PHONETIC EVIDENCE FOR IAMBIC/TROCHAIC LAW EFFECTS IN CHAOZHOU

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ABSTRACT

The Iambic/Trochaic Law has been a long standing hypothesis on linguistic rhythm. However, it has yet to be tested with languages that are rich in tone. Based on predictions of the Iambic/Trochaic Law, this paper examines phonetic evidence in terms of duration and intensity in Chaozhou (Teochew, Southern Min), a six-tone language with bidirectional sandhi spoken in the Chaoshan region of China, Hong Kong, and Southeast Asia. Data elicited from two native speakers reading seventy-two disyllabic units exhausting the tonal combinations based on the two sandhi types (i.e. left and right dominant tone sandhi) was submitted to LMER models with R to test whether there is an interaction between rhythmic types (i.e. positions of prominence within a disyllabic domain) and tone sandhi types. Results showed the expected interaction, and significant duration and intensity contrasts for the respective sandhi type.

Keywords: Iambic/Trochaic Law, linguistic rhythm, bidirectional tone sandhi, tone and stress, Chaozhou

1. INTRODUCTION

As an extralinguistic basis for prosodic foot typology [e.g. 1-3], the Iambic/Trochaic Law [4, 5] states that elements contrasting in intensity naturally form groupings with initial prominence (trochees), whereas elements contrasting in duration naturally form groupings with final prominence (iambs). While the Iambic/Trochaic Law has been proposed as independent evidence for metrical foot since 1980s by Hayes based on relevant support from psychology since over a century ago, its applicability to tone languages has yet to be thoroughly discussed. [6]'s study on Betaza Zapotec (Oxaca, Mexico), a four-tone language whose tone and stress do not interact, has offered a succinct review of studies on rhythmic grouping, pointing out that earlier studies just tested native speakers of a few languages, among which speech-like stimuli were only used for western European languages [7-9]. They called for testing of more non-European languages and phonetic baseline measures of intensity from production studies. Beyond European languages and Zapotec, tone languages spoken in Asia typically adopt pitch in form of tone sandhi as the most salient cue to indicate phonemic and prosodic contrast. We know little about how prominence in terms of intensity and duration as stated in the Iambic/Trochaic Law is indicated and interacts with pitch in terms of tone sandhi.

In an attempt to find rhythm in tone languages based on the Iambic/Trochaic Law, this paper tests the Law with phonetic evidence in terms of duration and intensity [10-13]. Duration and intensity cues are expected to be present on top of tone sandhi to indicate rhythm. First hand data of Chaozhou, one of the Teochew dialects (Southern Min, Chaoshan) [14-17], will be used to illustrate the discussion.

Audio-recordings from two native speakers of Chaozhou were recorded in a sound booth, processed with Praat [18], and submitted to Linear Mixed Effect Regression (LMER) Models with R [19] to generate estimates of duration (ms) and intensity (dB) for determining whether the durational and intensity contrasts within disyllabic units of both sandhi types are significant. Model comparisons were also made to check whether sandhi type interacts with syllable position. Based on the statistic comparisons of phonetic measurements, this paper evaluates the hypothesis and predictions based on the Iambic/Trochaic Law [4, 5].

2. BIDIRECTIONAL TONE SANDHI AND RHYTHMIC TYPES

2.1. Tone inventory and bidirectional sandhi

Table 1 depicts the six lexical tones for sonorant-final syllables in Chaozhou as tone letters [14], following previous treatments for Chaoyang [11-12, 20].

Table 1: Tones in Chaozhou [14].

Citation tone	Tone letter
33	M
53	HM
213	LM
55	H
35	MH
11	L

Each of the six tones undergoes sandhi to another tone depending on whether it is on the first or second syllable of a disyllabic unit, regardless of the tonal content of the trigger. Right dominant tone sandhi refers to tonal changes observed on the left syllable whereas left dominant tone sandhi on the right. For example, the disyllabic unit HM.MH surfaces as MH.MH for right dominant sandhi but HM.L for left dominant sandhi. As in Table 2, right dominant sandhi holds four different tones (H, M, L, and MH) in its sandhi position, and left dominant position holds only two (L and LM) in its sandhi position.

Table 2: Right and left dominant tone sandhi [14].

Tone letter	Right dominant tone sandhi	Left dominant tone sandhi
M	M	L
HM	MH	LM
LM	H	L
H	L	L
MH	L	L
L	L	L

With bidirectional tone sandhi [21] within one language, not only can we make within sandhi type comparison between the first and second syllables, but also across sandhi type comparison between the citation syllables in both sandhi types, between the sandhi syllables in both types, and between the sandhi syllables and their citation counterparts in the other type. This offers a six-way comparison in terms of duration and intensity to unveil the relative prominence of syllables in different positions within a disyllabic unit of both sandhi types.

Based on the assumption of the relationship between tonal stability and prosodic prominence [22], syllables with citation tones are considered to be more prominent than those with sandhi tones. Since right dominant tone sandhi changes the tone on the left, it is expected to pattern with the iambic rhythm. As the left dominant tone sandhi changes the tone on the right, it is expected to behave like trochees.

2.2. Hypothesis and predictions

Hypothesis: The Iambic/Trochaic Law [4, 5] holds for complex tone languages.

Prediction 1: Duration contrast is expected for right dominant tone sandhi whereas intensity is expected for left dominant tone sandhi.

Prediction 2: Sandhi syllables are less prominent than citation syllables in the same syllable position, in terms of duration and intensity.

Prediction 3: Citation syllables of different rhythmic types are more prominent in their corresponding phonetic cues, while sandhi syllables are less prominent.

3. METHODOLOGY

3.1. Subjects

Audio-recordings were obtained from two native speakers of Chaozhou in their 20s. They were both born and raised in the Chaozhou speaking area of the Chaoshan region, China.

3.2. Stimuli

The data was elicited with a wordlist of seventy-two disyllabic units, covering all possible tonal combinations for both sandhi types. For example, citation tone H was paired with each of the six citation tones, so as to obtain data of all six sandhi forms when in combination with another syllable, resulting in six combinations for each tone, and thirty-six combinations for all six tones. After repeating the same process for the two sandhi types, this provides seventy-two combinations. The wordlist was randomized, and produced five times by each speaker. This gives us a total of 1440 tokens of data (6 tones x 6 tones x 2 syllables x 2 sandhi types x 5 iterations x 2 speakers).

This study used real words to ensure expected sandhi effects. Onset (nil, sonorant, aspirated stop, non-aspirated stop), vowel height (high, mid, low), and coda (nil, nasal, stop) were treated as random factors in the LMER models in section 4. For morphosyntactic structures, there are compounds, noun phrases, verb phrases, adjectival phrases, and adverbial phrases.

3.3. Data collection and analysis

The data was recorded in a sound booth using an earset microphone, attaching to a portable digital recorder at a sampling frequency of 44100Hz, monitored by the experimenter with a headphone set. The subjects were presented with the randomised words on a laptop one at a time, and were asked to read the words in a natural way. Subjects were also asked to fill in a language background questionnaire after the recording session so as to provide information on the specific Teochew dialect that they speak and potential interference from other dialects or languages to the one under investigation.

Segmentation of the recordings, and extraction of syllable duration and maximal intensity were performed in Praat [18]. The duration and intensity measurements were compiled as a main data file to submit to LMER models in R [19]. lmerTest [23] was adopted in order to generate estimates for disyllabic units at both positions (i.e. the first and second syllables) of two sandhi types (i.e. right dominant and left dominant tone sandhi) for determining whether the durational and intensity contrasts of each estimate point are significantly different from each other in the expected direction under the Iambic-Trochaic Law [4, 5]. *P*-values were calculated with the Satterthwaite approximation, one of the most conservative methods of *p*-value calculation for LMER models having a small number of subjects [24].

4. RESULTS

The LMER model for both duration and intensity consists of fixed effects of sandhi type (left dominant and right dominant) and position of syllable (first, second). As random effects, there are intercepts for items, speakers, onset, vowel height, coda. Since sandhi type and position of syllable are important factors to our model, the model has also specified the by-speaker and by-item random slopes for the effect of position of syllable. It has also specified the by-speaker random slope for the effect of sandhi type.

Figures 1 and 2 display the plots of LMER estimates of duration and intensity respectively. Right dominant tone sandhi is in pink and left dominant tone sandhi is in blue. The estimates and *p*-values are listed in Tables 3 and 4 following their corresponding figures. For the convenience of description, I will refer to the first and second syllables of right dominant tone sandhi as R1 and R2; and those of left dominant tone sandhi as L1 and L2.

Figure 1: Plot of LMER estimates of duration (ms) for right (pink) and left dominant tone sandhi (blue).

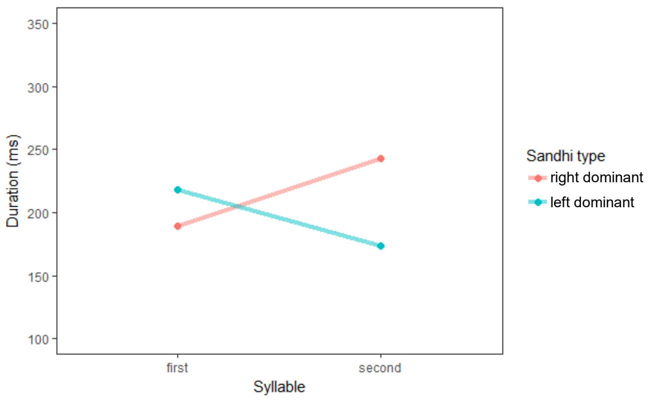

Table 3: LMER estimates for duration (ms).

	est. 1	est. 2	*p*	sig.
R1 vs. R2	189.255	242.877	< 2e-16	***
L1 vs. L2	218.43	173.614	< 2e-16	***
R1 vs. L1	189.255	218.43	3.92e-05	***
R2 vs. L2	242.877	173.614	<2e-16	***
R1 vs. L2	189.255	173.614	0.0248	*
L1 vs. R2	218.43	242.877	0.000447	***

For duration, LMER results show that the two sandhi types go different directions over the course of a disyllabic domain, in which the right dominant tone sandhi has a longer second syllable than its first syllable while the left dominant tone sandhi has a shorter second syllable than the first. The citation syllables R2 and L1 are significantly longer than the sandhi syllables R1 and L2, with L1 being significantly the longest and L2 being significantly the shortest.

Figure 2: Plot of LMER estimates of intensity (dB) for right (pink) and left dominant tone sandhi (blue).

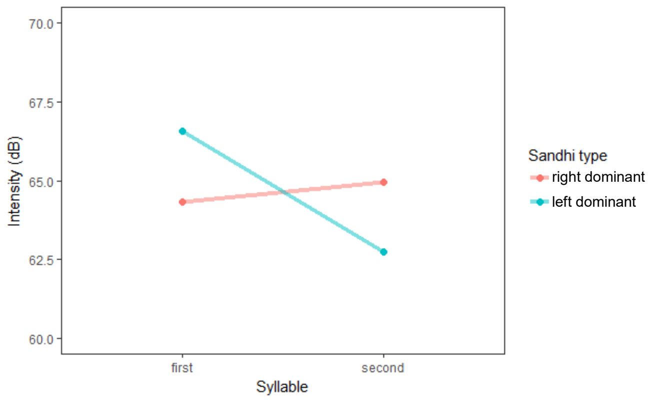

Table 4: LMER estimates for intensity (dB).

	est. 1	est. 2	*p*	sig.
R1 vs. R2	64.3391	64.9631	0.017408	*
L1 vs. L2	66.5522	62.7347	< 2e-16	***
R1 vs. L1	64.3391	66.5522	6.16e-06	***
R2 vs. L2	64.9631	62.7347	7.06e-06	***
R1 vs. L2	64.3391	62.7347	0.000928	***
L1 vs. R2	66.5522	64.9631	0.000815	***

For intensity, LMER results show that the citation syllables L1 and R2 are significantly louder than the sandhi syllables R1 and L2, with L1 being the loudest and L2 being the quietest, stretching for a bigger intensity contrast for the left dominant tone sandhi.

Overall, the citation syllables of both sandhi types are longer and louder than the sandhi syllables of both sandhi types. Between the citation syllables, syllables are longer or louder according to the prominence cue for each sandhi type as predicted. Moreover, for intensity, the sandhi syllable of left dominant tone sandhi L2 is also found to be the quietest among the four, maximizing intensity as a cue to signal initial prominence within a disyllabic domain.

Besides, likelihood ratio tests indicate that the interaction is significant between sandhi type and position of syllable for both duration ($\chi 2$ (1) = 43.58, *p* = 4.069e-11) and intensity ($\chi 2$ (1) = 18.599, *p* =

1.613e-05). The effect of sandhi type increases over the course of a disyllabic unit.

5. DISCUSSION

For Prediction 1, the hypothesis predicts duration and intensity asymmetries between the two sandhi types. For duration, syllables within a disyllabic unit contrast significantly for both left and right dominant tone sandhi. For intensity, syllables within a disyllabic unit also contrast significantly for both left and right dominant tone sandhi.

This indicates that the Chaozhou speakers rely fairly evenly for both duration and intensity to signal prominence, which is not predicted. The details of the relative prominence of syllables in different positions within disyllabic units of the two sandhi types in terms of duration and intensity will be examined via Prediction 2 and Prediction 3.

For Prediction 2, sandhi syllables are predicted to be less prominent than citation syllables in the same position of syllable, in terms of duration and/or intensity. When holding the position of syllable constant, the sandhi syllable of right dominant tone sandhi (R1) is expected to be shorter and quieter than the citation syllable of left dominant tone sandhi (L1). Similarly, the sandhi syllable of left dominant tone sandhi (L2) is expected to be quieter and shorter than the citation syllable of right dominant tone sandhi (R2).

From the LMER results, R1 is significantly shorter and quieter than L1 as predicted. Also as predicted, L2 is significantly shorter and quieter than R2. The results suggest that prosodic heads are more prominent than non-heads in a way that conforms with the Iambic/Trochaic Law.

For Prediction 3, citation syllables of different rhythmic types are predicted to be more prominent in their corresponding phonetic cues, while sandhi syllables are less prominent. When comparing the citation syllables of left and right dominant tone sandhi, that is L1 and R2, L1 is expected to be louder but shorter than R2. When comparing the sandhi syllables of left and right dominant tone sandhi, R1 is expected to be shorter but louder than L2.

Based on the LMER results, L1 is significantly louder but shorter than R2 as predicted. This indicates that the prosodic heads of the two sandhi types tend to be more prominent particularly in duration or intensity depending on whether the head is initial or final within a disyllabic unit, just as iambs and trochees.

Also, R1 is significantly louder than L2 as predicted. This suggests that the non-head of an initial prominent disyllabic unit tends to be quieter. However, R1 is longer than L2, which is not predicted.

Thus far, prominence based on duration and intensity contrasts largely matches that based on tonal behaviours. All comparisons except three do not match the hypothesis. They are the durational and intensity asymmetries in Prediction 1, and that the sandhi syllable of right dominant tone sandhi (R1) is expected to be shorter than the sandhi syllable of left dominant tone sandhi (L2).

6. CONCLUSIONS

This paper has presented a brief illustration of testing the Iambic/Trochaic Law [4, 5] on a complex tone language, Chaozhou, with phonetic measurements in terms of duration and intensity. LMER results have shown that prominence indicated by duration and intensity contrasts largely behaves the way as predicted by the Law. This suggests that tone sandhi can be metrically-motivated via duration and intensity, contributing to the rhythmic organization of tone languages altogether. It also provides an explanation for relevant segmental changes in tone languages under metrical influences. This paper has offered novel evidence for metrical prominence of tone languages based on the Iambic/Trochaic Law, adding complex tone languages spoken in Asia and production results to our understanding of rhythmic groupings in human speech. Future analysis can look into the morphosyntactic and semantic structure of the two sandhi types, and longer prosodic domains.

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