The Phonetics of Downtrends in Chokri

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ABSTRACT

This paper investigates f0 downtrend processes in Chokri, a Tibeto-Burman language spoken in Nagaland, India. Three types of downtrends- temporal declination, final lowering, and automatic downstep, are considered in this study. The mathematically fitted f0s were used to examine the dependency of f0 on different tonal sequences of syllables (viz., all high, all mid, all low). The results confirm a general time-dependent declination in all high, mid, and low tones sequences. Furthermore, the fitted equations confirm that all high and low tone sequences follow a declining linear trend with an adjusted R-squared value of 0.79 and 0.87, respectively. In contrast, the mid-tone sequence follows an exponential decay, with a final lowering. The language indicates the presence of an automatic downstep when there is an intervening L tone between two H tone sequences.

Keywords: downtrends, prosody, declination, downstep, mathematical modeling.

1. INTRODUCTION

Researchers working on intonation in tonal and non-tonal languages have analyzed downtrend patterns, i.e., the gradual lowering of f0 from the starting towards the end of utterances. This implies that the pitch of a tone occurring later in the utterance will be lower than that of the same tone occurring at the beginning. Although debatable, such progressive pitch descent is attributed to phonetic effects [1]. Downtrends include (i) declination- the time-dependent lowering of f0, (ii) downstep- the lowering of f0 of H tones induced by the intervention of an L tone; and (iii) final lowering [2]. In intonation-only languages, studies on downtrends are focused chiefly on declination. However, downtrend analysis in many African tone languages reports the presence of downstep, a process involving H and L tones occurring alternatively, wherein the later H in an HLH sequence has a lower f0 due to the influence of the intervening L tone [1].

Declination refers to the global downward trend of f0 contour stretched over phrases or utterances. [3, 4, 5, 6, 7, 8] It is the "gradual modification (throughout a phrase or utterance) of the phonetic backdrop against which the phonologically specified F0 targets are scaled" [9]. Generally considered a phonetic effect, declination is considered universal in declarative utterances across languages. However, many researchers observed the absence of declination in some tonal languages, which has been one of the exciting findings from the works on intonational downtrends. For example, declination and final lowering are not found in Yoruba for sentences with all-H and all-M tones [9]. In Mambila, Tone 1, the highest tone, shows little tendency for downtrends [1]. While the declination effect can be seen for all tones, in tone languages, they are clearer through analysis of sentences containing words with the same lexical tones, like all H or all L sequences.

Final lowering is the more abrupt and excessive lowering of f0 at the end of speech domains like phrases or utterances [2, 6, 10]. Welmers [11] reports the presence of final lowering in several discrete level tone languages of Africa.

Another type of downtrend frequently reported in African tone languages concerns alternate H and L tone sequences. H tone following an L tone is realized with a lowered F0 compared to the H tone preceding an L tone. This process is called automatic downstep or downdrift [8]. Non-automatic downstep, on the other hand, is the lowering of an H tone without a conditioning L tone being physically present. A floating L tone triggers such a downtrend. This study investigates how different types of (f0) downtrends affect sentence prosody in Chokri.

2. THE LANGUAGE: CHOKRI

Chokri is a Tibeto Burman language primarily spoken in the Phek district of Nagaland, North-East India. The language is spoken by the Chokri-mi or Chokri subgroup of the Chakhesang tribe. The 2011 Census Reports of India estimates a total of 111,062 Chokri speakers. Bielenberg and Nienu [12] report the presence of 39 consonants, six vowels, and four tones in the language. However, our study shows that the segmental phoneme inventory of Chokri consists of 33 consonants, 7 vowels, and 5 lexical tones (four level tones- Extra High, High, Mid, and Low, and a contour (mid-rising) tone) [13].

3. EXPERIMENTAL PROCEDURE

We recorded speech data from 5 native Chokri speakers (three male, two female, and aged between 18 and 55 years) in the form of scripted sentences. The subjects were shown each sentence on a

computer screen and instructed to produce them naturally. Each speaker repeated the entire dataset five times, with a considerable gap between each repetition. Individual sentence files were segmented at the syllable level using PRAAT (version 6.0.43) [14]. The mean f0 and time-normalized f0 values were extracted using the ProsodyPro [15]. The resulting values were plotted as line graphs for visual inspection. A one-way repeated measure ANOVA (RM ANOVA) was performed to verify the statistical significance of the observed f0 differences.

The corpus used for this study consisted of three datasets containing 58 sentences. Following is the structure of the dataset used for the experiment:

A. All high-tone (henceforth H) sequences
   All low-tone (henceforth L) sequences
   All mid-tone (henceforth M) sequences
B. H tone sequences with an intervening L

4. RESULTS

4.1. Declination

Production experiments were conducted to examine the trends of declination in all L, H, and M tone sequences in Chokri. Results show that the (phonetic) declination process is present in this language for all three tone sequences, viz., H, L, and M tone sequences. However, the rate of decline is not constant for all syllables. Time-normalized average f0 values calculated for each speaker showed that declination is steepest on the first syllable of the utterance. The first drop in pitch is realized during the production of the very first syllable. The rate of declination then becomes progressively slower as the utterance progresses. While the phonological specification of all the syllables is the same (High), the phonetic value of f0 of the syllables occurring late in utterance is less compared to the ones in the beginning. Figures 1-4 represent the time-normalized average f0 trend for male and female speakers for H and L tones. The error bars depict the standard error of the aggregated data.

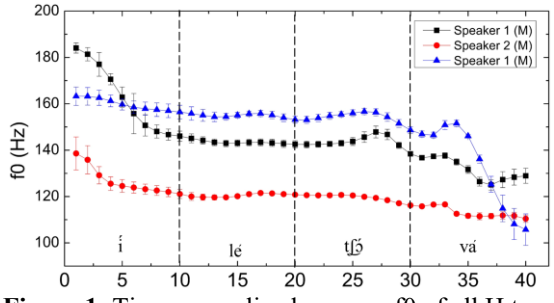

Figure 1: Time-normalized average f0 of all H tone sequence /í lé ʧɔ́vá/ *I am cooking* by 3 male speakers.

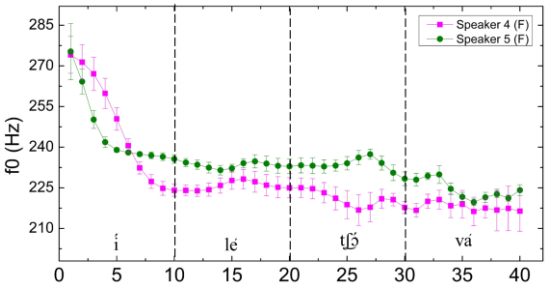

Figure 2: Time-normalized average f0 of all H tone sequence /í lé ʧɔ́vá/ *I am cooking* by 2 female speakers.

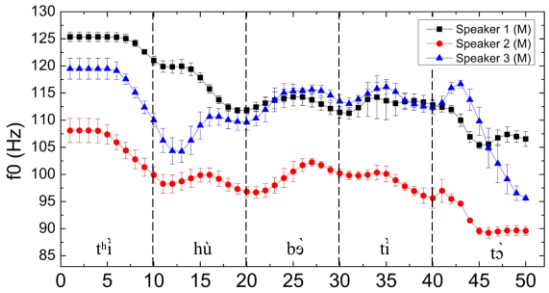

Figure 3: Time-normalized average f0 of all L tone sequence /tʰì hù bɔ̀ tì tɔ̀/ *(I) will boil some meat and eat* by 3 male speakers.

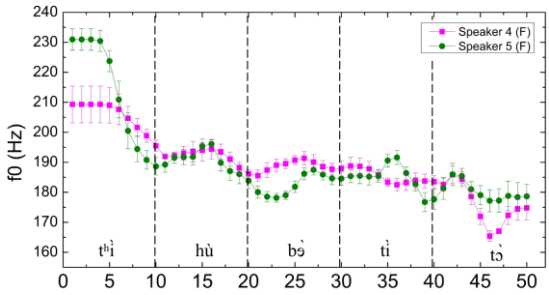

Figure 4: Time-normalized average f0 of all L tone sequence /tʰì hù bɔ̀ tì tɔ̀/ *(I) will boil some meat and eat* by 2 female speakers.

4.2. Final Lowering

Final lowering is not observed in the sentences featuring the sequences of all H and L tones across speakers' repetitions considered in this study. However, the sentences featuring the sequences of all M tones indicate a final lowering in Chokri.

4.3. Automatic Downstep

We also examined sentences where an intervening L occurs in an all-H sequence to explore the possibility of automatic downstep in Chokri. Results indicate that the intervening L might influence the preceding and the following H tone syllables. The visual observations of each speaker's time-normalized contours across repetitions indicate that an H tone appearing after an L has relatively lower f0 values than the H tones preceding the L (Figure 5). The precise nature of automatic downstep is discussed in section 5.

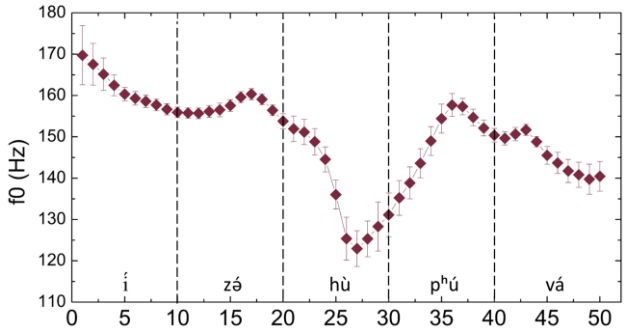

Figure 5: Time-normalized average f0 of all tokens of the sentence / í zə́ hù pʰú vá/ *I am searching for some water* by all 5 speakers.

5. DISCUSSIONS

To examine whether the declination patterns (Figures 1 - 4, for examples) observed in all H, M, and L tone sequences are significant, we conducted one-way repeated measured ANOVA. The results confirm that f0 differences observed in each syllable are significantly different in the sequence of all H ($F[3, 12] = 66.7$, $p < 0.0001$*), all M ($F[5, 20] = 30.83$, $p < 0.0001$*), and all L ($F[3, 12] = 69.52$, $p < 0.0001$*), respectively. A subsequent post hoc Bonferroni test confirmed a significant interaction between each syllable in the sequence of all H, M, and L tones, respectively.

Different mathematical equations, viz., (i) linear equations (for the sentences with all H and L tone sequences) and (ii) exponential decay (for the sentences with all M tone sequences), are individually fitted to examine the slopes of declination (Figures 6 - 8). The following formulas for (a) a linear equation with $y = m*x + c$, where m is the slope and c is the intercept, and (b) an exponential decay equation with $y = a*\exp(-x/b) + d$, where a, b, and d are the constants, are incorporated to calculate the slopes. In figures 6 – 8, the Y-axis shows the f0 range, and the X-axis shows the number of syllables present in the target sentence.

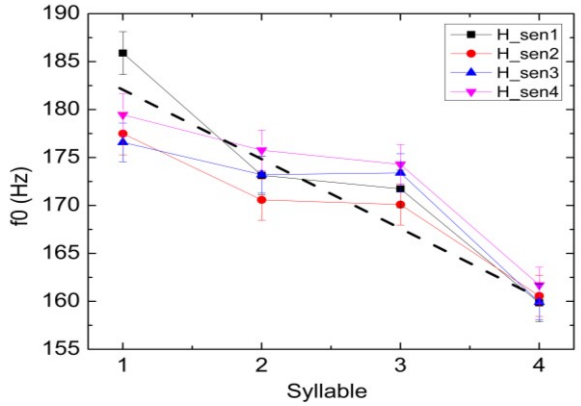

Figure 6: Time-normalized average f0 contours of all the sentences featuring all H tone sequences produced by all the subjects. The dashed solid line depicts the trends of declination.

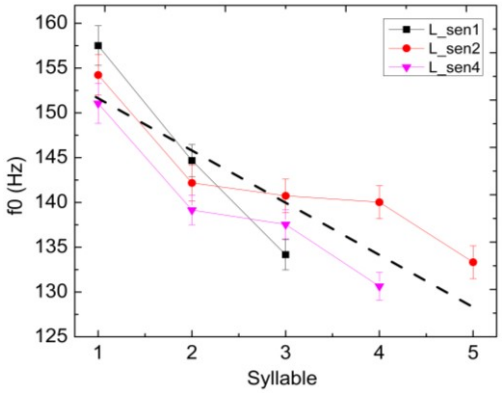

Figure 7: Time-normalized average f0 contours of all the sentences featuring all L tone sequences produced by all the subjects. The dashed solid line depicts the trends of declination.

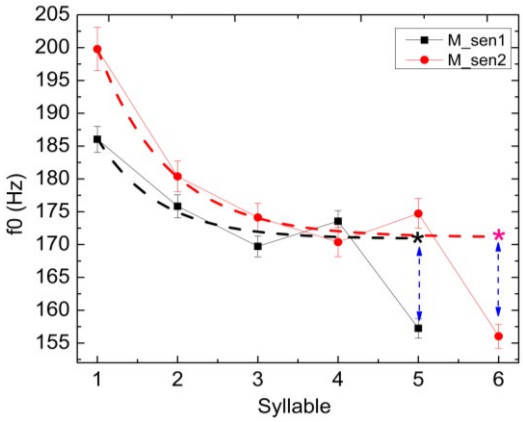

Figure 8: Time-normalized average f0 contours of all the sentences featuring all M tone sequences produced by all the subjects. The corresponding dashed lines exhibit the exponential decay fitted lines. The blue dashed line shows the distance between the fitted lines and the (actual) final point.

The visual observations of the f0 contours shown in Figures 6 – 8 could be misleading. The observation of the final syllable in all these contours may seem like a final lowering. However, the quantitative interpretation confirms that it is not the case. Only a linear line could be fitted for the sentences featuring the sequences of all H and L tones, respectively. The f0 range depicted in the Y-axis varies from ~188 to ~161 Hz (for the syllables with all H tone sequences) and ~157 to ~130 Hz (for the syllables with all L tone sequences). It implies that the f0 range between the successive syllables is relatively low (only 27 Hz) for an exponential decay to fit in. Furthermore, the f0 value of a particular syllable is relatively closer when compared to the preceding and the following syllables (of the target syllable). The adjusted R-squared values for the linear fit of all the sentences featuring all H tone sequences are 0.88, 0.85, 0.65, and 0.77, respectively. Similarly,

the adjusted R-squared values for the linear fit of all the sentences featuring all L tone sequences are 0.99, 0.77, and 0.84, respectively.

In contrast, the linear fit equation cannot the applied to the f0 contours of the sentences featuring all M tone syllable sequences (due to higher R-squared values). The R-squared values increased from 0.46 to 0.81 for M_sen1 and 0.47 to 0.92 for M_sen2. The increased R-square values confirm that the fitted equation is more justified for an exponential decay than a linear fit. When the exponential curves are extrapolated, it is also observed that the final point is relatively lower than the fitted point (~15 Hz), implying a *final lowering* in the syllable sequences featuring all M tones in Chokri.

	Fitted value	Std Error
M_sen1_d	170.87427	1.87488
M_sen1_a	57.52609	46.00498
M_sen1_b	0.75476	0.45813
M_sen2_d	171.10861	1.41236
M_sen2_a	90.08204	29.68016
M_sen2_b	0.87493	0.22661

Table 1: Fitted values for the exponential decay equation applied on sentences featuring all M tone sequences.

Table 1 tabulates the fitted values for the exponential decay, where the decay constant (b) is dependent on the syllable no., i.e., the value of "b" changes from 0.75 to 0.87, when the number of syllables in the sentences featuring all M tone sequences increases from 5 to 6.

It is to be noted that the number of syllables in the sentences featuring all H tone sequences is fixed at 4. The ranges of the slope values (m) observed in all four sentences featuring all H tone sequences are -7.85 ± 1.62 Hz, -5.12 ± 1.18Hz, -5.13 ± 1.98Hz, and -5.69 ± 1.69 Hz, respectively. The negative values confirm the presence of declination in Chokri. On average, the slope value (i.e., the change of the f0 value with respect to the syllable number) is observed to be a constant value of 5.94 ± 1.61 Hz.

The parameters of the mathematical fitted equations are exploited to examine the interactions between the (increased) syllable numbers and declination. The number of syllables in the sentences featuring all L tone sequences varies from 3 to 5. The range of slope values in the sentences containing all L tone sequences is -11.55 ± 0.71Hz (three syllables), -5.85 ± 1.39Hz (four syllables), and -4.21 ± 1.09 Hz (five syllables), respectively. The trend of slope values indicates an inversely proportionate correlation with the number of syllables present in a sentence, i.e., the slope values decrease with the increased number of syllables in a sentence (from -11.55 to -4.21 Hz). The sample size concerning the number of syllables featuring different tonal sequences is relatively small (n = 0 for all H tone sequences, 2 for all M tone sequences, and 3 for all L tone sequences). It is, therefore, beyond the scope of this approach to confirm the exact dependency of the syllable number on declination patterns.

Finally, to examine the effect of an intervening L tone on the preceding H (denoted as H_p) and following H (denoted as H_f) tone sequences, we have considered three different tonal sequences in this study, viz., HLHH, HHLH, and HHLHH. Figure 9 shows the time-normalized average f0 contours (averaged across all the repetitions produced by all the subjects) for the sentences with HLHH, HHLH, and HHLHH tonal sequences. The visual observations of the contours confirm that the intervening L tone, by and large, reduces the f0 of the H_f tone. The f0 of H_p also gets reduced, most likely as a result of the declination effect. A stiff fall on the intervening L syllable, followed by a linear f0 contour, could be observed in the HLHH and HHLH tonal sequences, indicating the presence of an automatic downstep in Chokri.

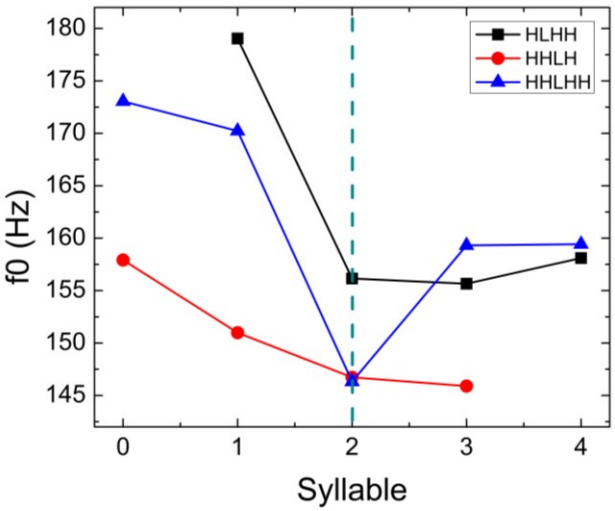

Figure 9: Time normalized average f0 for different syllable numbers. The green dashed line is the reference line to distinguish the preceding and following H tones.

5. CONCLUSIONS

This study shows the nature of f0 downtrends in Chokri. Temporal declination is present in *like level tone* sequences (H, L, and M) with statistically significant f0 differences among syllables. Final lowering is found only in all M sequences. Furthermore, this paper also confirms the presence of automatic downsteps in the language.

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