Downtrend in Sylheti phrasal tones

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Abstract

This study examines the phonological nature of the fundamental frequency (f0) downtrend in Sylheti, an Indo-Aryan tonal language exhibiting both lexical and phrasal tones. Speech data from five native speakers were analysed using Praat, ProsodyPro, and statistical modelling in R and Python to investigate the behavior of phrasal tones within Accentual Phrases (APs) across Intonational Phrases (IPs). The results reveal a consistent stepwise lowering of f0 peaks, independent of sentence length, indicating a phonological rather than purely phonetic process. Mathematical modelling based on Liberman and Pierrehumbert's (1984) downstep and final-lowering equations accurately predicted observed f0 patterns ($R^2 = 0.98$). These findings confirm that Sylheti exhibits a systematic, phonologically governed downtrend across utterances.

Keywords: sylheti, downtrend, f0 modelling, phrasal tones, intonation

Introduction

The gradual downward movement of fundamental frequency (f0) or pitch during the production of utterances, known as 'downtrends,' is well documented across languages and can be phonetic or phonological in nature (Connell, 2001; Gussenhoven, 2004; Gogoi et al, 2024). This study explores the f0 downtrend in Sylheti, an Indo-Aryan tonal language exhibiting both lexical and phrasal tones (Gope, 2016, 2018, 2021, 2025; Gope & Mahanta, 2014–2016; Gogoi, 2024; Gogoi & Gope, 2023; Mahanta & Gope, 2018). The focus is on whether Sylheti's f0 downtrend reflects a phonological process through how phrasal tones marking Accentual Phrases (APs) behave across Intonational Phrases (IPs). Two central questions guide this research: (i) how the overarching f0 downtrend across IPs shapes the surface realization of phrasal tones, and (ii) whether the peak-by-peak descent can be systematically modelled.

Experimental procedure

Five native Sylheti speakers (three males, two females; aged 18-33) from Dharamnagar, Tripura, recorded 11 scripted neutral declarative sentences (8-11 syllables) five times each to analyze f0 downtrend patterns. Sentences incorporated varied tonal sequences to assess lexical tone effects on f0. Recordings (44.1 kHz, 32-bit) were manually annotated at the syllable level using Praat (Boersma & Weenink 2012), and syllable-wise mean and time-normalized

f0 values were extracted with ProsodyPro (Xu 2013). Pitch contours were visually inspected. Statistical analysis involved one-way repeated measures ANOVA (R 4.2.3) for f0 differences, and downward slopes were modelled using Origin 8.1 and Python's linregress function, with model accuracy evaluated via R^2 values from sklearn.metrics.

Results and discussion

Downstep in Sylheti manifests as a gradual lowering of successive f0 peaks. Neutral declaratives are structured into Accentual Phrases (APs) marked by L* pitch accents and Ha boundary tones, with downstep examined through Ha tone peaks. Speakers typically divide Intonational Phrases (IPs) into two or three APs, forming recursive structures that group lexical and functional items (Gogoi 2024).

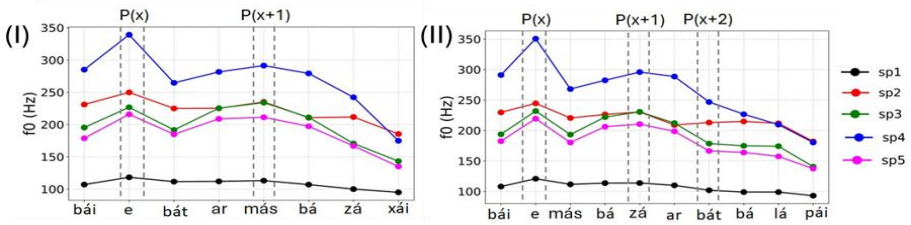

Figure 1. The average f0 contours for five speakers (sp1-5) across different sentences: (I) [bái-e bát ar más bázá xái] '(my) brother eats rice and fried fish,' and (II) [bái-e más bázá ar bát bá lá pái], '(my) brother likes fish fry and rice.'

Visual inspection (Figure 1) reveals that female speakers have higher peaks and wider pitch ranges than male speakers, but all maintain consistent contour shapes. Sentences feature two to three peaks, with P(x) highest and subsequent peaks (P(x+1), P(x+2)) progressively lower. Underlying lexical tones affect only the scaling of L* pitch accents and do not impact peak positions. Scaling changes from IP medial H tone roots adjust pitch height by interpolating L and H tones, but do not alter phrasal tone specification.

Figure 2 illustrates the average f0 contours for selected sentences, highlighting key peaks P(1), P(2), and P(3) with stars denoting the highest tonal points. Linear fits applied to final f0 points using the equation $y = m*x + c$ (where m is the slope indicating the f0 change per syllable and c is the intercept) model overall pitch movement across sentences. The negative slopes confirm a consistent downtrend, with f0 gradually declining toward the end of the sentence.

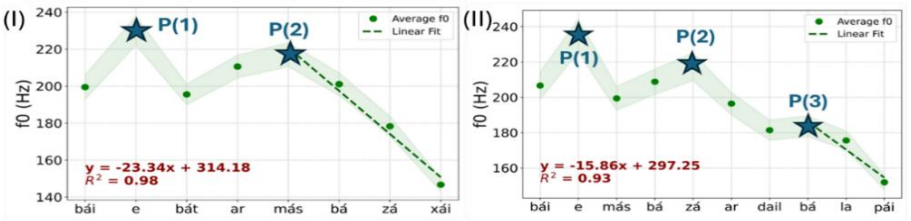

Figure 2: The average f0 contours for two different sentences (I) [bái-e bát ar más bázá xái] '(my) brother eats rice and fried fish,' and (II) [bái e máś bá zá ar dáil bá la pái] '(my) brother likes fish fry and lentils.'

Phonological nature of the downstep of f0 peaks in Sylheti

The stepwise lowering of f0 peaks reflects a phonological pattern rather than a phonetic effect. The consistent and predictable f0 decline across sentences of varying lengths and syllable counts (Figures 1-2) supports this interpretation (Liberman & Pierrehumbert, 1984), with initial and final f0 values and the rise to the first peak remaining similar across utterances. This stability indicates the downtrend in peak height is a phonological property, not an articulation artifact. Following Liberman and Pierrehumbert's (1984) exponential model, the downstep ratio between consecutive peaks was calculated as r = (P(x+1) – R) / (P(x) – R), where R = (Mean f0_last peak + Mean f0_minimum)/2. Each successive peak was predicted as P(x+1) _predicted = R + [r × (P(x) – R)]. For two-peak utterances, the average downstep ratio was r = 0.69 ± 0.09, showing stability independent of intervening syllables. For three-peak utterances, the ratio between the third and second peaks dropped to r = 0.27 ± 0.17, likely due to final lowering, a pattern reported also in American English and Mexican Spanish (Liberman & Pierrehumbert, 1984; Prieto et al., 1996).

To model this, the final lowering constant 1 (Liberman and Pierrehumbert 1984) was applied using P = R + l * (P(down) - R), where *P* is the height of the last peak, P(down) is the peak height predicted by the downstep rule, R is the reference line, and l is the final lowering constant. The ratio determines the value of l, computed as l = (P(obs) - R) / (P(down) - R), where P(obs) is the observed peak height. Once known, l predicts the next peak height using the formula: P(x+2) _predicted = R + l* (P(x+1) - R), where the P(x+2) _predicted is the predicted f0 value. A comparison of predicted and observed f0 values shows that the final lowering model achieves an R^2 of 0.98, surpassing the basic downstep model's R^2 of 0.75. These confirm that Sylheti's downstepped f0 peaks are mathematically modelled and phonological in nature. Moreover, in sentences with more than two peaks, final lowering significantly influences the last peak, as effectively described by Liberman and Pierrehumbert's lowering constant.

Conclusion

The analysis confirms that Sylheti exhibits a consistent, predictable f0 downtrend across utterances, indicative of a phonological rather than a phonetic process. Mathematical modeling accurately captures both the stepwise and final lowering of f0 peaks. These findings deepen our understanding of Sylheti prosody and provide a valuable foundation for comparative research on tonal organization in South Asian languages.

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