# /a-a/ AND /i-i/ AT THREE JUNCTURES IN CANTONESE

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## ABSTRACT

The absence of overt markings of prosodic units between Syllable and Intonational Phrase in Cantonese that are comparable to Tone Sandhi Group in Wu Chinese or Accentual Phrase in Korean presents a challenge for proposals on universal prosodic hierarchy. This study is part of a larger effort to address this issue. Here we report acoustic data on /a-a/ and /i-i/ sequences in V#CV, VC#V, and VC#CV at three levels of morpho-syntactically defined junctures: within-word (corresponds to Syllable boundary), across-words, and across-phrases (corresponds to Intonational Phrase boundary). Both /a/ and /i/ were more peripheral at postboundary than at preboundary positions. Both vowels were also more peripheral at higher boundaries than at lower boundaries, in a way that is consistent with contrast enhancement. F2 of /a/ differed significantly across boundary conditions, thus offering evidence in favour of prosodic constituents between Syllable and Intonational Phrase in Cantonese.

**Keywords**: Cantonese; prosodic strengthening; vowel; prosodic structure; phonetic-prosody interface

## 1. INTRODUCTION

Cantonese presents an interesting challenge to theories on universal prosodic hierarchy. A commonly posited universal prosodic hierarchy typically consists of Intonational Phrase, Phonological Phrase, Prosodic Word, Foot and Syllable [24] (see e.g. [2] for alternatives); even in more parsimonious structures, such as in [15, 24], there are three levels of prosodic constituents: Intonation Phrase (matches syntactic clause), Phonological Phrase (matches syntactic phrase), and Prosodic Word (matches syntactic word). Cantonese, however, does not have overt markings of prosodic constituents (e.g. the presence of a tone sandhi group[25]) between Syllable and Intonational Phrase [29]. Yet no study before has examined more covert markings of prosodic constituents in Cantonese.

The current study is part of a larger project that systematically examines phonetic cues in three levels of morpho-syntactically defined junctures (the term juncture is adopted to avoid a priori assumptions of the presence of prosodic boundaries): within-word (WW), across-words (AW), and across-phrases (AP), in order to explore the proposal that possible prosodic constituents between Syllable and Intonational Phrase may be phonetically distinguishable. The specific phonetic correlate this study reports on is vowel formants at these boundaries.

Discussions in literature on vowels at edges of prosodic constituents center around *strengthening*, which is defined as “temporal and/or spatial expansion of articulation” [10, 11, 14]. Further, s*trengthening* (of vowels) is oftentimes predominantly associated with the domain-initial (postboundary) position, while the domain-final (preboundary) position is described as characterized by *lengthening* (without much discussion on spatial displacement of articulators), e.g. [9]. However, as the definition of strengthening suggests, lengthening may well be a corollary of strengthening, and consequently the nature of events at pre- and post-boundary positions may be the same (see [7, 8] for discussions on alternative/ complementary explanations on final lengthening).

It is in fact assumed in the task-dynamics model under the framework of Articulatory Phonology, that “prosodic gesture” or “π gesture” at prosodic boundaries, which would modulate the temporal realization of articulatory gestures before and after the boundary, making them temporally longer and (consequently) spatially larger and farther apart, have the same effects on the pre- and post-boundary positions, despite possible differences in degree or in kinematic characteristics due to “coordination of the π gesture with constriction gestures”[6].

There is also evidence that spatial expansion of articulation does occur at preboundary positions. For instance, [14] reported that preboundary /o/ has more extreme articulation (less linguopalatal contact) at higher boundaries than at lower boundaries. [10] reported more extreme articulation for preboundary vowels at higher boundaries than at lower boundaries (significant raising in tongue height for /i/, significant backing and lowering for /ɑ/). [10] also reported acoustic patterns of preboundary vowels: there were significant effects of boundary for both /ɑ/ and /i/ in F1 and F2. It is interesting to note that in [10] the effects of boundary on preboundary /i/ was more robust acoustically (main effect in F2) than articulatorily (no main effect in tongue fronting). Moreover, [10] also reported data on postboundary vowels, which did not show patterns of strengthening as robust and consistent as preboundary vowels.

Since a large portion of speech perception in daily life is performed with acoustic information only (i.e. no visual input of articulatory movements), e.g. phone conversations, radio and podcasts, voice-over in dramas, understanding of boundary effects in the acoustic dimension is indispensable to a full understanding of prosodic grammar. Yet other than [10], very few studies examined the acoustic consequences of articulatory strengthening, specifically, the spatial displacement of articulators reflected on vowel formant values (studies that measured durational properties such as [14], and studies that reported glottalization of postboundary vowels, such as [16], are not of concern here). Even fewer studies directly compared effects of boundary on pre- vs. post-boundary positions. The current study explores these two aspects in our examination of Cantonese /a/ and /i/ at three boundaries (AP, AW, WW), with the overarching goal of probing the possible existence of phonetically distinct boundary level(s) between AP and WW in Cantonese.

## 2. METHOD

Production of /a-a/ and /i-i/ sequences in (C)V#CV(C), (C)VC#V(C), and (C)VC#CV(C) templates (all intervocalic consonants were labial, /m, p, $p^h$/, to minimize influence on vowel-to-vowel coarticulation) from six native speakers of Hong Kong Cantonese (three females, three males; aged 21-25), at three boundary levels (WW, AW, AP), with six instances of each specification, were examined. Altogether 2864 tokens of vowels were analyzed. All target syllables were presented in natural sentences. Table 1 below demonstrates one set of examples with /$ts^hi^{21}$#$pit^2$/ as the target syllable sequence.

**Table 1**: Sample stimuli (only the portion containing target sequences is shown)

| juncture | example |
|---|---|
| within word | … 辭別 …<br>… $ts^hi^{21}pit^2$ … |
| across words | … 保持別人 …<br>… $pou^{25}ts^hi^{21}pit^2jɐn^{21}$ … |
| across phrases | … 保持，別人 …<br>… $pou^{25}ts^hi^{21}pit^2jɐn^{21}$ … |

### 2.1. Data analysis

For each disyllabic sequence, mean frequencies for the first and second formants were measured for the 25ms portion at the end of the first vowel and the 25ms portion at the beginning of the second vowel [20, 23]. Measurement was done in Praat [3] using the Burg method for formant tracking, with 50Hz pre-emphasis, 25ms window length, and 50dB dynamic range. Settings for *maximum formant* and *number of formants* were adjusted on a case-by-case basis, so as to attain faithful tracking of the formants. Raw Hertz data was normalized by speaker using the Lobanov (z-score) method [18]. Normalization was performed in R [21] using the normVowels function in phonR package [19].

### 2.2. Predictions

In line with [10, 26, 27], strengthening effects, if present, are expected to drive vowels more peripheral in the F1-F2 space: /i/ would be higher and/or fronter, corresponding to lower F1 and higher F2, /a/ would be lower and possibly backer, corresponding to higher F1 and lower F2.

Strengthening effects are expected to be stronger at AP than at WW. If AW is a phonetically distinct boundary level from AP and WW, strengthening effects should follow this order (from strong to weak): AP > AW > WW.

Pre- and postboundary positions are expected to demonstrate the same amount of strengthening.

## 3. RESULTS

Four linear mixed effects models were built using the lme4 package [1] on R [21] to estimate normalized F1 and F2 in /a/ and /i/ respectively. The base model included boundary level (AP, AW, WW), position (pre-boundary vs. post-boundary), and template (V#CV, VC#CV, V#CV), as fixed effects, and by-speaker, as well as by-item random intercepts. All categorical variables were treatment coded. Two-way and three-way interactions among the fixed effects were tested.

Similar procedures for model selection and post-hoc pairwise comparisons were applied for all the analyses. For lack of space, such details are reported only for F1 of /a/. Interested readers may contact the first author for statistical results.

### 3.1. F1 of /a/

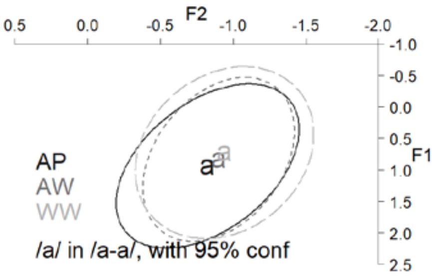
For F1 of /a/, in comparison with the base model, the model with an interaction between position and template significantly improved model fit ($\chi^2$ = 32.715, chi df = 2, $p < .001$) and was therefore selected as the final model.

Post-hoc pairwise comparisons with Bonferroni adjustments were conducted with the emmeans [17] package on R [21] to assess main effects of boundary, position and template. When averaged over levels of position and template, there was an effect of boundary: as shown in Fig. 1, /a/ was lower at higher boundaries. (The F1 value): AP > AW (df = 740.20, t = 2.878, p = 0.012) and AP > WW (df = 751.14, t = 5.201, p = <.0001). We also observed AW > WW, but the difference was not significant.

There was also an effect of position: /a/ was lower in postboundary than preboundary position (df = 745.14, t = 6.455, p <.0001).

To explore the two-way interaction between position and template, post-hoc pairwise comparisons at each level of specification (e.g. comparing F1 in postboundary vs. preboundary vowel in V#CV) with multivariate *t* ("mvt") adjustment were conducted with the emmeans [17] package on R [21]. /a/ was lower at postboundary than at preboundary position in all three templates, but the difference was significant only in VC#V (df = 745.14, t = 8.278, p < .0001).

**Figure 1**: Effects of boundary on /a/




### 3.2. F2 of /a/

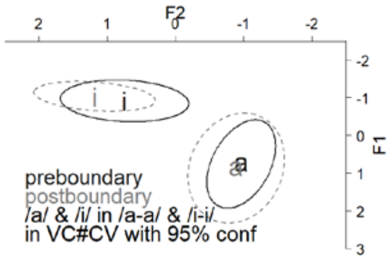
There was an effect of boundary, though not in the expected direction: as shown in Fig. 1, /a/ was *fronter* at higher boundaries. In terms of F2 value, AP >AW (df = 743.59, t = 3.886, p = 0.0003) and AP > WW (df = 744.91, t = 6.491, p = <.0001), AW > WW (df = 743.87, t = 2.478, p = 0.040).

There was also an effect of position: /a/ was fronter in postboundary than in preboundary position (df = 740.78, t =4.176, p <.0001).

Pairwise comparisons revealed that the effect of boundary was consistently found across templates. It was most prominent in V#CV, with significant distinctions showing F2 from high to low followed the order AP >AW >WW (AP – AW: df = 745.36, t = 4.078, p = 0.001; AP – WW: df = 746.11, t = 7.459, p <.0001; AW – WW: df = 742.78, t = 3.063, p = 0.034). Data on VC#CV and VC#V followed the same patterns, but only the contrast AP – WW in VC#V was statistically significant (df = 741.37, t = 3.552, p = 0.007).

Significant effects of position were found across templates: /a/ was significantly fronter in postboundary than in preboundary position in VC#CV (df = 740.78, t =2.877, p = 0.031), which is shown in Fig. 2, and in VC#V (df = 740.78, t = 7.914, p <.0001), but it was significantly backer in postbundary than in preboundary position in V#CV (df = 740.78, t = -3.729, p = 0.002).

**Figure 2**: Effects of position on /a/ and /i/



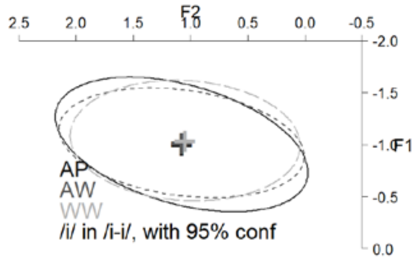

### 3.3. F1 of /i/

As shown in Fig. 3, there was no effect of boundary.

There was, however, an effect of position: /i/ was significantly higher in postboundary than in preboundary position (df = 691.54, t =-6.905, p <.0001). This pattern was consistently attested across template conditions, but the differences were statistically significant only in VC#CV (df = 691.54, t = -4.374, p = 0.001) (illustrated in Fig. 2) and VC#V (df = 691.54, t = -6.639, p < .001).

The effect of position was also consistently found across boundary conditions: postboundary /i/ was significantly higher than the preboundary /i/ at AP and AW, but not at WW (AP: df = 691.54, t = -6.526, p < .0001; AW: df = 691.54, t = -2.883, p = 0.0319; WW: df = 691.54, t = -2.499, p = 0.091).

**Figure 3**: Effects of boundary on /i/




### 3.4. F2 of /i/

The pattern with regard to boundary was in the expected direction: /i/ was fronter at higher boundaries: AP > AW > WW, but the main effects were not statistically significant. In further pairwise comparisons, significant boundary effects were found for the preboundary vowel in V#CV: /i/ was significantly fronter at AP than at lower boundaries: AP > AW (df = 690.02, t = 4.478, p = 0.0004), AP > WW (df = 691.16, t = 4.810, p = 0.0001)

Again, there was an effect of position: /i/ was fronter in postboundary than in preboundary position (df = 687.63, t =14.949, p <.0001). Further break-down of data showed that the pattern was significant at all boundary levels for VC#CV and VC#V (all $p < .0001$), and at AW boundary for V#CV ($p = 0.008$).

## 4. DISCUSSION

The current study examined F1 and F2 of /a/ and /i/ in /a-a/ and /i-i/ sequences in V#CV, VC#V and VC#CV at three boundaries (WW, AW, AP).

Regarding the acoustic manifestation of strengthening, our results were partially consistent with [10], which reported acoustic strengthening of /ɑ/ as lower and backer (higher F1, lower F2) and /i/ as fronter (higher F2) at higher boundaries than at lower boundaries. In our data, the strengthening of /a/ fleshed out differently: /a/ at higher boundaries (e.g. AP) was not only lower but also *fronter* than at lower boundaries (e.g. WW). While it is possible that strategies for strengthening may differ cross-linguistically depending on language-specific phoneme and contrast inventories [12], it is important to note that the English /ɑ/ is a back vowel, but the Cantonese /a/ is central [30]. In light of contrast enhancement (e.g. [10]), further backing the English /ɑ/ would enhance the contrast between [+back] and [-back], but moving the Cantonese central /a/ backer does not enhance [-back], despite the fact that backing would facilitate its distinction from /i/ (as it is backer relative to /i/ in the vowel space). Thus, /a/ in Cantonese is strengthened in a way consistent with the [-back] feature (i.e. moving fronter). Our results lend support to the view that prosodic strengthening serves to enhance contrasts, in particular, the contrast of distinctive features.

In terms of boundary effects, distinctions between AP and WW were repeatedly attested. Both /a/ and /i/ in our data were more peripheral at AP than at lower boundaries, which corroborates findings in previous literature, e.g. [10, 14], and highlights the contrast between AP and lower boundaries.

More importantly, there was an indication of prosodic grouping(s) between the level of AP and WW. F1 and F2 of /a/ showed layered differences between AP, AW, and WW; the differences in F2 was statistically significant. F2 of /i/ also showed a similar pattern, though the differences were not statistically significant. These results, along with the observation in [28] that speakers merge highly frequently co-occurring syllables in casual and fast speech through a prosodically-driven process, argue in favour of the existence of intermediate groupings between WW and AP, which could correspond to prosodic units between Syllable and Intonational Phrase.

Relatedly, /a/ in our data appeared more flexible than /i/ was, as /a/ showed consistent and significant effects of boundary strengthening, while although the differences on /i/ were in the predicted direction, they did not reach statistical significance. This is in keeping with the observation in literature that /i/ is more resistant to strengthening effects [27] and coarticulation [22] than /a/.

With respect to pre- and postboundary positions, our results indicate that those positions are different, which echoes findings from [5, 8], e.g. [5] reported that articulatory movements in terms of time-to-peak-velocity and spatial displacements were more consistent at the postboundary position than at the preboundary position. In our data, effects of strengthening were stronger on postboundary position than on preboundary position. The observation that /a/ was backer in postboundary position than preboundary position in VC#V but fronter in postboundary than in preboundary position in VC#CV (section 3.2) may at first glance seem to indicate a lack of consistency in the effects of position. However, considering that the syllabification was different across templates: in VC#V, the second vowel was strictly adjacent to the boundary, hence subject to stronger strengthening effects than vowels in #CV or VC# [4, 6, 10, 13], it is not surprising that the second vowel in VC#V was pronounced with more extreme articulation than the first vowel. Such confounds that stem from whether V being strictly adjacent to the boundary or not, would be mitigated in VC#CV. VC#CV in our data indeed showed effects of position: as shown in Fig. 2, the postboundary /a/ in VC#CV was fronter than the preboundary one, the postboundary /i/ in VC#CV was higher and fronter than the preboundary /i/. Such asymmetrical effects call for different treatment of pre- vs. post-boundary positions in models of speech articulation, e.g. [6].

Finally, it is worth noting that the current study has focused on the spatial aspect of strengthening. For a more comprehensive understanding of strengthening, future studies may incorporate the temporal aspect.

## 5. CONCLUSION

Through close examination of /a-a/ and /i-i/ sequences in Cantonese at three juncture levels, we showed that the prosodic strengthening drives /i/ fronter, /a/ lower but also fronter. The strengthening effects were stronger at higher boundaries than at lower boundaries, and stronger in postboundary than in preboundary position. The result that F2 of /a/ differed significantly across boundary conditions offered tentative evidence in favour of prosodic constituents between Syllable and Intonational Phrase in Cantonese. Our findings contribute to the understanding of acoustic manifestation of prosodic strengthening, contrast enhancement, asymmetric roles of pre- and post-boundary positions, and the prosodic structure of Cantonese.

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