

Segmental effects on tone: an acoustic analysis of tonal polarity in Xitsonga

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Abstract

Xitsonga nouns have plural prefixes that are added to a singular prefix-less root. These added prefixes (ADD) are described as being realized with a tone polar to the root vowel (RV): when RV is high (H) ADD is low (L), but when RV is L, ADD is H. Based on qualitative observations, Lee [8] formally analyzes tonal polarity in a constraint-based framework. This paper presents results from quantitative analyses of two speakers (male and female) and shows that tonal polarity in Xitsonga is asymmetrical. First, only H-toned roots are preceded by the ADD prefix with a polar tone. Second, the ADD prefix before toneless roots has a surface L tone. Any large F₀ difference in the latter case can be explained by segmental effects on pitch, such as depressor consonants and vowel height. The new findings are formalized by proposing that the specific OCP-H constraint outranks the general OCP constraint.

Index Terms: Tonal polarity, Xitsonga, noun class prefixes, OCP, depressor consonants

1. Introduction

Xitsonga is a southern Bantu language (S53 [5]) spoken in South Africa, Mozambique and Zimbabwe. Xitsonga has a two-way tonal contrast (high (H) tone and toneless (Ø)) and its Tone Bearing Unit (TBU) is the syllable. H tone is mobile and can spread rightward over multiple syllables. Xitsonga also has a group of consonants called depressors that include voiced obstruents and breathy voice consonants [1] [7] [9]. When H tone spreads (HTS) to an ØH noun, for example, HTS is blocked by depressors when they are the onset of an ØH noun [8].

In Xitsonga, singular nouns become plural in two different ways. In one way, plural prefixes substitute in place of singular prefixes. These are called the substitution type prefixes (SUB). In the other way, plural prefixes are added to prefixless singular roots. These are called the addition type prefixes (ADD). Cole-Beuchat [3] first describes that prefixes in Xitsonga display tonal polarity, in which an H tone initial root is preceded by a toneless prefix and a toneless initial root is preceded by an H tone prefix. The term ‘polarity’ refers to the assignment of opposite tonal values assigned to prefixes. Lee [8] presents data in which ADD shows tonal polarity (table 1), whereas SUB does not (table 2).

The ADD prefix is underlyingly toneless but is assigned to a tone that is polar to the tone of the root-initial vowel (RV). Based on tonal patterns in 196 nouns in a female Xitsonga speaker, the formal analysis in Lee [8] argues that tonal polarity is dissimilation c.f. [6], in which the Obligatory Contour Principle (OCP) constraint outranks the affix faithfulness constraint on tonal identity. Under this ranking, changes in the prefix tone are tolerated as long as they do not incur OCP violations. Xitsonga, however, has SUB prefixes that may violate the OCP in the surface representation. Lee [8] proposes that the high-ranked

Table 1: *Tonal pattern of ADD*

Singular root	PL Prefix	PL formation	Noun
[HL]	/Ø/	[L-HL]	
trónkò	ma-	mà-trónkò	‘prison’
[LL]	/Ø/	[H-LL]	
nàwù	mi-	mí-làwù	‘law’

Table 2: *Tonal pattern of SUB*

Singular root	PL Prefix	PL formation	Noun
[H-HH]	/Ø/	[H-HH]	
mú-gájó	mi-	mí-gájó	‘mealie meal’
[L-LH]	/Ø/	[L-LH]	
mù-gàngá	mi-	mì-gàngá	‘village’

paradigm uniformity constraint outrank OCP [4, 8] so that only ADD prefixes demonstrate tonal polarity.

In table 1, the plural [ma-] prefix (class 6) is realized with a surface L tone when the root has an H tone as in [trónkò], but it is realized with an H tone when the root begins with a surface L tone as in [nàwù]. The segmental change from [n] to [l] in [mí-làwù] is not relevant to the current study. In table 2, both an H-H sequence and a surface L-L sequence between the SUB prefix and the root are found. Empirically, SUB prefixes are capable of bearing the same tone as the first syllable of the root; tonal polarity is not observed in SUB.

The goal of this paper is to reexamine the data that is used for the basis of Lee [8]. Pitch measurements were taken from the vowel of ADD and the root-initial vowel (RV), both of which are CV. If ADD prefixes are subject to tonal polarity, we predict that pitch will be low before an H-toned RV and pitch will be high before a toneless RV. Results of an acoustic analysis, however, confirm only half of the prediction; the ADD prefix is low before an H-tone RV. When an ADD prefix has an H tone before a toneless RV, the surface H-L difference can be contributed to a co-articulatory factor; root-initial depressors affect the pitch difference between ADD and RV in that it lowers the pitch of the RV. This results in an apparent H-L tonal contrast. We suggest that tonal polarity in Xitsonga is uni-directional: an H-toned RV is preceded by a surface L-toned ADD prefix, but not vice versa.

Descriptively, the ADD prefix is realized with a surface L tone before an H-toned RV. What was previously described as H-L tonal polarity is in fact a phonetic artefact due to tonal co-articulation. These findings are also compatible with the previously proposed formal analysis. If roots are toneless (and not L-toned), adding a toneless prefix vacuously satisfies the OCP constraint. Additionally, the paradigm uniformity constraint is needed to explain why SUB prefixes can be realized with an H tone before an H-toned RV.

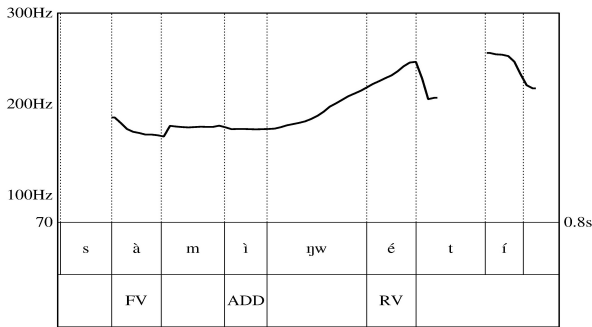


Figure 1: Female speaker *mì-ɲwétí* ‘moonshine’

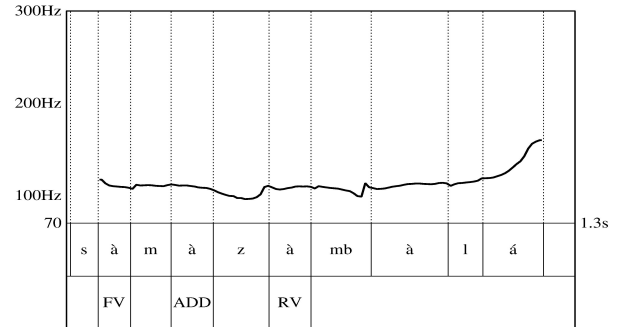


Figure 2: Male speaker *mà-zàmbàlá* ‘potato’

2. Method

Data in this paper comes from elicitations conducted by the first author in Limpopo, South Africa in 2010. The analyzed recordings are part of a larger set that aims to study the sound system of Xitsonga. Recordings were made into a Zoom H-4 recorder with a Shure WH-30 head-worn microphone. The sampling rate was 44.1 KHz and the quantization was 16-bit. Part of the data from the female speaker was used in Lee [8].

Stimuli were first elicited in a singular form in the L-toned carrier sentence *nì tìrhìsà* noun *kàɲwè* ‘I use *noun* once’. Speakers were thereafter instructed to produce a plural form in the same carrier sentence. Each form was spoken three times. Stimuli used in the analysis consist of 145 plural forms with the ADD prefix. Three repetitions of the forms by each speaker resulted in 870 tokens. Due to noise and other recording errors, 39 of the tokens were not used because F0 values could not be calculated.

In the plural forms, the following six landmarks were annotated in Praat [2]: (i) the beginning and end of the final vowel (FV) *à* of the verb in the carrier sentence, (ii) the beginning and end of the nucleus of the ADD prefix, and (iii) the beginning and end of the nucleus of the root vowel (RV). In singular forms, which lack the ADD prefix, four landmarks were annotated: (i) and (iii). Segmental information was added to the segment tier.

Measurements of F0 were extracted from the midpoint of every annotated segment using a Praat script. The results were then imported into R-studio for further statistical analysis. The targets for the statistical analysis were F0 of the nucleus of ADD and F0 of the nucleus of RV. If tonal polarity were attested in Xitsonga, we would expect a negative correlation between the value of these F0 measurements.

Figure 1 shows a pitch track of *mì-ɲwétí*”, in which the RV of the noun is H-toned. The pitch difference between the ADD prefix and RV is close to 55 Hz.¹

In figure 2, the RV of *zàmbàlá* ‘potato’ is toneless. The pitch track of the ADD prefix *ma-* displays a non-dynamic pattern. The pitch is relatively flat from the toneless FV of the carrier sentence to the second syllable of the root. Thus, the ADD prefix is toneless.

3. Analysis

Statistical analysis was conducted on 210 items of a singular-plural pair with 3 repetitions, resulting in a total of 630 tokens. From the 630 tokens, 24 tokens were not included in the analysis

¹Measurements of the two additional repetitions record a 45 Hz and a 55 Hz pitch difference between ADD and RV. The intra-speaker reliability is high.

because they belong to a singular form or a plural form with less than 3 data points. Data from the male speaker comprises 102 tokens of nouns with the lexical H tone and 78 tokens of toneless nouns (total 180 tokens). Data from the female speaker consists of 228 tokens with the lexically H-toned nouns and 198 tokens of toneless nouns (total 426 tokens).

A linear mixed model was run with the lmer package in R on tokens that have ADD and RV: 90 tokens (270 items) from the male speaker and 213 tokens (639 items) from the female speaker. The random effects were *speaker* and *item*. The factors were (i) the lexical tone of root vowel (two levels: H and toneless), (ii) the vowel quality of RV (three levels: high, mid and low) and (iii) the nature of the root initial consonants (two levels: depressor and non-depressor). The dependent variable was the pitch difference between ADD and RV (calculated by subtracting the ADD value from the RV value).

4. Results

Results show that the [L-H] tonal polarity exists, but not the [H-L] tonal polarity. RVs with a lexical H tone are preceded by an ADD prefix that has a low pitch, but a toneless RV is not preceded by an H-pitched ADD prefix. This finding suggests that tonal polarity in Xitsonga is asymmetrical. Scatter plots of pitch values of RV and ADD for male and female speakers are shown in figures 3 and 4 respectively. The asymmetrical pattern of tonal polarity is found in both figures. If tonal polarity were symmetrical in Xitsonga, we would predict that scatter plots of F0 values taken from ADD and RV would show a negative correlation; when RV has a high F0 value, ADD should have a low F0; when RV has a low F0 value, ADD should have a high F0. Figures 3 and 4 show that no such negative correlation exists between ADD and RV in Xitsonga. Even so, the scatter plots display an interesting pattern. Both figures 3 and 4 demonstrate that the F0 value of ADD is always low in the male’s speech (less so in the female’s speech), regardless of the tone of RV.

Our hypothesis is that there is a difference in the pitch value between the ADD prefix and RV, assuming tonal polarity is asymmetrically present. The null hypothesis was that the pitch value of ADD and that of RV are not the same.

The linear mixed effects model shows that there is more variation in the results for different items (s.d. = 14.005) than there is for different speakers (s.d. = 8.669). The standard deviation of the residual (s.d. = 8.267) is close to that of *speaker*, which suggests that the effects of the speakers are minimal. Between the random effects, the item differences have a bigger effect on the pitch difference.

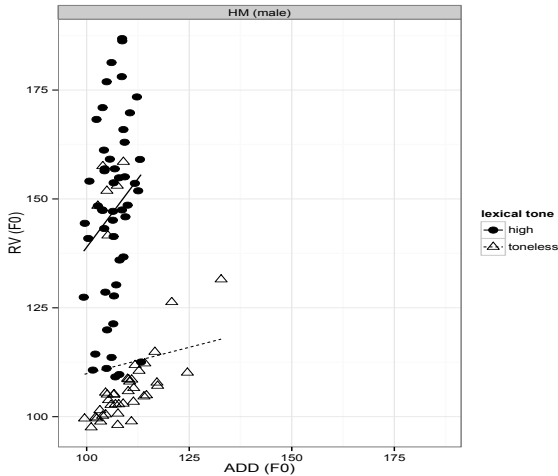


Figure 3: A scatter plot of F0 values extracted from ADD (x-axis) and RV (y-axis); RV is lexically H or toneless, male speaker

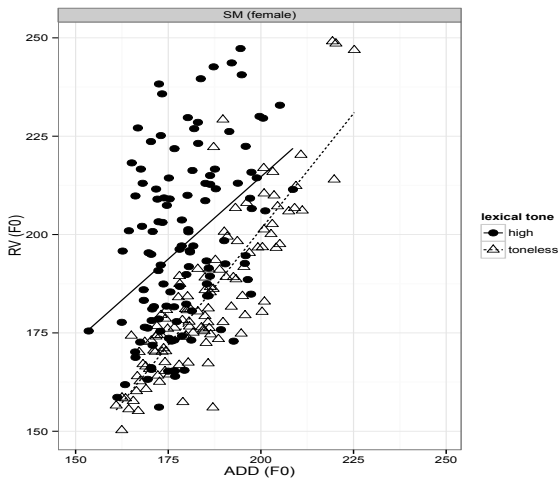


Figure 4: A scatter plot of F0 values extracted from ADD (x-axis) and RV (y-axis); RV is lexically H or toneless, female speaker

The baseline condition is when the RV is a high vowel with a high tone and when the RV is preceded by a depressor consonant. The average pitch difference between RV and ADD for this baseline condition is 25.691 Hz; the positive value indicates that RV has higher pitch than ADD. Among the fixed effects, the lexical tone root of the vowel is a factor with the largest effect. The RV tone (H tone vs. toneless) affected the pitch difference between RV and ADD ($\chi^2 = 57.60$, $p < 0.01$), lowering it by about 23.3 Hz +/- 2.8 (standard errors). The root initial consonant (depressor vs. non-depressor) also affected the pitch difference between RV and ADD ($\chi^2 = 6.66$, $p < 0.01$), raising it by about 8.73 Hz +/- . However, the vowel quality did not affect the pitch difference ($\chi^2 = 5.0353$, $p = 0.08$)

Figure 5 shows the effect of lexical tone to the ADD-RV pitch difference: there is a significant pitch difference with H-toned RVs but not with toneless ones (marked as L). When RV is toneless there is no significant pitch difference between ADD and RV (on average, -5 Hz for the male speaker and -3 Hz for the female speaker). When RV has a lexical H tone, the pitch differ-

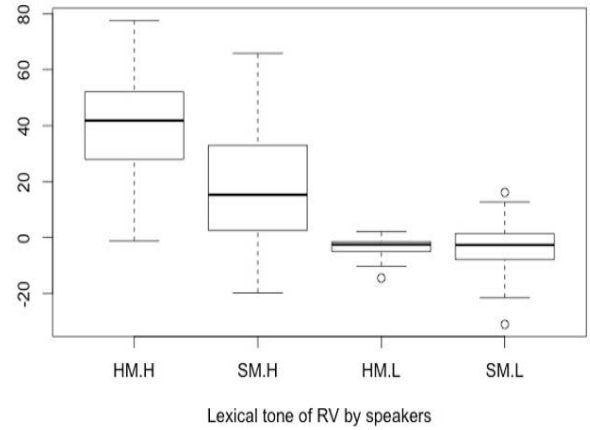


Figure 5: A result of a linear mixed effects model showing the effect of the the lexical tone of RV on the pitch difference between ADD-RV by speakers (HM = male, SM = female, H = H tone, L = toneless)

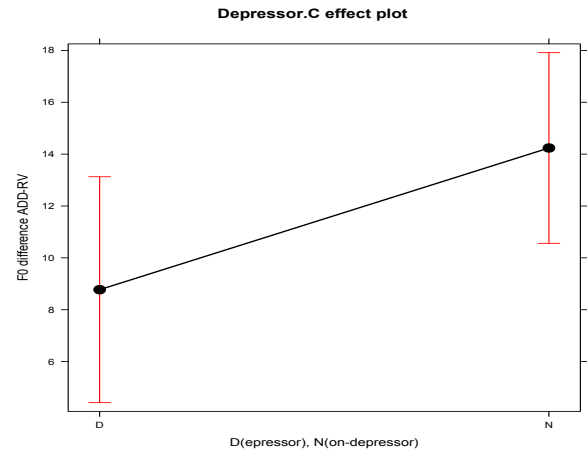


Figure 6: A result of a linear mixed effects model showing the effect of the RV consonant on the pitch difference between ADD-RV

ence between ADD and RV is significantly greater, confirming that H-tone RVs are preceded by the ADD prefix with a surface L tone (underlyingly toneless).

Figure 6 represents the effect of depressor onsets in the RV. Regardless of the lexical tone of RV, depressor consonants (D, left side) induces smaller pitch difference between ADD and RV than non-depressors (N, right side). Our statistical model showed that root initial consonants have a significant effect on the pitch difference. This means that any pitch lowering by depressors cannot be considered as a phonological factor. There are 31 toneless items (9 from male, 12 from female) with a depressor initial root. Qualitative examinations of these roots would have produced a result where the pitch of RV of a depressor-initial root is lower than the pitch of ADD. This is probably why the symmetrical tonal polarity analysis was proposed in the first place.

Figure 7 illustrates the phonetic depressor effect on pitch in toneless nouns: *byàlwá* 'beer'. Although the pitch of the ADD prefix *ma-* is 15 Hz higher than the RV, it is not the case that

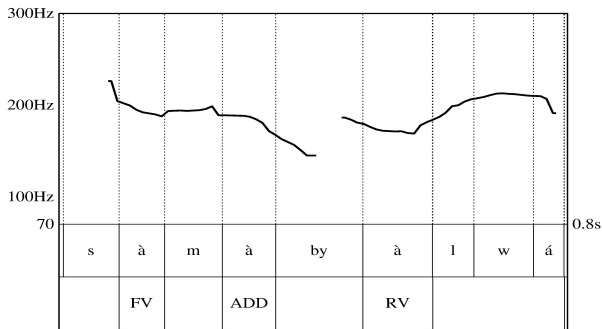


Figure 7: female speaker mà-byàlwá ‘beer’

ADD has a phonological high tone. Rather, it is the initial depressor consonant *by* in the beginning of the root that is phonetically lowering the pitch of RV.

Results of acoustic analyses show that H-toned roots are preceded by a surface L tone, and toneless roots are also preceded by a surface L tone. Depressor consonants of the RV have a significant effect on the ADD-RV pitch difference while vowel quality does not.

5. Discussion

Previous descriptions and analyses of Xitsonga argue that tonal polarity is an active phonological process in Xitsonga [3] [8]. These analyses were based on qualitative observations of Xitsonga data. However, acoustic analyses presented in this paper bring a new understanding of tonal polarity. In Xitsonga, tonal polarity has at most an asymmetrical pattern. Only H tone nouns are preceded by a surface L-toned ADD prefix. Toneless nouns are not preceded by an H tone. Depressor consonants in RV attest an effect on the pitch difference between ADD-RV. This accounts for nouns such as *byàlwá* ‘beer’ in figure 7. (If the F0 difference between ADD and RV is greater than 15 Hz in toneless roots, the difference can be explained by other acoustic factors such as the presence of a root-initial depressor consonant, which lowers F0, coupled with a high vowel in the ADD prefix, which raises F0.)

In the absence of acoustic evidence for symmetrical tonal polarity, we need to revisit the previous tonal analysis proposed in [8]. First, are constraints that drive tonal polarity in [8] still active in Xitsonga? Tonal polarity surfaced when OCP dominates Ident-T. The acoustic results show that nouns with a lexical H tone display tonal polarity, but not toneless nouns. As such, the active constraint driving tonal polarity should be the specific OCP-H, which only bans two adjacent but separate H tones in the surface. Any L-L sequences in the surface will be vacuously satisfied by the specific OCP-H constraint, which is ranked higher than the general OCP constraint. Second, is paradigm uniformity still at work in Xitsonga ([8])? The paradigm uniformity constraint (Ident-BO-T) needs to outrank OCP-H, so that the plural *mí-gájó* ‘mealie meals (cl4)’ and the singular *mú-gájó* ‘mealie meal (cl3)’ have both H-toned prefixes followed by an H-toned root. The higher ranked Ident-BO-T will have no effect on toneless roots with the ADD prefix.

The findings also have implications for tonal marking in Xitsonga. A notation system must mark H tones but may dispense with marking L tones. In [3], surface L tones are marked with a grave accent and surface H tones are not marked. This type of

representation misguides readers by giving the impression that L tones are active, when it is in fact H tones that are active in the tonal grammar. As such, in a representational theory of tone, the tonal contrast in Xitsonga is H versus \emptyset . Such an underlying tonal contrast can account for the absence of polar tone in the ADD prefix preceding toneless roots. When RV is toneless, ADD has no tonal reference for its tone assignment. Thus, ADD remains toneless (or L tone) in the surface. When RV is H, ADD is realized with a polar tone.

6. Conclusion

We have shown that Xitsonga has an asymmetrical tonal polarity pattern. The acoustic analysis demonstrates that significant pitch differences between the ADD prefix and the root vowel (RV) are found when RV has a lexical H tone, but not when RV is toneless. Deviations from this pattern are accounted for by segmental effects on pitch caused by depressor consonants. The significant effect of lexical tone and depressor consonant on the ADD-RV pitch difference is shown by a linear mixed effect model. These findings suggest that Xitsonga tonal polarity is better analyzed with the specific OCP-H constraint, rather than the general OCP constraint (updated from [8]). The OCP-H constraint is still outranked by the Base-Output Identity constraint because OCP-H may be violated in the SUB prefixes.

7. Acknowledgements

This study would not have been possible without the assistance from two Xitsonga consultants from University of Venda. We would like to thank Felix Golcher for the help with R, Jeremy Perkins for a Praat script and Imer statistics and Clementinah Burheni for additional Xitsonga data. Parts of the research were funded by CCSU Research Grant, Dean’s Research Initiative, CCSU travel funds and a post-doctoral fellowship by the Volkswagen Foundation and the Andrew W. Mellon Foundation, all of which were awarded to the first author. We also thank Marzena Żygis, Caterina Petrone and Will Bennett for their comments and suggestions. Of course, the usual disclaimer applies.

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