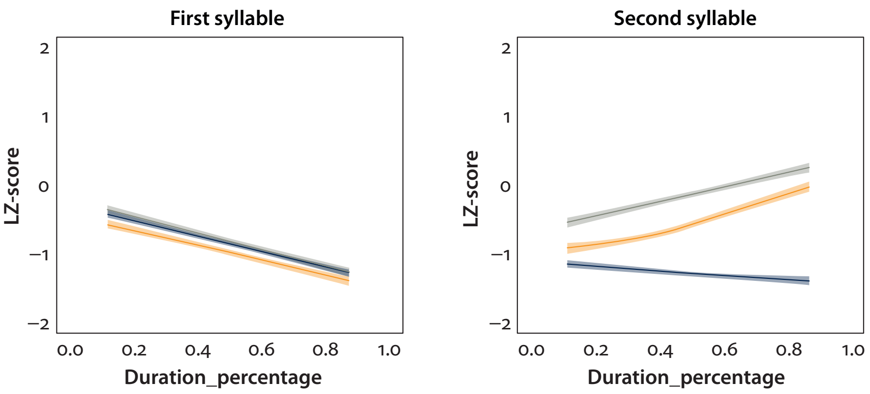



**Figure 5.** SS ANOVA results of the first and second syllables of T5 sandhi (Yellow: Disyllables, Blue: Trisyllables, Gray: Tetrasyllables)

## 4. Discussion

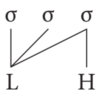
The results of the experiment can be summarized as follows: significant differences between disyllables and tri- to tetrasyllables are found not only in the second syllable but also in the first syllable in all but T1 sandhi. More specifically, disyllables have the lowest pitch contour except in the second syllable of T5 sandhi, where trisyllables show the lowest pitch contour. These results seem to be more compatible with the boundary interpretation, which predicts a lower pitch contour in disyllables because a boundary Low tone may affect pitch values of the first and second syllables. Conversely, the default interpretation does not predict the pitch differences in the first and second syllables among di- to tetrasyllables, since there is no difference of surface representations among them.

As for T5 sandhi, a continuous pitch-rise occurred over the entire sandhi domain in di- and trisyllabic words, while tetrasyllables show the same pattern with T2 to T4 sandhi. Previous phonological studies of Shanghai tone sandhi (Zee & Maddieson 1979: 123; Zee 1988: 345–347, among others) suggest that this continuous pitch-rise can be attributed to the overall spread of the tonal features of the initial syllable, which is illustrated in (7a–b). In tetrasyllables (7c), on the other hand, the same phonological operations with T3 sandhi can be applied.

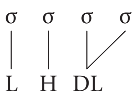
(7) Surface representations of di- to tetrasyllabic T5 sandhi using the default interpretation (Zee & Maddieson 1979: 123, 126–127, T5= /LH/, DL: Default tone)

a. Disyllables


b. Trisyllables




c. Tetrasyllables




To investigate whether a boundary Low tone exists in T5 sandhi, it is not useful to compare pitch values of the second syllables of di- to tetrasyllables, because they have different surface representations: [LH] for disyllables, [L] for trisyllables, and [H] for tetrasyllables. In contrast, we can compare the pitch contours of the first syllables because their surface representations are all [L]. From Figure 5, it is clear that disyllables have the lowest pitch contour in the first syllable, which is also compatible with the boundary interpretation.

Before concluding, however, we shall consider other possibilities for explaining the results. In T1 to T4 sandhi, anticipatory dissimilation may influence the pitch realization of the second syllable in tri- and tetrasyllables.[10] In an analysis of the phonetic tonal variation of Mandarin, Xu (1997: 78) reports that tone with a low onset tends to raise the maximum F0 as well as the overall contour of the preceding tone, except in cases where the preceding tone is Tone 3 (*shang*). In Shanghai Chinese, similarly, the anticipatory dissimilation might make the pitch values of the second syllables of tri- and tetrasyllables higher than those of disyllables because they have a low pitch target at the third and fourth syllables. However, the author suspects that this interpretation cannot account for the results shown in § 3. because anticipatory dissimilation is a very local phonetic phenomenon: In Mandarin, Xu's data clearly show that anticipatory effects are limited at the immediately preceding rhyme of a low tone and almost disappear at the preceding onset (Xu 1997: 75, Figure 6). In Shanghai Chinese, in contrast, disyllables took the lowest pitch contours at not only second but also first syllables, which likely

10. An anonymous reviewer points out this possibility.

exceeds the scope of anticipatory dissimilation. For this reason, the author considers that the pitch differences at the first and second syllables cannot be attributed to anticipatory dissimilation.

The biggest problem of the boundary interpretation may be how to explain the pitch-fall at tetrasyllables. As explained in § 1.1, the pitch-falling pattern of Shanghai tone sandhi is different between Middle and New Shanghai: the former has a gradual fall while the latter has a sharp fall. Here, we shall consider the latter pattern first because the sandhi pattern of the younger generation was just investigated in the experiment. In the results, it is noted that the time points of minimum pitch values in tetrasyllables are relatively consistent, which is shown in Table 6.

**Table 6.** Minimum pitch values (LZ-score) and their time points of tri- and tetrasyllables

| | T1 sandhi | T2 sandhi | T3 sandhi | T4 sandhi |
|---|---|---|---|---|
| Trisyllables: 3rd σ | −1.44 (90%) | 0.04 (90%) | 0.05 (90%) | −0.02 (90%) |
| Tetrasyllables: 3rd-4th σ | −2.15 (50%) | −1.81 (70%) | −1.73 (70%) | −1.85 (70%) |

In Table 6, we can see that trisyllables always take the lowest pitch values at the final measured time point (i.e. 90% point of the third syllable). In tetrasyllables, the lowest pitch values were attested at the 70% time point of 大學 /da. oʔ/ (T3. T5) in T2 to T4 sandhi but at the 50% point in T1 sandhi. According to Zhu (2005: 145, 192), the mean duration of T3 syllables (256ms) is far longer than that of T5 syllables (116ms); therefore, it is natural to think that in tetrasyllables, a Low pitch target is always realized at the third syllable.[11]

In the strictest framework of autosegmental-metrical theory, a tone (especially a boundary tone) associates with a TBU when it occurs simultaneously with its segments and it is identified with a turning point in the F0 contour (Bruce 1977; Pierrehumbert & Beckman 1988, among others). Based on this framework, we have to associate a low tone with the third syllable in tetrasyllables and this is a typical condition of SECONDARY ASSOCIATION of a boundary Low tone. As noted in § 1.2, a boundary tone is sometimes associated not only with either side of the periphery of prosodic constituents but also with TBUs at the non-peripheral position: In addition to the case of Tokyo Japanese by Pierrehumbert & Beckman (1988) already introduced, Grice (1995) suggests that in Palermo Italian interrogative intonation, a boundary Low tone attached to an intermediate phrase can be further associated with the final syllable of the phrase. Moreover, Grice et al. (2000) suggest that

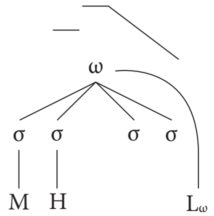
11. The difference of the timing between T1 and T2 to T4 sandhi may reflect the different starting points of pitch-fall. As shown in Figure 2, the pitch-fall starts at the second syllable in T1 sandhi while at the third syllable in T2 to T4 sandhi.

in European languages like Hungarian, Standard Greek, and Romanian, "phrase accents," a kind of boundary tone, can be associated with syllables at the periphery of the phrase as well as syllables which are a considerable distance from the phrasal edge. Gussenhoven (2000) also proposes that in Roermond Dutch, final boundary tones in the intonation phrase have a target at the right periphery of the phrase as well as a non-peripheral target. These ideas are all based on actual pitch movements not induced by lexical pitch accents. In tetrasyllables of New Shanghai, similarly, the pitch-fall is not induced by lexical items but occurs at almost the same timing, which can be explained by an assumption that a boundary Low originally assigned at the edge of a phonological word is additionally associated with the third syllable.[12]

We further note that this boundary interpretation can straightforwardly explain the difference of the pitch-fall between Middle and New Shanghai. As explained in § 1.1, Middle Shanghai has a gradual pitch-fall, while New Shanghai has a sharp fall at the third and fourth syllables (Chen 2008 for Middle Shanghai; Takahashi 2013 for New Shanghai). These differences can be reflected by a contrast between having and not having a secondary association of the boundary Low. In Middle Shanghai with a gradual pitch-fall, secondary association may be prohibited, and the third syllable may remain toneless; if so, the pitch value of the third syllable is determined by the surrounding syllables, as noted by Zhang (2007: 262). In New Shanghai, meanwhile, the boundary Low can be associated with the third syllable, which leads to a sharp pitch-fall there. The difference can be schematized as in (8).

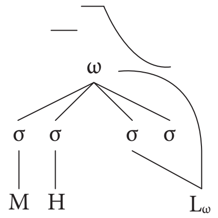
(8) Surface representations of tetrasyllabic T2 sandhi in Middle and New Shanghai by the boundary interpretation (T2=/MH/, $L_\omega$: Boundary Low)

a. Middle Shanghai (Chen 2008)




12. An anonymous reviewer suggests that the sharp pitch-fall at the third syllable can be attributed to "sagging transition" between a High tone at the second syllable and a Low tone at the right edge of the phonological word. Pierrehumbert (1980) firstly proposes this concept to explain the "sagged" pitch shape between two sequential H* accents in English. The author doubts that the sharp pitch-fall in tetrasyllables of New Shanghai is induced by the sagging transition: as shown in Table 6, minimum pitch values of the tetrasyllabic words were constantly attested at the third syllable, which indicates that an obvious Low pitch target exists there.

b. New Shanghai (Takahashi 2013)




On the contrary, the default interpretation is not able to reflect this difference in the phonological representation: a default Low tone should be always associated with the third and fourth syllables in Middle and New Shanghai due to the Well-formed Condition and we have to rely on additional phonetic operations to account for the pitch difference between them.[13]

In sum, the boundary interpretation not only precisely corresponds to the results of the experiment but also directly captures the pitch difference between Middle and New Shanghai. In contrast, the default interpretation must rely on additional phonetic operations as well as TOO STRONG Well-formedness Conditions to account for them. For these reasons, the author concludes that boundary tone is the better interpretation of Shanghai tone sandhi.

Finally, let us consider the relationship between boundary tone and the syllables in disyllabic words. We found that in disyllables, the pitch contours of the first and second syllables tend to be lower than those of tri- and tetrasyllables. However, it appears that the pitch target of the boundary Low is not accomplished in T2 to T4 sandhi.[14] In Shanghai Chinese, a syllable associated with two tonal features has a contour tone to accomplish their pitch targets. For example, citation forms of T1 /HL/ and T3 /LH/, which have tonal representations as shown in (9), are realized as rising and falling contours respectively, as shown in Figure 6.

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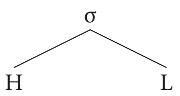
13. An anonymous reviewer points out that the default interpretation can also account for the difference by assuming that the Low tone following a High tone is depressed or down drifting as seen in the Bantu languages. However, the author thinks that depression or down drift is not a good resolution to explain the difference because it generally works on a High tone (Kenstowicz & Kisseberth 1979: 265; Yip 2002: 147–150). In Shanghai Chinese, the pitch-fall at the third and fourth syllables is clearly induced by a Low tone and beyond the scope of the depression or down drift.

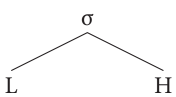
14. It is not clear whether the pitch target of the boundary Low was realized in T1 sandhi because the second syllable is associated with a lexical Low tone.

(9) Tonal representations of monosyllabic T1 /HL/ and T3 /LH/ words (cf. Duanmu 1993: 28)

a. T1 /HL/




b. T3 /LH/



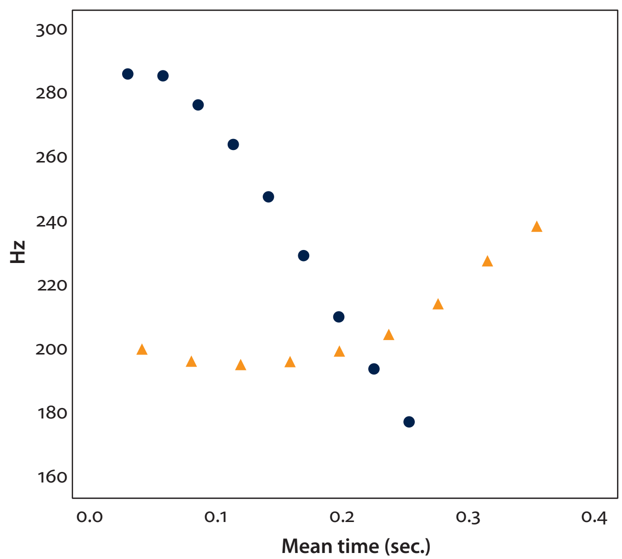




**Figure 6.** F0 contours of T1 (circles) and T3 (triangles) by Speaker F3[15]

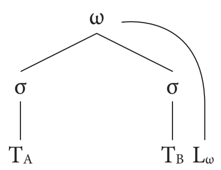
These facts indicate that in disyllables, the boundary tone is only associated with the phonological word and cannot realize its pitch target at any syllable; instead, it may have a weak influence on the entire phonological word, which makes the overall pitch contour of the phonological word slightly lower. In trisyllabic words, the third syllable without a lexical tone gets a low pitch target from a boundary Low tone at the post lexical level. In tetrasyllabic words, the boundary Low tone

15. Each contour is an average of 10 tokens (2 words*5 repetitions). The target words were 爸 [pa] and 刀 [tɔ] for T1 and 牌[ba] and 逃 [dɔ] for T3. The same method provided in § 2 without the frame sentence and normalization was adopted.

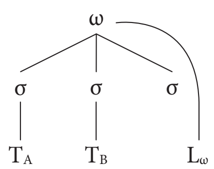
associates with the third syllable as well as the right edge of a phonological word, which leads to a constant pitch-fall at the penultimate position. The surface representations of di- to tetrasyllables in New Shanghai can be summarized as in (10).

(10) Surface representations of New Shanghai tone sandhi
($T_A$, $T_B$: Tones of the initial syllable, $L_\omega$: Boundary Low)

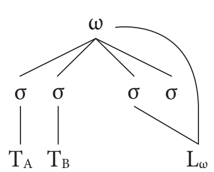
a. Disyllables




b. Trisyllables[16]




c. Tetrasyllables




16. (10) is based on the framework of Pierrehumbert & Beckman (1988) and the author did not draw an association line between the third syllable and a boundary Low in (10b). Pierrehumbert & Beckman (1988: 127) suggest that boundary tones that are realized right at the boundary have no additional link between tones and TBUs.

## 5. Conclusion

This study compares the pitch realization of the first and second syllables among di- to tetrasyllabic words and concludes that a boundary Low tone, rather than a default tone, is assigned at the right edge of a phonological word. The boundary Low is realized at the right periphery of the phonological word in trisyllables while at the penultimate syllable in tetrasyllables. In disyllables, on the other hand, the boundary Low cannot realize its pitch target instead makes the overall pitch value of the phonological word slightly lower. This interpretation has phonetic and phonological advantages over the default one: Phonetically, it corresponds to the pitch realization of Shanghai tone sandhi more accurately and, phonologically, it does not need to rely on the Well-formedness Condition regarded as TOO STRONG in the recent autosegmental framework.

This study further sheds light on the relationship between lexical tone and intonation in Chinese. It is commonly known that in Chinese dialects, an intonation tone cannot accomplish its own pitch target because a lexical tone takes precedence in phonetic realization. For example, in Mandarin, intonation can only affect the pitch range of phrases (Shen 1994; Shi 2013, among others). However, in Shanghai Chinese, pitch values of toneless syllables may be determined solely by a boundary tone rather than a lexical tone, indicating that, as with other languages, boundary tones of Chinese dialects may have clear pitch targets although they can only be accomplished in a limited environment. In this regard, we may be able to compare intonation tones of Chinese dialects with those of other languages in the framework of intonation phonology.

## Acknowledgements

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## Abbreviations

| | | | |
|---|---|---|---|
| α | accentual phrase | L | low tone |
| μ | mora | LOC | locative |
| σ | syllable | M | mid tone |
| ω | phonological word | T | tone |
| $_{\omega}]$ | right edge of a phonological word | $T_{\alpha}$ | boundary tone assigned by an accentual phrase |
| ACH | achievement | $T_{\omega}$ | boundary tone assigned by a phonological word |
| DL | default low tone | TBU | tone bearing unit |
| H | high tone | | |

## Appendix. Mean LZ-scores of the first and second syllables in di- to tetrasyllabic words

| | | T1 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | 1.22 | 1.28 | 1.35 | 1.41 | 1.46 | 1.50 | 1.53 | 1.51 | 1.42 |
| | SD | 0.40 | 0.35 | 0.31 | 0.30 | 0.31 | 0.34 | 0.37 | 0.40 | 0.42 |
| Trisyllables | Mean | 1.24 | 1.31 | 1.39 | 1.45 | 1.50 | 1.54 | 1.58 | 1.58 | 1.54 |
| | SD | 0.43 | 0.36 | 0.32 | 0.30 | 0.30 | 0.31 | 0.33 | 0.34 | 0.34 |
| Tetrasyllables | Mean | 1.21 | 1.27 | 1.34 | 1.40 | 1.45 | 1.49 | 1.51 | 1.51 | 1.49 |
| | SD | 0.49 | 0.44 | 0.39 | 0.35 | 0.34 | 0.33 | 0.34 | 0.34 | 0.34 |

| | | T1 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Second syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | 0.76 | 0.51 | 0.30 | 0.13 | −0.01 | −0.13 | −0.22 | −0.31 | −0.41 |
| | SD | 0.46 | 0.52 | 0.56 | 0.59 | 0.63 | 0.65 | 0.65 | 0.61 | 0.58 |
| Trisyllables | Mean | 1.25 | 1.09 | 0.92 | 0.74 | 0.56 | 0.38 | 0.20 | 0.02 | −0.18 |
| | SD | 0.37 | 0.37 | 0.38 | 0.39 | 0.39 | 0.38 | 0.37 | 0.35 | 0.33 |
| Tetrasyllables | Mean | 1.36 | 1.27 | 1.17 | 1.05 | 0.92 | 0.76 | 0.58 | 0.36 | 0.12 |
| | SD | 0.34 | 0.34 | 0.36 | 0.37 | 0.37 | 0.37 | 0.38 | 0.38 | 0.36 |

| | | T2 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | 0.30 | 0.23 | 0.14 | 0.06 | −0.02 | −0.08 | −0.10 | −0.07 | 0.03 |
| | SD | 0.27 | 0.29 | 0.29 | 0.30 | 0.30 | 0.30 | 0.31 | 0.30 | 0.31 |
| Trisyllables | Mean | 0.40 | 0.32 | 0.24 | 0.16 | 0.09 | 0.05 | 0.05 | 0.10 | 0.21 |
| | SD | 0.26 | 0.28 | 0.28 | 0.29 | 0.29 | 0.29 | 0.30 | 0.29 | 0.29 |
| Tetrasyllables | Mean | 0.44 | 0.36 | 0.28 | 0.20 | 0.13 | 0.08 | 0.08 | 0.12 | 0.23 |
| | SD | 0.30 | 0.30 | 0.29 | 0.29 | 0.30 | 0.30 | 0.30 | 0.29 | 0.28 |

| | | T2 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Second syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | 0.56 | 0.68 | 0.75 | 0.80 | 0.84 | 0.86 | 0.87 | 0.88 | 0.89 |
| | SD | 0.30 | 0.32 | 0.34 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 |
| Trisyllables | Mean | 0.73 | 0.85 | 0.93 | 0.99 | 1.04 | 1.08 | 1.11 | 1.13 | 1.12 |
| | SD | 0.25 | 0.26 | 0.26 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Tetrasyllables | Mean | 0.75 | 0.87 | 0.95 | 1.01 | 1.05 | 1.07 | 1.06 | 1.02 | 0.92 |
| | SD | 0.31 | 0.31 | 0.32 | 0.33 | 0.33 | 0.33 | 0.34 | 0.35 | 0.36 |

| | | T3 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | −0.23 | −0.43 | −0.71 | −1.04 | −1.36 | −1.60 | −1.73 | −1.71 | −1.45 |
| | SD | 0.48 | 0.48 | 0.44 | 0.38 | 0.31 | 0.26 | 0.24 | 0.25 | 0.28 |
| Trisyllables | Mean | −0.18 | −0.36 | −0.63 | −0.95 | −1.24 | −1.46 | −1.55 | −1.53 | −1.28 |
| | SD | 0.44 | 0.44 | 0.42 | 0.37 | 0.32 | 0.29 | 0.28 | 0.31 | 0.30 |
| Tetrasyllables | Mean | −0.15 | −0.32 | −0.56 | −0.85 | −1.14 | −1.37 | −1.49 | −1.49 | −1.24 |
| | SD | 0.42 | 0.42 | 0.38 | 0.32 | 0.27 | 0.24 | 0.23 | 0.25 | 0.26 |

| | | T3 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Second syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | −0.20 | 0.04 | 0.19 | 0.30 | 0.39 | 0.45 | 0.49 | 0.53 | 0.56 |
| | SD | 0.23 | 0.26 | 0.28 | 0.30 | 0.31 | 0.32 | 0.32 | 0.33 | 0.33 |
| Trisyllables | Mean | −0.13 | 0.09 | 0.25 | 0.37 | 0.47 | 0.56 | 0.64 | 0.71 | 0.76 |
| | SD | 0.25 | 0.28 | 0.29 | 0.30 | 0.31 | 0.32 | 0.33 | 0.33 | 0.33 |
| Tetrasyllables | Mean | −0.08 | 0.15 | 0.32 | 0.45 | 0.56 | 0.64 | 0.70 | 0.71 | 0.68 |
| | SD | 0.28 | 0.31 | 0.33 | 0.34 | 0.34 | 0.35 | 0.36 | 0.37 | 0.37 |

| | | T4 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | 0.23 | 0.20 | 0.18 | 0.16 | 0.16 | 0.15 | 0.16 | 0.17 | 0.21 |
| | SD | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 | 0.36 | 0.36 | 0.36 | 0.36 |
| Trisyllables | Mean | 0.38 | 0.36 | 0.35 | 0.34 | 0.34 | 0.34 | 0.35 | 0.38 | 0.41 |
| | SD | 0.32 | 0.32 | 0.33 | 0.33 | 0.32 | 0.32 | 0.33 | 0.32 | 0.32 |
| Tetrasyllables | Mean | 0.46 | 0.43 | 0.41 | 0.41 | 0.40 | 0.40 | 0.40 | 0.43 | 0.47 |
| | SD | 0.35 | 0.36 | 0.35 | 0.35 | 0.34 | 0.34 | 0.34 | 0.34 | 0.33 |

| | | T4 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Second syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | 0.51 | 0.59 | 0.66 | 0.71 | 0.75 | 0.78 | 0.80 | 0.82 | 0.84 |
| | SD | 0.39 | 0.40 | 0.41 | 0.42 | 0.43 | 0.44 | 0.44 | 0.44 | 0.44 |
| Trisyllables | Mean | 0.70 | 0.79 | 0.87 | 0.93 | 0.99 | 1.04 | 1.08 | 1.11 | 1.11 |
| | SD | 0.29 | 0.29 | 0.30 | 0.32 | 0.34 | 0.35 | 0.38 | 0.39 | 0.40 |
| Tetrasyllables | Mean | 0.75 | 0.84 | 0.91 | 0.95 | 0.99 | 1.01 | 1.01 | 0.97 | 0.87 |
| | SD | 0.33 | 0.34 | 0.34 | 0.35 | 0.36 | 0.37 | 0.38 | 0.40 | 0.41 |

| | | T5 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | −0.49 | −0.64 | −0.78 | −0.90 | −1.00 | −1.10 | −1.22 | −1.30 | −1.39 |
| | SD | 0.57 | 0.49 | 0.45 | 0.43 | 0.40 | 0.36 | 0.31 | 0.29 | 0.28 |
| Trisyllables | Mean | −0.36 | −0.49 | −0.62 | −0.73 | −0.85 | −0.97 | −1.09 | −1.18 | −1.27 |
| | SD | 0.44 | 0.40 | 0.38 | 0.37 | 0.34 | 0.31 | 0.28 | 0.28 | 0.30 |
| Tetrasyllables | Mean | −0.28 | −0.42 | −0.55 | −0.69 | −0.82 | −0.94 | −1.06 | −1.17 | −1.25 |
| | SD | 0.50 | 0.47 | 0.44 | 0.42 | 0.41 | 0.39 | 0.33 | 0.31 | 0.31 |

| | | T5 sandhi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Second syllable | | | | | | | | |
| | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% |
| Disyllables | Mean | −0.87 | −0.86 | −0.81 | −0.71 | −0.57 | −0.39 | −0.24 | −0.08 | 0.03 |
| | SD | 0.38 | 0.39 | 0.40 | 0.40 | 0.40 | 0.39 | 0.38 | 0.38 | 0.37 |
| Trisyllables | Mean | −1.11 | −1.20 | −1.25 | −1.30 | −1.32 | −1.35 | −1.37 | −1.38 | −1.39 |
| | SD | 0.32 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.33 | 0.34 | 0.34 |
| Tetrasyllables | Mean | −0.45 | −0.40 | −0.33 | −0.24 | −0.12 | 0.02 | 0.16 | 0.29 | 0.35 |
| | SD | 0.45 | 0.45 | 0.45 | 0.44 | 0.43 | 0.43 | 0.44 | 0.44 | 0.46 |

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