

The Interaction of Tone, Phonation Type and Glottal Features in Zaiwa

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1. Introduction

Zaiwa (Tsaiwa) is a language of about 100,000 speakers in the Northern Burmish Branch of the Tibeto-Burman language family. It is spoken in parts of Kachin State in Northern Burma and in parts of Southwest Yunnan China. The Zaiwa have a close cultural relationship with the Jinghpaw people and borrow extensively from the Jinghpaw language, as well as from Burmese and Yunnanese Chinese. Zaiwa has contrastive tone and contrastive tense-modal voice quality.²

Tibeto-Burman languages, and Asian languages in general, tend to show some correlations between initial consonant voicing, voice quality and tone register (Haudricourt 1954, Matisoff 1973). In particular, voiceless initials correspond with high tone and voiced initials correspond with low tone. Attempts have been made to explain the correlations between tone, consonant voicing and voice quality using feature geometry and features of the glottis under the laryngeal node (Duanmu 1991, Yip 1993, 1995). Both Duanmu and Yip propose models of the laryngeal node in which obstruent voicing always correlates with tone register. Neither model is adequate for Zaiwa, which distinguishes tone based on glottal features of the initial and final consonant in checked syllables only.

In this paper I will discuss the interaction between tone, syllable type, phonation type and laryngeal features. I will then propose a model of feature geometry which accounts for tone in both checked and unchecked syllables. Finally, I will present an analysis which accounts for the

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²In this paper 'phonation type' and 'voice quality' are used interchangeably.

observed interactions between tone, phonation, and laryngeal features based on underspecification theory and the proposed feature geometry.

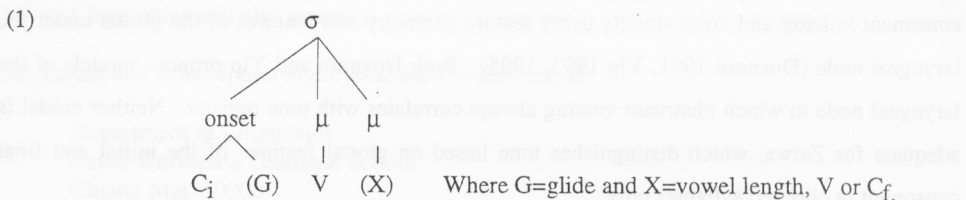
2. Zaiwa Syllable, Tone, Phonation Type and Glottal Features

In order to address the interactions between tone, syllable type, phonation type and the laryngeal features of segments, a brief introduction to each area is necessary.

2.1 Zaiwa Syllable Structure

Zaiwa has six types of stressed syllables: CV:, CVV, CCV:, CCVV, CVC and CCVC. Each syllable consists of an obligatory initial consonant (C_i), an obligatory vowel nucleus (V), and carries an obligatory tone and either clear or tense voice quality. The Zaiwa syllable can be either open or closed with the coda (C_f) inventory limited to voiceless plosives and nasals. The V: is a long vowel while the VV represents a diphthong. Syllable initial consonant clusters begin with plosives or nasals and the second member of the cluster is either /j/ or /ɹ/.

In a previous paper, (Wannemacher 1995), the moraic framework for Zaiwa syllable structure was represented as shown in (1):



Examples of each stressed syllable type are shown in (2):³

(2)	CV:	[pɔ ³¹]	'frog'	[wa ³¹]	'bamboo'
	CCV:	[k ^h jɔ ⁵³]	'road, path'	[bjɔ ³¹]	'bee'
	CVV	[bui ³²]	'sun'	[mau ³¹]	'rain'
	CCVV	[grai ³²]	'very'		

³A "+" symbol under a vowel designates tense voice quality.

CVC	[tʃ ^{ba} 31ŋ]	'ginger'	[nɔ ⁵ t]	'mouth'
CCVC	[mjɪ ³⁴ n]	'night'	[mjɔ ⁵⁴ k.e21]	'bury'

Zec (1995) has shown that cross-linguistically, syllabic and moraic segments may belong to different sonority classes. The sonority of the syllabic segments is equal to or greater than the sonority of the moraic segments. Three classes of segments can be identified in Zaiwa based upon sonority. Two classes correspond to syllabicity and moraicity, while an additional third class corresponds to tone bearing units (TBUs). Zaiwa sonority classes are shown in (3):

- (3)
- | | | |
|------------|--------------|-----------------------------------|
| a. [-cons] | vowels | corresponds to syllabicity |
| b. [+son] | sonorants | corresponds to tone bearing units |
| c. ----- | all segments | corresponds to moraicity |

This table shows that in Zaiwa all segments are moraic, but not all segments can be tone bearing units. A TBU in Zaiwa is defined as a [+son] mora. All non-sonorant moras in Zaiwa are voiceless stops and therefore are unable to carry pitch.

2.2 Zaiwa Tone

Zaiwa has three contrastive tones: high falling (53), mid-high level (4), and mid-falling (31). In open syllables and in syllables closed by a nasal, all three tones contrast irrespective of initial consonant voicing and voice quality. In checked syllables there are only two tones, high-falling (53) and mid-falling (31). The 53 tone is shortened to 5 or 54, and the 31 tone is shortened to 3 or 32 due to the inability of the non-sonorant coda to carry pitch. Examples of Zaiwa tone distribution and tone shortening are shown in (4):

- (4)
- | | | | | | | | |
|---|----------------|--------------------------------------|-------------|--|---------|--------------------------------------|---------------|
| a. [hu ⁵³ ŋ] | 'gold' | [hu ⁴ ŋ.e ³] | 'long' | [hɔ ³¹ ŋ] | 'canal' | [hu ⁵ p] | 'small leach' |
| b. [mu: ⁵³] | 'job' | [mau ⁴] | 'body hair' | [mu: ³¹] | 'then' | [mu ³² t.e ³] | 'hungry' |
| c. [mja ⁵³ ŋ.e ³²] | 'about horses' | [mja ³ ŋ.e ³] | 'long time' | [mja ³¹ ŋ.e ¹²] | 'see' | | |
| d. [nɲa ⁵³ m.e ³²] | 'slow' | [nɲa ³ n.e ³] | 'shiver' | [mja ³² ŋ.e ¹²] | 'tall' | | |

Rows a. and b. show that tone is fully contrastive on unchecked syllables with both voiced and voiceless initial consonants and also show tone shortening in checked syllables. Rows c. and d. show that tone is not dependent on voice quality in unchecked syllables.

In unchecked syllables tone is assigned by associating tone from an autosegmental tier to a TBU as expected. In checked syllables, however, tone is derived by spreading glottal features from the surrounding segments. The specifics of tonal derivation in checked syllables is the focus of this paper and will be addressed further in section 3, Tone Derivation from Glottal Features in Checked Syllables.

2.3 Zaiwa Phonation Types

Phonation types are determined by different states of the glottis and give the voice a certain distinctive quality. Zaiwa has contrastive tense and modal voice qualities. Tense voice is characterized by tightened vocal folds and a constricted glottal aperture. It is distinguished by a distinct 'tight' setting which overlays the segments of the syllable. Modal voice has normal vocal fold tension and normal glottal aperture.⁴ The syllable is the domain of contrastive voice quality. Tense voice quality only occurs on syllables which have [-spread] initial consonants due to its historical origins.⁵

2.4 Laryngeal Features of Zaiwa

The laryngeal features of Zaiwa segments and autosegments are relevant to the discussion of tone-feature interactions. The inventory of consonants and vowels in Zaiwa is shown in (5):

⁴For a more detailed description of tense and modal voice qualities, see Laver, 1980.

⁵Burling (1967) attributes laryngealization in Tibeto-Burman languages to a proto-Tibeto-Burman preglottalized series. Aspirated stops were not preglottalized.

(5)

ZAIWA CONSONANTS				ZAIWA VOWELS	
p ^h	t ^h	k ^h	ʔ	i	u
b	d	g		e	ɔ
	ts ^h	tʃ ^h		a	
	dz	dʒ			
	s	ʃ	h	ZAIWA DIPHTHONGS	
m	n	ɲ	ŋ	ui	ai
	l			ua	
w	r	j			

Allophonic variations which are relevant to this discussion are shown in (6):

- (6)
1. Syllable final voiced stops become voiceless and unaspirated and occur as co-articulated stop-ʔ, written [p t k] syllable finally.

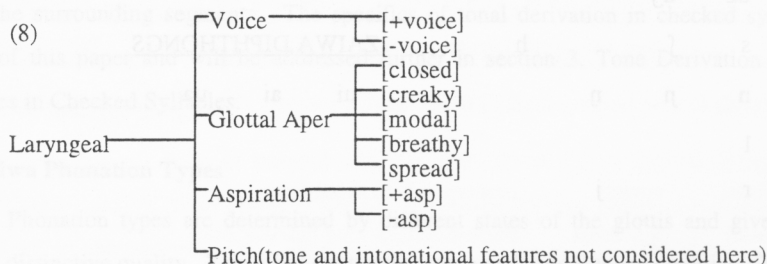
2. Syllable initial voiced obstruents become voiceless [p t k tʃ ts] in tense syllables.

Voicing, pitch, glottal aperture, and vocal fold tension are the laryngeal features which are necessary to represent the interaction of tone with other aspects of Zaiwa phonology. Halle and Stevens (1971) proposed [+/-spread glottis], [+/-constricted glottis], [+/-stiff vocal folds] and [+/-slack vocal folds] as features which are distinctive for voicing, tone height and phonation types. The problem with this model is that consonant voicing and tone are both linked to vocal fold tension and cannot be represented independently as shown in (7):

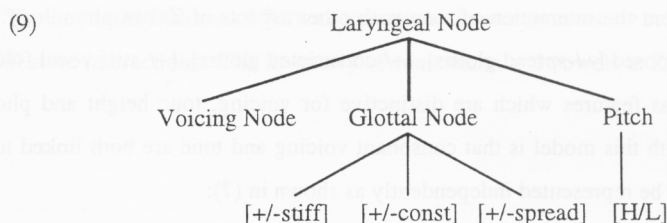
(7)

Stops	b	p
Vowels	V (low tone)	V (high tone)
stiff vocal folds	-	+
slack vocal folds	+	-

Ladefoged (1989) suggests voicing, glottal aperture, aspiration and pitch as laryngeal features which should apply to all contexts as shown in (8). His glottal aperture node has five settings ranging from [closed] (glottal stop) to [spread] (voiceless segments). Tension settings and glottal aperture are assumed to coincide.



In this paper a combination of three of the laryngeal features proposed by Halle and Stevens, [+/-spread], [+/-stiff] and [+/-const], and three of the nodes dependent on the laryngeal node proposed by Ladefoged, voicing, glottal aperture and pitch, will be used. The glottal aperture node will be redefined as a glottal node, including both glottal aperture and vocal fold tension settings. The suggested laryngeal feature hierarchy is shown in (9):⁶



In this paper we are interested in tone in checked syllables only, which, as stated earlier, will be derived from the glottal features of the segments surrounding the syllable nucleus. Therefore, the pitch node of the laryngeal feature tree is unnecessary in checked syllables and

⁶Using the three laryngeal features of Halle and Stevens (1971) it is possible to reduce all five of Ladefoged's glottal aperture distinctions to binary features of the glottis. The [H/L] features of the pitch node are actually tonal registers with pitch features, but this is not in focus here.

will be left out in the following discussion. Table (10) shows the laryngeal features of segment classes and voice quality in Zaiwa, (where vf=vocal folds):⁷

(10)

	[+son]	tense voice	[-son] voiced	[-son] vl asp	[-son] vl unasp (tense voice) ⁸	vl unasp stop-ʔ,ʔ
voicing	+		+	-	-	-
stiff vf	-	+	-	+	+	-
const vf	-	+	-	-	+	+
spread vf	-	-	-	+	-	-

These features will be used to derive tone in checked syllables.

3. Tone Derivation From Glottal Features in Checked Syllables

Tone in checked syllables is predictable from the voicing of C_i and the presence or absence of tense voice quality. If C_i is voiceless, then tone is a shortened high-fall (5, 54). If C_i is voiced, then tone is a shortened mid-fall (3, 32). If the syllable has tense voice ([+stiff] autosegment), then tone is a shortened high-fall (5, 54) independent of C_i voicing. A syllable final stop-ʔ (C_f) is the necessary environment to allow initial consonant voicing and tense voice quality to effect tone. Examples of tone in checked syllables are shown in (11):

(11)

[bi ³² k]	'shoot'	[p ^h ji ⁵ k]	'spicy'	[p ⁱ ⁵⁴ k]	'kick'
[lɔ ³² ʔ]	hand	[su ⁵⁴ t]	'kill'	[lɔ ⁵ p]	'flash'
[nr ³² k]	'bamboo shoot'			[nr ⁱ ⁵ k]	'heart'

⁷Feature assignment to classes follows Halle and Stevens (1971). A glottal stop or glottal closure may be either [+const] or both [+const] and [+stiff]. The Zaiwa glottal stop allows more tone fall than a coarticulated stop-ʔ because air is allowed to leak through the glottis similar to a creaky glottal closure. A creaky glottal closure is [-stiff], giving [-stiff] for Zaiwa stop-ʔ, and ʔ.

⁸Allophonic variation described in (6), no. 2. Restricted to vl, unaspirated stops and affricates since [+spread] segments never initiate tense syllables.

⁹Allophonic variation described in (6), no. 1.

It is clear that syllable type, voice quality, and voicing, all interact to predict tone in checked syllables. I will show that all of these interactions can be reduced to the spreading of glottal features from segments and autosegments to the glottal nodes of vowels. Underspecification and the feature geometry of the laryngeal node will be used to explain the interactions.

3.1. Underspecification of Laryngeal Features

Underspecification of the laryngeal features is useful in associating only the necessary contrastive features of the larynx to the segments so that the three glottal features involved in tonal derivation, [+/-stiff], [+/-const], and [+/-spread], can perform their phonological functions without interference from features which do not contrastively distinguish tonal or segmental differences. Underspecification also allows features to be associated with segments in unchecked syllables without an effect on tone. The laryngeal feature classes can be represented using underspecification as shown in table (12):

(12)

	[+son]	tense voice	53		[-son] voiced	[-son] vl asp	[-son] vl unasp (tense voice)	vl unasp stop-?,?
voicing								
stiff vf		+	+				+	
const vf			+	+				+
spread vf				+		+		

Table (12) shows that the same laryngeal features can be used for segments, voice quality and tone in checked syllables. The voicing of sonorant segments is unspecified and is filled in later with a default rule. The voicing of non-sonorant segments is unspecified and is predictable from the glottal features in the table. Notice that tone 53 has been added and specified by features of the glottal node. Tone 31 is unspecified and filled in by a default rule.

There are two glottal feature combinations which will lead to a shortened high-falling tone in a checked syllable. The glottal features [+stiff] and [+const] work in combination to raise the frequency of vibration of the vocal folds and, therefore, raise pitch. Stiff vocal folds vibrate at a higher frequency than non-stiff vocal folds. A constricted glottis requires greater sub-glottal air pressure to vibrate the vocal folds which are approaching closure as the vowel anticipates the

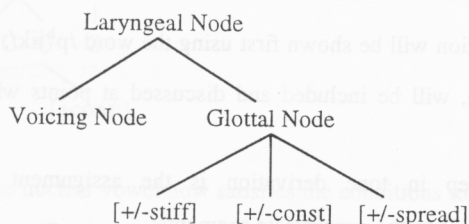
co-articulated stop-?. The higher the sub-glottal pressure, the higher the frequency of vibration of the constricting vocal folds. The spreading of these two features to the glottal node of the vowel nucleus of the syllable raises pitch. The glottal features [+spread] and [+const] also work together to raise pitch, but in a slightly different manner than [+stiff] and [+const].¹⁰ The pitch raising effect here depends to some extent on the Bernoulli effect (Ladefoged 1972). Air moving past a constriction (larynx) in a tube (trachea) causes a suction to be produced and pulls air through the constriction at a faster rate over time. The higher the airflow, the greater the effect. A spread glottis allows air to move through the glottis at a high rate. As the spread glottis closes to allow for voicing, the high rate of airflow vibrates the vocal folds at a higher frequency. This, in combination with increased sub-glottal pressure due to a narrowing of the glottis, raises pitch.

In summary, the underspecification table shows the overlap between tone and glottal features in checked syllables and shows that voicing of stops is redundant with glottal features. The next step is to refine the laryngeal feature tree to allow for representation of all necessary features in checked syllables with minimal apparatus.

3.2 Feature Geometry of the Laryngeal Node in Checked Syllables

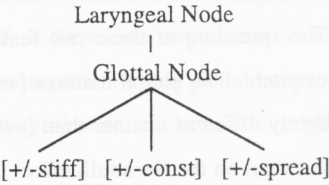
The basic feature geometry of the laryngeal node is shown in (9). As mentioned in sections 2.4 and 3.1, the pitch node is not necessary in checked syllables and voicing of non-sonorants is predictable from the features of the glottal node. These facts give the adjusted feature geometry for sonorants, (13), and non-sonorants, (14), in checked syllables:

(13) Sonorants:



¹⁰[+spread] segments are also generally [+stiff] and both features may influence the rise in pitch. The choice of [+spread] as the distinctive feature for aspirated obstruents is based on the use of [+stiff] for tense voice quality. Separating [+spread] and [+stiff] and making each a distinctive feature in the underspecified representations allows both to have a similar effect on pitch in checked syllables, but separates the features for tense voice and aspiration in unchecked syllables so that they can work independently.

(14) Non-sonorants:



Using the reduced feature geometry, it is now convenient to show how tone in checked syllables is derived based on glottal features of the segments surrounding the vowel nucleus.

3.3 Step by Step Derivation of Tone in Checked Syllables

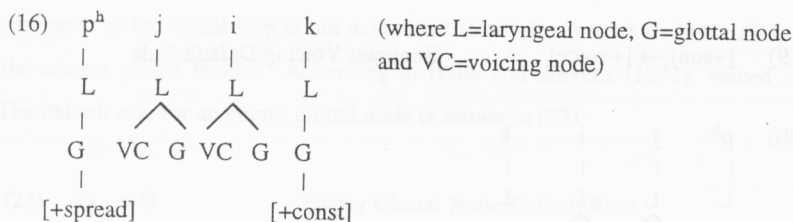
The derivation of tone will now be demonstrated step by step in checked syllables with the initial consonants and voice qualities shown in (15). This will demonstrate the observed interactions between tone, glottal features and voice quality.

(15) Initial Consonant/VQ	Represents Class	UF ¹¹	SF	gloss
a. p ^h	[-son], voiceless, aspirated	/p ^h jik/	[p ^h ji ⁵ k]	'spicy'
b. b	[-son], modal voice	/bik/	[bi ³² k]	'shoot'
c. b, tense voice	[-son], tense voice	/bjik/	[p _i ⁵⁴ k]	'kick'
d. n	[+son], modal voice	/nik/	[ni ³² k]	'bamboo shoot'
e. n, tense voice	[+son], tense voice	/njik/	[n _i ⁵ k]	'heart'

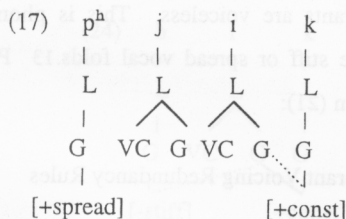
A full derivation will be shown first using the word /p^hjik/, 'spicy'. Portions of the other derivations, (15) b-e, will be included and discussed at points where they differ and provide further insight.

The first step in tone derivation is the assignment of the features from the underspecification table to the appropriate segments:

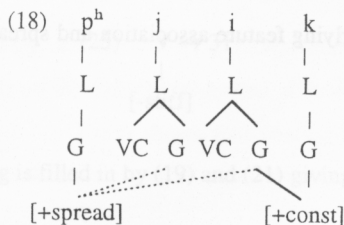
¹¹Notice that tone is not marked in the phonemic representation of checked syllables. Since tone is predictable, no overt reference is necessary. This would agree with Mazaudon's observation that proto-Tibeto-Burman had a single tone in checked syllables (1976).



Next, the feature [+const] is spread from right to left to the empty glottal node of the preceding segment, which is always the vowel nucleus. It does not spread any farther since the only segment which is effected by the glottal closure is the immediately preceding vowel.



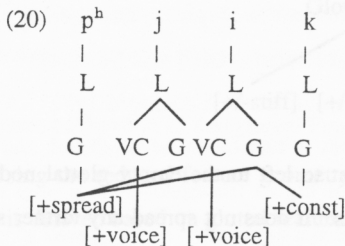
Next, the glottal features from the initial consonant are spread left to right to all available glottal nodes:



The glottal node of the nuclear vowel now satisfies the conditions to derive a high-falling tone as shown in the underspecification table. The voicing of sonorants is filled in using the sonorant voicing default rule (19). This is demonstrated in (20):¹²

¹²Notice that the association lines between glottal features and the glottal node do cross the association lines between voicing features and the voicing node. These two nodes are on different tiers, however, and therefore the line crossing is not prohibited.

- (19) [+son] → [+voice] Sonorant Voicing Default Rule



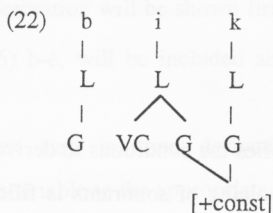
The surface voicing for [-son] segments is determined by the glottal features. A [-stiff] non-sonorant is voiced. [+stiff] or [+spread] non-sonorants are voiceless. This is phonetically plausible due to the fact that it is difficult to vibrate stiff or spread vocal folds.¹³ Phonetic redundancy rules for non-sonorant voicing are shown in (21):

- (21) [-stiff] → voiced Non-sonorant Voicing Redundancy Rules

[+stiff] or [+spread] → voiceless

Filling in phonetic tone and following the phonetic redundancy rules for non-sonorant voicing gives the correct surface form for 'spicy': [pʰji⁵k].

The derivation of /bik/, 'shoot', following underlying feature association and spreading as above, gives the representation in (22):



¹³Obstruents are affected due to the high supraglottal pressure caused by oral closure, decreasing airflow to a level too low for focal fold vibration. Sonorants, however, have sufficient airflow to maintain voicing.

The glottal node of the initial stop is not associated to any feature. A default rule is needed to assign the correct glottal feature. According to Halle and Stevens (1971), voiced stops are [-stiff]. The default rule for an empty glottal node is shown in (23):

- (23) $G \rightarrow G$ Empty Glottal Node Default Rule
 |
 [-stiff]

The [-stiff] feature is associated to the left most unassociated glottal node and spreads left to right to available glottal nodes:

- (24)
- ```

 b i k
 | | |
 L L L
 | / \ |
 G VC G G
 | | |
 [-stiff] [+const]

```

The glottal node of the nuclear vowel is now [-stiff], [+const], which is not a valid feature combination for a 53 tone. The default mid tone rule fills in the phonetic tone:

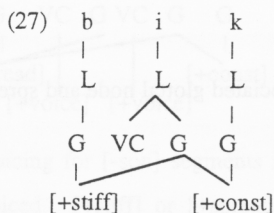
- (25)  $V \rightarrow 31$                       Default Mid Tone Rule  
       |  
       [-stiff]

Voicing is filled in by (19) and (21) giving the surface form shown in (26):

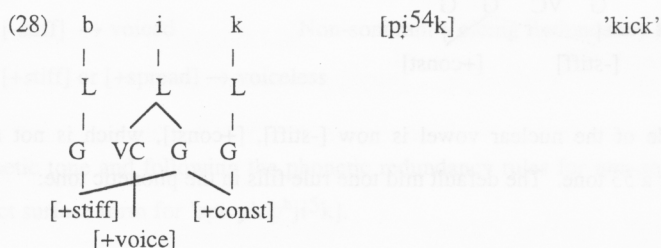
- (26)
- ```

      b       i       k           [bi31k]       'shoot'
      |       |       |
      L       L       L
      |       / \      |
      G      VC  G     G
      |       |       |
      [-stiff] [+voice] [+const]
  
```

The derivation of the word /bik/, 'kick', starts with the association of features from the underspecification table and feature spreading. The feature [+stiff], the tense voice autosegment, comes from the underspecification table, and is associated with the first slot in the syllable and spreads left to right.



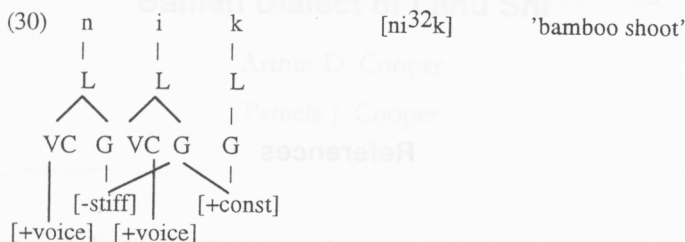
Tone is assigned and rules (19) and (21) are applied to give the surface form in (28):



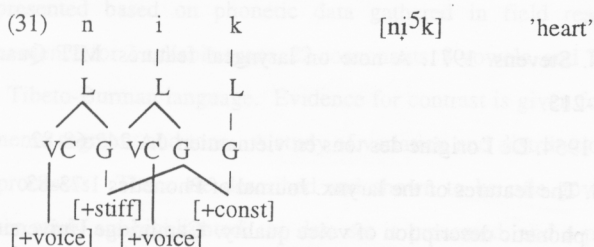
The rules used to derive tone and voicing for (15) a, b, and c, are listed in (29):

- (29)
1. Associate glottal features from the underspecification table (12).
 2. Spread the glottal features to the vowel nucleus.
 3. Apply default sonorant voicing rule (19) and empty glottal node rule (23).
 4. Assign phonetic tone based on glottal features in underspecification table. If features for tone assignment are not associated apply the default mid tone rule (25).
 5. Assign phonetic voicing to non-sonorants based on non-sonorant voicing redundancy rules (21).

Sonorant initial checked syllables behave similarly to non-sonorant initial checked syllables. Rules 1-4 apply to derive the correct surface structure for (15d):¹⁴



Rules 1-4 are also applied to sonorant initial syllables with tense voice quality as demonstrated with in (15) e:



Comparing 'bamboo shoot', (30), and 'heart', (31), shows that sonorant voicing is not determined by features of the glottal node. Therefore an independent voicing node is necessary for sonorants. (31) also shows that voicing is not a critical feature for determining tone height in checked syllables.

4. CONCLUSION

This paper presents an analysis of the interaction between tone, glottal features and voice quality in checked syllables. By using underspecification and feature geometry, the process by which tone is assigned in checked syllables is described. The spreading of the glottal features

¹⁴The sonorant voicing default rule could be modified to associate [+voice] to the first [+son] segment in a syllable and spread to satisfy the OCP. This would do away with two [+voice] features in 'bamboo shoot'.

[+/-stiff] and [+/-spread] in combination with [+/-const] are shown to be responsible for the determination of tone at the surface level in checked syllables. It is also shown that voicing correlates with glottal features in non-sonorant initials but is not a critical feature for tone assignment.

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