Boundaries and Tonal articulation in Taiwanese Min

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Abstract

This study investigates the effect of the boundary on Taiwanese falling tones at domain final and domain initial positions across intonational phrase (IP), tone group (TG), word (WRD) and syllable (SYL)boundaries. The boundaries occurred at the same position within sentences produced with broad focus. The results showed that for falling tones at domain-final position, the f0 fall decreased slower before IP and TG boundaries than before WRD and SYL boundaries. In contrast, at domain initial position, the f0 fall is faster and steeper after an IP, followed by TG, SYL, and then WRD boundaries. It is proposed that f0 decreasing rate, reflecting vocal fold vibration, varies as a function of the strength of approaching and receding boundaries. At supra-segmental levels, f0 velocity decreases as the approaching boundary strengthens, whereas f0 velocity increases as the preceding boundary strengthens.

1. Introduction

Two types of measures have been found to mark prosodic boundary. These include articulatory measures at a segmental level (hyper-articulation of lip, tongue, jaw, and velum movements) and acoustic measures at a supra-segmental level (pause, anacrusis, final lengthening, and f0 reset) [1], [2], [3], and [4].

It was discovered that at either domain initial or domain final positions, the degree of articulatory strengthening varies as a function of adjacent boundaries [1], [3]. In addition, cross-boundary segmental coarticulation has also been found to vary according to the strength of intervening boundaries. For example, Cho [4] reported greater V-to-V coarticulation resistance across stronger prosodic boundaries.

Though most articulatory prosodic studies have focused on supra-laryngeal movements, Byrd [5] pointed out a new frontier for articulatory prosody; that is to expand the scope of articulatory prosodic studies to lexical tone and intonation. As prominence and boundary are the two major factors found to influence segmental articulation, at the supra-segmental level the production of lexical tone and intonation are affected by prominence as well. Investigations of prominence (focus) and lexical tone have found that prominence (focus) influences f0 range, duration, or intensity of lexical tones in Beijing Mandarin, Taiwan Mandarin, Cantonese, and Taiwanese Min [6], [7], [8], and [9]. However, little is known about the effect of boundary on lexical tones.

This study explores the effect of boundary on lexical tones in Taiwanese Min. There are seven lexical tones including two checked tones, i.e. high falling (<u>H</u>) and mid falling (<u>M</u>) tones, and five unchecked tones, i.e. high level (HH), rising (LH), high falling (HL), mid falling (ML), and mid level (MM) tones. The two checked tones are carried by closed syllables while the five free tones are carried by open syllables. Each Taiwanese tone has two allophonic variants, one occurring at a tone group boundary, and the other, a "sandhi tone", occurring internally within a tone group.

The nature of a tone group boundary is a much debated issue in Taiwanese. Compared with Taiwanese prosodic boundaries such as IP (IP), word (WRD), and syllable (SYL) boundaries, tone group boundary (TG) in Taiwanese possesses unique properties. While Hsiao (1991) has claimed that a tone group boundary is potentially a part of the prosodic hierarchy, there are reasons for not treating a tone group boundary as such. First, from the point of view of the intonation-based prosodic hierarchy, a tone group is not systematically marked by the characteristic of intonation. The delimitation of a tone group for the same utterance produced by speakers of the same accent of Taiwanese is the same, regardless of the characteristics of the intonation.

Second, from the perspective of a syntax-based prosodic hierarchy, although the domain of a tone group coincides with syntactic grouping, there are cases when the domain of a tone group violates syntactic group boundaries. In such cases, it has been proposed that the delimitation of a tone group is prosodically determined, although the prosodic criteria for determining the tone group boundary in these cases are not explicitly stated [10], [11], [12], and [13].

Third, from the perspective of a phonologically-determined prosodic hierarchy, the domain of a tone group boundary violates the strict layer hypothesis [14] by coinciding sometimes with a higher prosodic level, such as an IP, while at other times only coinciding with a lower word boundary nested within a higher IP. For example, in

[gua˥ t^{h}ak<u>˨˩</u> pũã˥˧ tiam˥ tsiŋ˧ ku˥ ts^{h}eʔ<u>˨˩</u>]^{TG}
'I studied for half an hour.' [13],

the domain of a tone group coincides with the domain of an IP. However, in

[t^{h}ai˥˧ tsu˥˧]^{TG} [kĩũ˧ bo˥ aʔ<u>˨˩</u>]^{TG}
'Prince® ginger duck',

The entire compound noun contains two tone groups, with a tone group boundary between the free morphemes /t^{h}ai˨˩ tsu˥˧/ 'prince', which is a registered brand name, and the noun /kĩũ˥ bo˥˧ / 'ginger'.

Hsu and Jun [15], in a study comparing VOT of Taiwanese stops in tone group initial and medial positions, discovered that stops had more aspiration when in the initial position of a tone group as compared to final position. This finding indicates that tone group boundary influences the segmental articulation just as prosodic boundaries do. However, recognizing the violation of the strict-layer hypothesis, they proposed that both prosodic and non-prosodic boundaries can be marked phonetically.

By expanding the scope of articulatory prosody from the segmental to the supra-segmental level, this study investigates the effect of IP (IP), tone group (TG), word (WRD), and syllable (SYL) boundaries on f0 of Taiwanese falling tones at the domain initial, and the domain final positions. Two research questions are addressed: (1) what is the effect of boundary type on the domain initial and final lexical tonal strengthening? and (2) what is the effect of boundary types on the speed of f0 decreasing?

2. Method

2.1. Speakers

Three female native Taiwanese speakers participated in the experiments. They were students at the National Chiao Tung University at the time of recording. Besides Taiwanese, they can speak Taiwan Mandarin and received over 10 years of ESL education.

2.2. Corpus

Table 1: *Example of corpus.*

Boundary	Examples
IP	[a˧ mã˥˩, liam˥˩ a˧ ku˧] “Grandma, pinch aunt.”
TG	[a˧ mã˥˩ liam˥˩ a˧ k u˧] “Grandma pinched aunt.”
WRD	[i˧ lap˥˩ a˥˩ mɔ˧ p^{h}e˧] “He stepped on duck down comforter.”
SYL	[yoŋ˧ la˧˩ a˥˩ kun˧ mĩ˧] ”Use clam to cook noodle soup.”

To isolate the effect of declination on f0 values, the boundary occurred at the same position within sentences of the same length. The IP, TG, WRD, and SYL boundaries were placed between the second and third syllables within sentences five syllables in length. The first and fourth syllables were controlled to carry the mid level (MM) tone; whereas, the second and third syllables carried one of the four falling tones (HL, ML, H, M), as shown in Table 1. In sentences with the IP boundary placed between the second and third syllables, the first and second syllables formed a surname produced as a vocative form. Sentences with an IP between the second and third syllables were also produced as declarative sentences without vocative form on the surname to elicit sentences with a TG boundary between the second and third syllables. To distinguish between sentences with IP and TG boundaries, the IP boundary was defined by final lengthening, pause, and f0 reset, while the TG boundary lacked such cues.

In sentences with the WRD boundary, the first syllable was a monosyllabic pronoun; while the second syllable was a monosyllabic verb; whereas the third to fifth syllables formed a noun that was the object of the verb. The verb and the object formed a tone group in sentences with the WRD boundary at the target positions. Therefore, the verb (the syllable before the WRD boundary) carried a sandhi tone. Though TG and WRD boundaries were both placed after a word, in sentences with TG boundary, the syllable before the TG boundary carried a juncture tone; while in sentences with a WRD boundary, the syllable before WRD boundary carried a sandhi tone. Though both WRD and TG were viewed as a word boundary, the different tonal values preceding TG and WRD distinguished the two boundaries.

For sentences with a SYL boundary between the second and third syllables, the second and third syllables formed a noun with SYL boundary intervening in between. Each of the 192 sentences (4 falling tones at second syllables × 4 falling tones at third syllables × 4 boundaries × 3 repetitions) were randomized and produced with the target second and third syllables in either neutral focus, narrow focus, or de-focus conditions. The order of the sentences was written on a reading list without any indication of focus conditions.

2.3. Instrumentation

An AKG HSD200 head-mounted microphone placed three cms before the speaker’s mouth picked up acoustical signals that were transferred to a SONY MDS-E10 CD deck and recorded in digital quality. The sound tracks were converted into waveforms at 22kHz, 16 bits with Adobe Acrobat Audition.

2.4. Experimental Procedure

During the recording, both the experimenter and the speaker were present at a sound treated recording booth at the Phonetics Lab. As there were no indications of focus locations on the speaker’s reading list, the speaker waited till the experimenter asked a precursor question, then replied with a sentence from the reading list with the desired focus pattern. If the experimenter decided that the desired focus condition was not produced, then the precursor question was repeated again to elicit another utterance.

2.4. Data Analysis

Only sentences produced with broad focus were analyzed in the current study. The time at the onset and the offset of second and third vowels were taken, as were the time and F0 values at the highest F0 peak and lowest F0 valley of falling tones produced in the second and third syllables. The duration of the vowel /a/ in the second and third syllables was derived by subtracting the time of vowel onset from the time of vowel offset. The f0 ranges for the second and third syllables were calculated by subtracting the f0 of low (L) target from the high (H) target of the same syllable.

3. Results

As shown in Figure 1, the H targets of the second syllables before WRD and SYL boundaries were higher than the H targets before IP and TG boundaries. The L targets of the second syllables before the SYL and WRD boundaries were the highest, followed by the L target before the TG boundary which was the second highest, and finally the IP boundary which was the lowest. The ranking for H and L targets remained relatively similar for pre-boundary syllables at the domain final positions.

The H targets of the third syllable after an IP boundary were the highest, followed by the H targets after TG and SYL boundaries which were the second highest, and then by the H targets after a WRD boundary which were the lowest. The L targets for post-boundary domain initial syllables were the highest after SYL boundary, followed by L targets after IP and TG boundaries which were the second highest, and finally by L target after WRD boundary which were the lowest. For H and L targets of post-boundary syllables at domain initial, no consistent ranking was observed.

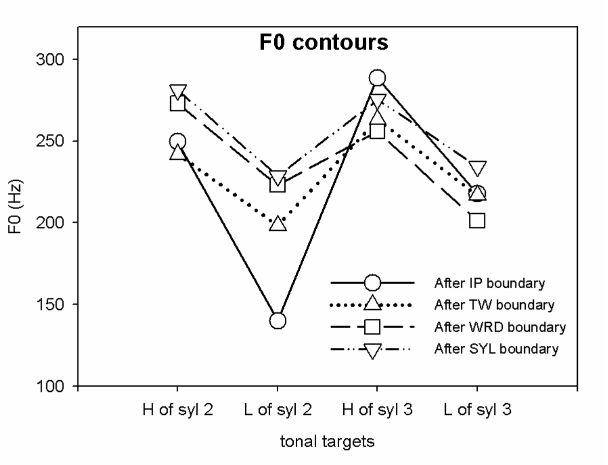

Figure 1: *F0 for H and L tonal targets at second and third syllables.*

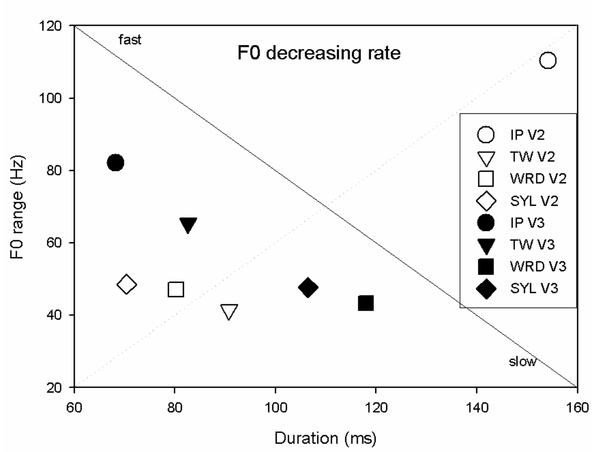

Figure 2: *Mean f0 range and mean duration of second vowel (v2) and third vowel (v3).*

As shown in Figure 2, the mean f0 range of the second syllable at domain final was the greatest before an IP boundary, followed by the mean f0 range after a SYL boundary, then WRD boundary, and finally TG boundary. The mean f0 range for third syllable at post-boundary domain initial positions were the greatest after an IP boundary, followed by TG boundary, then SYL boundary, and finally WRD boundary.

As shown in Figure 2, the duration of the vowel /a/ at the second syllable at pre-boundary position was the longest before an IP boundary, followed by TG boundary, then WRD boundary, and finally SYL boundary. Duration of post-boundary third vowel /a/ at domain initial position was the longest after WRD boundary, followed by SYL boundary, then TG boundary and finally IP boundary. The rankings for vowel duration at the second and third syllables showed relatively opposite rankings.

By calculating velocity using the duration of final lengthening with f0 range data, it was found that the f0 of the falling tone in the boundary final syllables fell at a slower rate before IP and TG boundaries than before WRD and SYL. As for the boundary initial syllables, it was found that f0 fell at the fastest rate after IP, then TG, then SYL and finally WRD boundaries. In other words, as the prosodic boundary between the two falling tones increased in strength, the velocity of f0 fall in boundary final tones decreased, while the velocity of the f0 fall in boundary initial tones increased. The ranking of WRD boundary was the only exception.

4. Discussion

Boundary affects the L target at domain final position by gradually lowering the L target from SYL to WRD, to TG, and finally IP boundary. The f0 value of the L target is influenced hierarchically by the strength of the approaching boundary. In other words the final lowering of the f0 contour is controlled by the hierarchical strength of approaching boundaries.

Boundary influences the duration of final lengthening for the pre-boundary syllables at domain final positions by gradually increasing the duration of the domain final syllable as the boundaries becomes stronger. In addition to final lengthening, the duration of the post-boundary syllable in domain initial position is also affected by the hierarchical level of preceding boundaries. It is found that the stronger the boundary, the shorter the duration of the initial syllable. However, there is one exception; that is, the duration of the syllable after a WRD boundary. Domain-initial syllables were longer after a WRD boundary than any other boundary type. This result is also observed in the nasal airflow flow study of Taiwanese nasals [16]. It is proposed that the longest duration after a WRD boundary is a unique marker to distinguish WRD from TG boundary, since both are considered as a word boundary from a prosodic point of view. While a TG boundary is uniquely marked with the surface of a juncture tone in pre-boundary syllables, WRD boundary is marked with the longest duration of post-boundary vowels.

The speed of the F0 fall in domain final syllables is influenced by the hierarchical strength of approaching boundaries; that is the higher the boundary, the slower the f0 decreased. On the other hand in domain-initial syllables, the reverse trend is true, that the higher the boundary is, the faster the f0 decreases.

Byrd and Saltzman [17] use the pi gesture to model the local shrinking and stretching of articulatory trajectories around prosodic boundaries. They proposed the existence of a central clock controlling the speed of articulatory movements as they approach and recede from boundaries. As the central clock speeds up, the articulatory trajectories shrink, whereas when the clock slows down, the articulatory trajectories stretch or expand. Furthermore, they suggested that the speed of the central clock can be influenced by the strength of approaching boundaries. Following Byrd's [5] suggestion of articulatory prosodic factors into the study of supra-segmental level articulation, it is suggested that, at the supra-laryngeal level, the speed of the f0 fall for both pre-boundary and post-boundary syllables at domain-final and domain initial vary according to the hierarchical strength of the approaching and preceding boundaries respectively. Consequently, the syllable before a strong boundary is lengthened to accommodate the slow f0 fall while the syllable after the IP boundary is shortened. Conversely, the syllable before a weak boundary is shorter given that the f0 fall is fast, and the following post-boundary syllable is longer produced with a slower f0 fall.

Comparing the f0 descending speed at domain final and domain initial across the boundaries of various strengths, it is proposed that the f0 descending speed slows down to the lowest rate before the IP boundary and speeds up to the highest rate after the IP boundary. Around the TG boundary, the speed of f0 descending is the second slowest before the TG boundary and the second fastest after the TG boundary. The speed of the f0 descending is the fastest before SYL boundary, but the second slowest after SYL boundary. If the hierarchical strength of a boundary is the only factor influencing the speed of f0 fall then the slowest speed at domain initial should have occurred after SYL boundary, however, this is not what we observed in Taiwanese. Instead, at the domain initial position, the slowest speed occurred after the WRD boundary, due to the longest post-boundary vowel after the WRD boundary. This violation of hierarchical ranking is proposed to result from the need to distinguish the WRD from the TG boundary with a unique marker in order to facilitate boundary identification. Therefore the WRD boundary is signaled with the second fastest f0 descending rate at domain final, but the slowest rate at the domain initial position.

In sum, the speed of f0 descending varies according to the level of approaching and receding boundaries. While the velocity of f0 falling slope increases as the approaching boundary varies from high to low level, the velocity reduces as the preceding boundary varies form high to low level. Articulation at the supra-segmental level is governed by the prosodic boundaries, just as segmental articulation is.

5. Conclusions

This study investigates the effect of the boundary on articulation of falling tones in Taiwanese and discovered that the speed of f0 falling contour varied in a hierarchical manner according to the strength of approaching and preceding boundaries. As boundary varies from a low to high level, the speed of f0 descending gradually reduces at a domain final position, but gradually increases at domain initial. In addition to the hierarchical influence of a boundary on the lexical tonal articulation, there is a unique marking associating with a WRD boundary that is potentially used to distinguish word boundaries from tone group boundaries in Taiwanese Min.

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