Abstract
This paper argues that the durational asymmetry predicted by the Iambic-Trochaic Law (Hayes 1985, 1995) for languages typically considered as stress languages is also found in complex tone languages such as the Chaoyang variety of Teochew (Southern Min, Hong Kong/Chaozhou). In Chaoyang, there are six phonemic tones, and tone sandhi can apply from both left and right. Given the bidirectional tone sandhi, duration and intensity measurements were obtained from ten disyllabic sandhi minimal pairs of two speakers to compare the relative prominence of different sandhi positions, citation positions, and sandhi-citation positions. Results show that a duration contrast holds for anterior type sandhi and an intensity contrast for posterior type sandhi, despite a tendency for higher intensity on the first syllable and longer duration on the second syllable across sandhi types. A metrical interpretation of prominence in complex tone languages is largely supported by the results, in addition to tonal prominence.

Keywords: tonal prominence, metrical prominence, tone and stress, bidirectional tone sandhi, Iambic-Trochaic Law, Chaoyang, Teochew

1 Introduction
One fundamental insight in the literature of tone studies is that tonal behaviour is diagnostic of metrical prominence. When two or more tones are in contact, the ones which stay intact are considered to be carrying accentual prominence and have the power to spread their influence to adjacent tones or even tones in a wider scope, whereas the others are in metrically recessive positions which tend to modify, neutralise, or even completely drop the tones (Chen 2000:294). Maddieson (1978:341) uses the term ‘stress-related tonal stability’ to refer to assimilatory processes driven by tones which are associated to stressed syllables.

Even though the above is generally assumed to be true, the possibility of stress interacting with tonal dominance motivates examining the role of phonetic correlates of stress other than pitch, notably duration and intensity. A clearer understanding of the role of duration and intensity in signalling prominence in tone languages can help us evaluate the legitimacy of the adoption of stress, and hence feet, as an organizing constituent for tonal distribution. If the duration and intensity measurements match the behaviour of pitch (from tone sandhi) in terms of prominence, we would like to see how closely they observe the predictions of the Iambic-Trochaic Law, which forms the core of Metrical Stress Theory (Hayes 1995). Otherwise, we may conclude that pitch (or related sandhi phenomena) signals prominence in tonal languages independent of other stress correlates.

In this paper, I seek phonetic evidence for a metrical representation of tone in complex tone languages, particularly in terms of duration and intensity, which are especially relevant in defining the asymmetric foot inventory for iambs and trochees. The metrical view hypothesizes that duration and intensity cues are present on top of tone sandhi to determine whether a language has iambic or trochaic-
like rhythmic structure. I present first-hand phonetic data from Chaoyang (Southern Min, Hong Kong/Chaozhou) to explore whether duration and intensity cues match bidirectional tone sandhi in signalling relative prominence of different positions within disyllabic units.

This paper gives a brief overview of the interaction between tone and stress in Chaoyang from a metrical perspective. In Section 2, I introduce the tone system of Chaoyang and the bidirectional tone sandhi. Section 3 lays out the basic expectation correlating sandhi location with duration/intensity. Section 4 details the hypotheses, predictions and results to see whether the phonetic measurements align with the tone sandhi behaviours. Section 5 discusses the results regarding the Iambic-Trochaic Law (Hayes 1985, 1995). Section 6 concludes the paper.

2 Tone system of Teochew (Chaoyang dialect)

There are six lexical tones in the Chaoyang variety of Teochew (Zhang 1979, 1981, 1982, 2016:18-19), as listed in the first column of Table 1. The six lexical tones shown here occur in sonorant-final syllables. There are also two checked tones, occurring in syllables that end with an unreleased final stop, which are shorter versions of the high tone and low tone shown in Table 1. The second column is a tone-letter representation of the tone numbers adopted from Yip (2001). Among the six citation tones, three of them are level tones: H(igh), M(id) and L(ow), and three of them are contour tones: HM, ML and LM.

Table 1: Tones in Chaoyang

<table>
<thead>
<tr>
<th>Citation tone (Zhang 2016)</th>
<th>Yip (2001)</th>
<th>Anterior (TxTy)</th>
<th>Posterior (TxTy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>53</td>
<td>HM</td>
<td>ML</td>
<td>ML</td>
</tr>
<tr>
<td>31</td>
<td>ML</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>55</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>313</td>
<td>LM</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>11</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
</tbody>
</table>

Given any disyllabic unit, either the tone on the first or second syllable undergoes sandhi to another tone, regardless of the tonal content of the trigger. Italicised $Tx$ and $Ty$ in the headings of Table 1 indicate the sandhi tone in anterior type and posterior type sandhi respectively.2

Anterior type tone sandhi changes the tone on the first syllable. For example, ML changes to H when it is on the first syllable of a disyllabic unit, regardless of the tone of the second syllable. Posterior type tone sandhi, on the other hand, refers to the type of sandhi happening on the second syllable with the tone on the first syllable remaining unchanged. For example, when ML is on the second syllable of a disyllabic unit, it undergoes sandhi as L, no matter which tone docks on the first syllable.

Note also in Table 1 that the variety of tone in the posterior position is more limited than the anterior position since it only holds two different tones (L and ML), rather than four as in the anterior position (H, M, L and ML) or even six as in the citation tone inventory (H, M, L, HM, ML and LM). I will come back to the discussion of this in Section 5. The bidirectional sandhi phenomenon makes it possible to examine the relative prominence of syllables in different positions in a disyllabic unit across sandhi types, and how well (or not) the relative prominence matches the metrical view.

With this background, we are in position to understand the hypotheses and predictions for different comparisons based on the sandhi types, the methods for testing those predictions, and the data itself, acoustic measurements and statistical tests of ten minimal pairs.

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2 This kind of bidirectional tone sandhi is widely reported in Chinese languages, especially in the Wu dialects, to a lesser extent in Southern Min. Chen’s (2000) book on tone sandhi patterns across Chinese dialects is an invaluable reference. This paper does not deal with the morphosyntactic side of the tone sandhi phenomenon; therefore, it cannot speak for its influence on arriving at such tonal outputs given the same tonal inputs. Instead, this paper focuses on exploring a metrical alternative to diagnose prominence by examining relevant phonetic measurements in terms of duration and intensity.
3 Hypotheses and predictions

This section lays out the basic expectation correlating sandhi location with duration/intensity. I will fine-tune the basics for the specific tests being discussed in Section 4.

According to the IT-Law (Hayes 1985, 1995), iambic and trochaic rhythmic types tend to adopt different acoustic cues to signal prominence (or stress): Iambs use length while trochees use intensity. This predicts that the second syllable is longer than the first syllable in iambic units, whereas the first syllable is louder than the second syllable in trochaic units. In the case of tone sandhi, based on the correlation between tonal stability and prosodic prominence, syllables with citation tones are considered to be more prominent than those with sandhi tones. Since anterior sandhi changes the tone on the left, it is expected to pattern with the iambic rhythm. As the posterior sandhi changes the tone on the right, it is expected to behave like trochees.

- Hypothesis 1 tests whether anterior sandhi units adopt duration and posterior sandhi units adopt intensity to signal prominence.
- Hypothesis 2 tests whether syllables carrying sandhi tones are less prominent than syllables carrying citation tones.
- Hypothesis 3 tests whether there are differences in terms of prominence between the sandhi syllables in both sandhi types depending on the rhythmic type that they pattern with.

4 Phonetic evidence for a metrical representation of tone

Ten disyllabic sandhi minimal pairs are selected for both sandhi types. They are identical in their segmental and tonal content before tone sandhi but differ in their tonal make-up depending on the type of sandhi taking place.

Two native speakers of Chaoyang were invited to make audio-recordings in a quiet room, reading 72 disyllabic units, among which there were ten sandhi minimal pairs (or 20 units). The disyllabic units were randomised and presented on paper for the speakers to read in a natural and casual way. Segmentation of the recordings, and extraction of syllable duration and maximal intensity were performed in Praat (Boersma and Weenink 2017). The duration and intensity data were then submitted to linear mixed-effects regression (LMER) models in R (R Core Team 2017) in order to determine whether the duration and intensity values in different sandhi positions, citation positions, and sandhi-citation positions are significantly different from each other. Each of the subsections below addresses one of the hypotheses.

4.1 Within-unit duration contrast for anterior sandhi and intensity contrast for posterior sandhi

The first comparison is the relative prominence in terms of duration within each unit for anterior type sandhi, and that of intensity within each unit for posterior type sandhi. The IT-Law predicts that the final syllable is longer than the first syllable in a trochee and the first syllable is louder than the final syllable in an iamb. If the predictions are correct, the second syllable [y] will be relatively longer than the first syllable [x] for anterior sandhi [TxTy], and the first syllable [x] will be relatively louder than the second syllable [y] for posterior sandhi [TxTy].

Figure 1 displays the duration and intensity measurements of the ten minimal pairs for both sandhi types. On the Minimal pairs axis, ‘a1-a10’ refer to the disyllabic units of anterior type sandhi which are numbered from 1 to 10 (see appendix for labelled tokens). The corresponding units of posterior type sandhi are ‘p1-p10’. For example, disyllabic unit 1 [sua tin] refers to ‘the top of a hill’ when sandhi occurs on [sua] (anterior), but ‘(on) a hill’ when sandhi happens on [tin] (posterior). ‘50%’ on the axis with ‘σ1’ and ‘σ2’ marks the midpoint of time (Figure 1a) and the midpoint of the total maximum intensity (Figure 1b) of the disyllabic units.
As seen in Figure 1a, the second syllable overall tends to be proportionally longer than the first. Importantly, the second syllable tends to be proportionally longer in anterior type sandhi than posterior type sandhi (eight out of ten pairs). Also, when we take the data of both speakers into the LMER model which contained a fixed effect of syllable number (syllable 1, syllable 2) and random effects of word and speaker, results show that the second syllable is significantly longer than the first syllable for anterior types sandhi ($p = 0.00123$).

b: Intensity
In Figure 1b, the first syllable tends to be proportionally louder in posterior type sandhi than in anterior type sandhi (eight out of ten pairs). And when we take the data of both speakers into the LMER model, results show that the first syllable is significantly louder than the second syllable for posterior sandhi ($p = 2.11 \times 10^{-6}$).

4.2 Sandhi syllables are quieter and shorter than their citation counterparts

With the minimal pairs, we can compare the sandhi syllables with their citation counterparts in the same position of a disyllabic unit. For instance, given a minimal pair [TxTy] and [TxTy], we can compare [Tx][Tx] and [Ty][Ty].

As sandhi syllables are considered to be less prominent than their citation counterparts based on lower tonal stability, they are expected to have shorter duration and lower intensity than the citation syllables. From the metrical perspective, it is also reasonable for syllables in the non-head position of a rhythmic unit to surface with shorter duration and lower intensity than those in the head position.

**Figure 2:** Intensity and duration of second syllables in posterior sandhi forms vs. their citation tone counterparts as found in anterior sandhi forms for speaker 2

a: Intensity

![Intensity Chart]

b: Duration

![Duration Chart]
For posterior type sandhi [TxTy], the sandhi syllable [y] is expected to be quieter and shorter than its citation counterpart in an anterior sandhi form [TxTy]. That is, the second syllable of the posterior type [y] is expected to be quieter and shorter than the second syllable of the anterior type [y].

In Figure 2, the ten minimal pairs are shown from left to right. For each minimal pair, we compare the proportion of intensity and duration taken by the sandhi syllable in each posterior unit (p) against that taken by the citation syllable in each anterior unit (a).

The sandhi syllables are quieter (eight out of ten pairs in Figure 2a) and shorter (eight out of ten pairs in Figure 2b) than the citation syllables in general. In the LMER model which contained a fixed effect of sandhi type (anterior, posterior) and random effects of word and speaker, estimates of the posterior sandhi are lower than those of anterior sandhi for both intensity (52.751 < 54.762, \( p = 0.225 \)) and duration (49.0347 < 49.5028, \( p = 0.174 \)), even though the differences between the two sandhi types are not significant.

### 4.3 Posterior sandhi syllables are quieter but longer than anterior sandhi syllables

Another cross-sandhi type comparison is comparing sandhi syllables in two sandhi types. When both syllables are prosodically weak in their respective sandhi type, we would like to know which position is weaker or stronger in terms of duration and intensity.

In terms of tonal stability, as the posterior type returns a narrower range of tones (two tones) than the anterior type (four tones) after sandhi, we expect the final position of the posterior type to be less prominent than the initial position of the anterior type, which will be reflected in the intensity and duration measurements, with no predictions on whether intensity and duration cues would be adopted differently for the two types of sandhi.

The metrical view makes hypotheses based on the IT-Law observed from how intensity contrast is associated with initial prominence (trochees) and duration contrast is associated with final prominence (iambs). Given that iambs prefer uneven feet, the non-head may suffer in terms of duration to meet the rhythmic ideal, but not in terms of intensity. Also, given trochees’ tendency to adopt intensity to signal prominence, the non-head is weaker in terms of intensity, but not necessarily shorter. When all else is equal, this predicts that the final syllable of trochees is quieter but longer than the initial syllable of iambs. In other words, it predicts lower intensity for the second syllable of the posterior type [y] than for the first syllable of the anterior type [x] in [TxTy] (anterior) and [TxTy] (posterior). Duration is reversed, with greater duration for [x] than for [y].

**Figure 3: Intensity and duration of the sandhi syllables in both sandhi types for speaker 2**

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3 For the interest of space and presentation, we will see results of the comparison between syllables [x] and [y] in Section 5.
Figure 3a shows that sandhi syllables in posterior type tend to be quieter than those in anterior type by eight out of ten pairs. In spite of being quieter than the anterior sandhi syllables, Figure 3b shows that sandhi syllables in posterior type tend to be longer than those in anterior type by seven out of ten pairs, as predicted by the IT-Law. With the LMER model which contained a fixed effect of sandhi type (anterior, posterior) and random effects of word and speaker, results show that the differences in both intensity (\(p = 0.000117\)) and duration (\(p = 0.00483\)) are significant.

In sum, results presented in Section 4 largely agree with the durational asymmetry predicted by the metrical account, indicating that tonal prominence can be signalled by the typical phonetic correlates of stress along with pitch in terms of tone. This offers phonetic support for a metrical account of prominence in tone languages.

5 Discussion

In the previous section, I have presented results from comparing the relative prominence of syllables i) within sandhi types, ii) between sandhi syllables and their citation counterparts for the posterior type sandhi, and iii) between sandhi syllables of the two sandhi types. To complete a schematic representation of the relative prominence of different positions of a disyllabic unit, we still need comparisons between sandhi syllables and their citation counterparts for the anterior type sandhi, and between citation syllables in the two sandhi types.

Further measurements and LMER analyses show that results of the sandhi syllables and their citation counterparts for the anterior type sandhi are similar to those of the comparison for the posterior type presented in Section 4.2, in that the sandhi syllables tend to be quieter (50.4972 < 50.9653, \(p = 0.174\)) and shorter (45.238 < 47.249, \(p = 0.225\)) than the citation syllables, but the LMER results show the difference is not significant. Results of the comparison between citation syllables of the two sandhi types are similar to those for sandhi syllables of the two sandhi types in Section 4.3, where the citation syllable of the anterior type is quieter (49.5028 < 50.9654, \(p = 0.000117\)) but longer (54.762 > 47.248, \(p = 0.00483\)) than that of the posterior type. Incorporating these additional measurements and analyses, Table 2 displays a schematic representation of the relative prominence of different positions within a disyllabic unit in terms of duration (_) and intensity (x).

Table 2 shows that duration contrast holds for anterior type sandhi and intensity contrast for posterior type sandhi, despite a general tendency for higher intensity on the first syllable and longer duration on the second syllable across sandhi types. The phonetic results neatly reflect the durational asymmetry predicted by the IT-Law, where the anterior type sandhi and posterior type sandhi pattern with iambic rhythm and trochaic rhythm respectively. The duration and intensity measurements therefore support a metrical interpretation of prominence for complex tone languages like Chaoyang, in addition to the pitch-related cue in terms of tone sandhi.
Table 2: Relative prominence within a disyllabic unit

<table>
<thead>
<tr>
<th></th>
<th>(\sigma_1)</th>
<th>(\sigma_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior type sandhi</td>
<td>_ xxx</td>
<td>_ _ _ _ xx</td>
</tr>
<tr>
<td>Posterior type sandhi</td>
<td>_ _ xxxx</td>
<td>_ _ _ x</td>
</tr>
</tbody>
</table>

For pitch, as shown in Table 1, the tone values of the posterior sandhi tones are much lower than their citation counterparts, indicating that the pitch on less prominent syllables is less marked. As for why the initial sandhi position in anterior type can accommodate more (and higher) tones than the final sandhi position in posterior type, positional faithfulness (Beckman 1998; Alderete 1999; Lombardi 1999) prefers the more prominent position of a prosodic unit to have more contrast. Even though both initial position of the anterior type and final position of the posterior type are the weaker position of their respective sandhi type in Chaoyang, the tone inventory supports the assumption that the initial position of the anterior type is more prominent between the two, and thus preserves tone contrast to a greater extent. Another possible explanation is foot-initial fortition, in that the initial position of a foot is strengthened, which agrees with the general cross-linguistic pattern of strengthening associated with the initial position of prosodic domains (Gordon 2011, citing Pierrehumbert and Talkin 1992; Byrd 1994; Keating et al. 2003, etc.)

6 Summary

This paper represents an exploration of a metrical approach to understanding how prominence is signalled in complex tone languages, motivated by the IT-Law via phonetic evidence from duration and intensity measurements. It has carefully gone through the two types of tone sandhi in the Chaoyang variety of Teochew, anterior type and posterior type, which correspond to iambic and trochaic rhythmic patterns respectively. A metrical interpretation of tone sandhi helps to understand the rhythm of complex tone languages, and to build a unified rhythmic account for languages as a whole.

Not only does Chaoyang represent a different case from the mainstream studies of linguistic rhythm on stress or simple tone languages with the use of metrical theory, its whole-tone replacement sandhi also differs from the ones previously reported for Chinese languages such as assimilation, dissimilation and spreading, enriching the pool of metrical phenomena.

With most descriptions of tone systems concentrating on the relatively well-recognised tone sandhi type in a language, the seemingly residual posterior sandhi type in Southern Min is often under-described and under-recognised for its importance in understanding the metrical structure of languages. Future studies may look into longer prosodic domains for more complex interactions between the two rhythmic types.

References


### Appendix

Ten sandhi minimal pairs

<table>
<thead>
<tr>
<th>Anterior</th>
<th>Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 [sua tıŋ]</td>
<td>M.HM ‘hill top’</td>
</tr>
<tr>
<td>2 [tsɛ tıŋ]</td>
<td>M.HM ‘old partner’</td>
</tr>
<tr>
<td>3 [lau hue]</td>
<td>L.HM ‘inside’</td>
</tr>
<tr>
<td>4 [tʰau tıŋ]</td>
<td>H.HM ‘house top’</td>
</tr>
<tr>
<td>5 [miŋ tıŋ]</td>
<td>M.HM ‘surface of sth’</td>
</tr>
<tr>
<td>6 [tsi kai]</td>
<td>ML.H ‘the nearer one’</td>
</tr>
<tr>
<td>7 [zik tʰau]</td>
<td>L.H ‘sun’</td>
</tr>
<tr>
<td>8 [soi kai]</td>
<td>H.H ‘small thing(s)’</td>
</tr>
<tr>
<td>9 [tua tʰau]</td>
<td>M.H ‘big head’</td>
</tr>
</tbody>
</table>
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