USING DISCRETE COSINE TRANSFORMS TO CHARACTERIZE TONES IN TWO ATHABASKAN LANGUAGES

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1 Tone in the Dene languages

Tone in North American languages has received very little phonetic attention. This paper is a preliminary analysis of the production of lexical tone in two related bitonal (H/L) Athabaskan languages spoken in Northwestern Canada: Dene Sų̨łine (Chipewayan) and Tłı̨chǫ Yatıì (Dogrib). The Dene languages are divided into two groups, those without tone (Alaska, Yukon and the Pacific coast) and the tone languages of the inland Dene and the Apachean languages. Tonogenesis arises from the incorporation of stem final glottalic elements into the stem nucleus, through an intricate set of reconstructed stem alternation patterns [1], [2]. The most commonly reported phenomenon is a type of tonal polarity, which reoccurs in daughter languages [3]. Tłı̨chǫ Yatıì (TY) and Dene Sų̨łine (DS) are examples of two-tone contrasts with opposing polar-type tone systems. In this study we looked at 2-syllable words taken from existing recordings of word lists by native fluent speakers in Tłı̨chǫ Yatıì ('H marked') and Dene Sų̨łine ('L marked'). There were 3 speakers for each language. Given the default status of the opposite tone in each language, we are investigating differences in the realization of the tones between the languages. If tonal implementation is affected by morphological, lexical or grammatical factors, we expect differences due to the asymmetries caused by the distribution of the default tone.

2 Discrete Cosine Tranform

We use the discrete cosine transform (DCT) to characterize tone trajectories of words in these two languages. The DCT is a transformation that decomposes a spline into a set of coefficients (k_0-k_n) from which the spline can be reconstructed; much like a Fourier transformation. Watson and Harrington [4] showed that k_0 is proportional to mean f_0; k_1 to slope and k_2 to (parabolic) curve. The DCT coefficients are all real numbers which provide numerical correlates for trajectory shape. The studies in [4] and [5] used these coefficients very successfully to characterize formant tracks. In this paper we use them to characterize pitch tracks in tone.

3 Study

3.1 Procedures

Two syllable words were extracted from recordings of word lists made by 6 native speakers (3 DS and 3 TY speakers). For Tłı̨chǫ Yatıì, which has phonological length, only words with short vowels were chosen. In the recordings each subject had repeated the words three times. For DS all three speakers produced all 9 of the words given in Table 1a and all repetitions were used. For TY not all speakers produced all the words and the distribution is shown in Table 1b. As well, in TY speaker P consistently produced noticeable list intonation so only the first two tokens of her examples were used. Speaker L also produced list intonation for gobò and kwìgha so only the first two tokens for those two items were used. All used tokens were annotated in PRAAT [6] and the vowels segmented out. Eleven equally spaced F_0 measurements were taken from each vowel, the values were converted to Barks and the DCT coefficients for each contour were calculated using the emu package [7] in R [8].

3.2 Results

Figures 1 and 2 show the interactions of k_0 (mean) and k_1 (slope) for DS and TY respectively. The plotting includes a division by syllable: the number indicates either the first or second syllable (1 or 2) and the tone is indicated as H or L. Tone is also indicated by colour. A plot along the central, vertical line (k_1 = 0) indicates a flat contour, plots to the right (positive k_1 values) correspond to a negative slope or a falling contour with the slope increasing as the k_1 value increases. Negative k_1 values correspond to a rising slope

a) **Dene Sułine**

WORD	TONE	GLOSS	SPKRS
yéłk'éth	HH	*he shot it*	S A H
yédzi	HL	*he caught it*	S A H
ghedéł	LH	*they are walking*	S A H
thitth'í	LH	*I pinched him*	S A H
destur	LL	*I mix it*	S A H
ghegał	LL	*he is walking*	S A H
ghiził	LL	*I screamed*	S A H
hegheth	LL	*he is itchy*	S A H
hestı̨	LL	*I succeeded*	S A H

b) **Tłı̨chǫ Yatıì**

WORD	TONE	GLOSS	SPKRS
degho	HH	*bark*	M L
gokwi	HH	*axe*	M L
sechi	HH	*younger brother*	M L
ekwò	HL	*caribou*	M P
gobò	HL	*abdomen*	P L
gokè	HL	*foot*	M P L
gokwì	HL	*head*	M P L
dìga	LH	*wolf*	M P
kìwgha	LH	*hair*	M P L

Table 1: The words used for each language and the speakers for each word.

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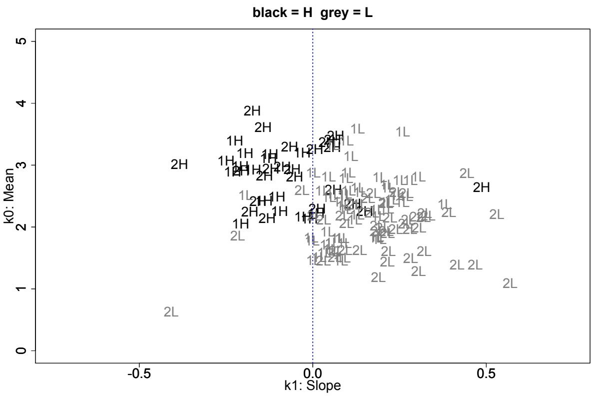

Figure 1: Interactions of k_1 (mean) and k_2 (slope) for high and low tones in Dene Sųłine.

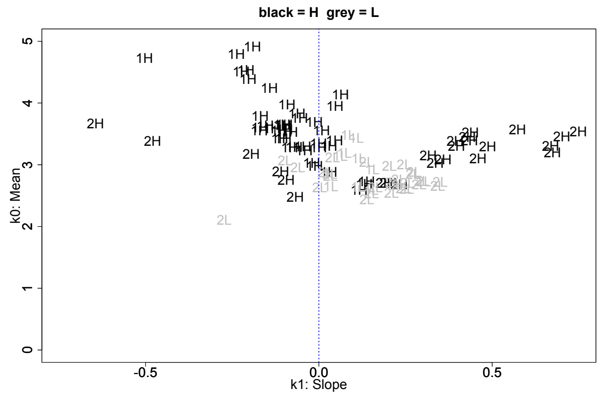

Figure 2: Interactions of k_1 (mean) and k_2 (slope) for high and low tones in Tłı̨chǫ Yatıì.

and increasing pitch contour. The mean corresponds directly with k_0 so a higher k_0 equals a higher pitch.

The calculations for each language were fitted separately to a linear model with k_0 (pitch) as the dependent variable and tone as the independent variable (high tone as the intercept). Results were significant for both DS ($F(1, 142) = 47.59$, $p = 1.60 \times 10^{-10}$) and TY ($F(1, 101) = 49.09$, $p = 2.79 \times 10^{-10}$). Similar models were fitted for k_1 (slope) but only DS showed significance ($F(1, 142) = 77.88$, $p = 3.654 \times 10^{-15}$).

4 Discussion

Visual examination of the graphs shows some interesting clustering for both languages. DS (Figure 1) shows fairly clear grouping by tone. The H tones appear to group to the left of the 0 slope line suggesting a slightly rising contour while the L tones show the opposite tendency.

Statistical analysis of the DCT coefficients for both languages show a significant difference in k_0 (pitch) between H and L tones. The languages differ when it comes to k_1 (slope). DS shows a significant difference between the tones in this regard. A closer look at the results also shows that H tones in DS do not differ significantly from the intercept (or 0) which would correspond to a level contour. This suggests that speakers of DS employ at least 2 different phonetic features to differentiate tone.

The graph for TY (Figure 2) shows binary clustering of the H tones with most of the 2H syllables showing a high k_1 well removed from the 1H syllables. This suggests word-final falling contours which may be a boundary tone effect. There was no significant difference between the k_1 (slope) values by tone suggesting that slope does not play a role in tonal differentiation in this language.

5 Conclusion

The findings suggest that the realization of the tones is quite similar between the two languages, with some interesting differences. There are differences in the realization of H tones in stems in Tłı̨chǫ Yatıì that may reflect an interaction of tone and vowel length [9]. Also, in Dene Sųłine, H tone tends to resist a fall in the stem (final syllable), unlike its L tones and both tones in Tłı̨chǫ Yatıì. This study implicates the importance of the differences in tonal specifications and alignment among the Dene tone languages in understanding tone patterns and tonogenesis. Future studies involve the interaction of tone, especially H tone and tonal alignment with vowel length, and the distinction between the realization of tone in the stem versus pre-stem domain.

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