SOME PHONOLOGICAL AND PHONETIC ASPECTS OF STRESS AND INTONATION IN LAKHOTA: A PRELIMINARY REPORT*

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1. INTRODUCTION

This paper investigates some phonological and phonetic aspects of stress and intonation in Lakhota. The simultaneous study of stress and intonation is necessary because it is known cross-linguistically that these features significantly interact with each other. For example, in English, pitch accent (e.g., H* or L*), which is one of the primary constituents of the intonation system, falls on lexically determined stressed syllables (e.g., Pierrehumbert, 1980; Beckman and Pierrehumbert, 1986); similarly, in Japanese, lexical stress draws the intonational peak (e.g., Beckman and Pierrehumbert, 1986). In what follows, I will first review some phonological aspects in Lakhota stress in section 2, and discuss some acoustic correlates of stress in section 3 based on results of a small-scaled acoustic study. In section 4, I will present a preliminary look at the intonation structure of Lakhota, based on qualitative observations.

2. SOME PHONOLOGICAL ASPECTS of STRESS

It has been agreed that stress plays an important role in Lakhota (Boas and Deloria, 1941, Carter 1974, Shaw 1980). Boas and Deloria (1941) note that stressed ('accented' in their term) syllable is not lexically determined, but rather occurs by rules. They claim that the stress is on the second syllable. A simple case is given in (1):[1]

(1) a. Lowá**n**-yelo. 'He is singing'
sing -M
b. Wa -l**ó**wan-yeló 'I am singing'
1s.sj- sing -M
('M' stands for a male speech particle.)

* This paper is a preliminary report of the two Filed Methods classes taught by Professor Pam Munro in the Winter and Spring quarters of 1999. I would like to thank our Lakhota consultant, Ms. Mary Iron Teeth, who made it possible for me to write this paper. I also thank Professor Pam Munro for everything that she teaches in the class and her encouragement throughout the course. I am also very much grateful to everybody in the class for their patience and valuable comments. This paper has greatly benefited from comments and suggestions from Pam Munro and Siri Tuttle.

[1] See Munro (2000, this volume) for a note on the orthography used in this paper.

In (1a), the stress falls on the second syllable [wán]. In (1b) where the first singular subject marker is prefixed, the stress falls on [ló] which becomes the second syllable after the prefixation. Chambers (1978, cited by Shaw 1980:31) formalizes this observation as in (2):

(2) Stress Rule
V -->V´ / #(C_0V)C_0__

This rule also explains the stress falling on the first syllable when a word is monosyllabic. An example is given in (3):

(3) a. Hoghán he **shá** na thó
fish det red and blue
'The fish is red and blue'
b. Thiyópa he **sha**-ún -ya -m
door det red -1pl.sj-make(caus.)-pl.
'We painted the door red'

(3a) shows that a monosyllabic word *shá* 'red' has stress. (3b) shows a case in which the monosyllabic word *sha* is not stressed when it becomes part of a word with other morphemes. In this example, we see that *únyam*, the string consisting of 1st pl. subject marker and the causative (which may be translated as 'make'), has stress on *ún*, suggesting that *un-* is attached to *sha-ya*, forming a tri-syllabic word.

2.1. *Predictable or lexical ?*

Despite the regularities observed above, there are a number of examples which seem to violate the generalization that stress falls on the second syllable of a word. Some of examples in our experience are given in (4):

(4)
1. shúnka 'dog'
2. thánka 'large'
3. shíce/a 'bad'
4. hánske/a 'tall'
5. wána 'now'
6. wóte/wáte/yúte 'eat'
7. ógle 'shirt'
8. míla 'knife'
9. máza 'metal, iron'
10. líla 'very'
11. thípi 'house'
12. kháte 'wind'

13. máskan 'money'
14. yámni 'three'
15. húnku '(his/her)mother'
16. nóghe 'ear'
17. cík'ala 'little/small'
19. shákpe 'six'
20. mázazi 'copper'
21. únshike 'poor'
22. wówapi 'book'
23. wó'unspe 'scholar'
24. wójuha 'bag'
25. wínyela 'female animal'
26. wíyuthe 'ruler'
27. íjehan 'often'
28. wóshkate 'toys'
29. wínyunpi 'paint'
30. wíyuzaza 'washboard'
31. wóijaja 'tub'
32. wóijanjan 'lightening'
33. mílaiyume 'grind stone'
34. mázayajopi 'brass instrument'
35. wínyuhomni 'wrench'
36. nóngheoxloka 'hole of the ear'

The surface forms in (4) have stress on the first syllable.[2] Presumably because of these apparent irregularities in the stress patterns, Carter (1974) argues that stress is lexically determined. Shaw (1980), however, argues against Carter's claim by pointing out the complexity and ad hoc rules in Carter, which obscure the basic generalization that the stress falls on the second syllable in a word. Shaw shows that some of the apparent exceptions are in fact nonexceptional but simply 'opaque' due to interactions between phonological rules. In what follows, I will introduce Shaw's analysis and investigate how each of her arguments fits our data.

2.1.1. *C-final stem*

According to Shaw, one such opaque case involves unprefixed noun and verb stems that end with a consonant. Words such as *shúnka, thánka, shíca/e,* and *hánska/e*[3] are assumed to end with consonants. Then the final vowel [a] is inserted by a 'stem formation' rule which surfaces

[2] Note that quite a few polysyllabic words are in fact compounds (e.g., míla 'knife' + yúme 'sharpen' --> mílaiyume 'grind stone'). It is possible that such morphologically complex words may have secondary stress. I will discuss the possibility of secondary stress in section 4.

[3] *shíca/e* and *hánska/e* has a [a]-[e] alternation due to an optional ablaut phenomenon.

disyllabic words. Since stress assignment rule applies before the stem formation ([a]-insertion) rule, the stress still remains on the first syllable. The derivation of *shúnka* 'dog' would be as in (5):

(5) /shunk/
shúnk Stress Assignment
shúnka Stem Formaton [a]-insertion

[shúnka] surface

2.1.2. *Vowel deletion and coalescence*
Shaw also argues that the stress assignment rule applies before vowel deletion or coalescence, which result in surface opacity where the first, rather than second syllable in polysyllabic words gets stressed. For example, in Lakhota, [a] deletes before another vowel inside a word ('A-Drop') as in (6):

(6) /tha-isto/ 'ruminant's foreleg'
tha-ísto Stress Assignment
thísto A-Drop

[t^hísto] Surface (from Shaw 1980:34)

Unfortunately, we were not able to find a comparable example in our data. But, we have several A-Drop cases such as *hina-iyuha* → *hiníyuha* 'all together' or *washte-ic'i-lake* → *washtíc'ilake*.

Another example that creates an initial stress is found in coalescence as in (7):

(7) /wa-yute/ 'to eat something'
wayúte Stress Assignment
wóte Coalescence

[wóte] Surface

In (7), the sequence *ayú* becomes [ó], which makes the stress opaque. One point worth mentioning here is the role of prefix *wa-* in (7). According to Buechel (1983), one of the functions associated with the prefix *wa-* is to make verbs 'absolute' or intransitive.[4] This seems to fit our data: *wa-* with such a function can be found only when there is no apparent object for the verb *yute* 'eat.'[5]

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[4] We observed ourselves that *yute* 'eat' is intransitive when it includes *wa-*.

[5] The prefix *'wa-'* for the verb *yute* 'eat' is found only if there is no object. Mysteriously, however, when the prefix *wa-* is attached to the verb *yute* as a 1st subject

2.1.3. *Boundaries*
Shaw also noted that there are some classes of morphemes which make the general stress assignment opaque. One such case involves verbal enclitics. These verbal enclitics include *-shni* 'Neg,' *-pi* 'plural', *-kta/e* 'future,' *-xca* 'intensifier,' *-ka* 'qualifier,' etc. The stress rule does not span the enclitic boundary between the verb stem and those enclitics. Thus, *úkte* 'come-Future' and *héshni* 'say-Neg' have the first syllable stressed, because the prosodic word is monosyllabic.

2.1.4. *Lexical vs. syntactic compound*
Chambers (1978, cited by Shaw) notes that there are two different kinds of compound derivations. The first case is when the compound is treated as a single word, which is lexically derived by a word formation rule. The second type of compound is assumed to consist of two separate words, whose compounding is syntactically derived. Thus, the stress falls on each element of the compound. A pair of examples is given in (8). (8a) is lexically derived while (8b) is syntactically derived.

(8) a. skal - ó - mani 'he goes about in order to play'
play-about-go
b. skál - o -maní 'he goes playing about'
play-about-go
(from Shaw 1980:37)

2.1.5. *Reduplication and Stress*
Shaw also shows that the stress patterns in reduplicated forms differ depending on whether a verb belongs to the non-active (stative) or the active class. The stress patterns for non-active verbs are consistent with the basic generalization (i.e., stress under the second syllable). Relevant examples found in our data are given in (9):

(9) a. Hiyánkho **sha-shá** hiná thankínkia
'The red socks are big' (136.1)
b. Kaná shúnka **sha-shá chik-chík'ala** hiná John yaxtákap
'The small red dogs bit John.'

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marker, rather than as an intransitive marker , there seems to be a deletion process involved rather than coalescence as below:

/wa-yute/ '1st.sj-eat'
wayúte Stress Assignment
wáte deletion

[wáte] Surface

The reduplicated forms *sha-shá* in (9a-b) and *chik-chík'ala* in (9b) receive stress on the second syllable. By contrast, data in Shaw (1980), and Boas and Deloria (1941) show that reduplicated active verbs have initial accent. (Since in our data, we have reduplicated active verbs only with second syllable copied which is always stressed (e.g., *kasáka vs. ka-sá-saka* (124.12) 'hit/spank'), we cannot test the above claim.)

Related to this non-active/active contrast, Boas and Deloria (1941:38) provide a number of morphologically related pairs where the non-active vs. active distinction is made simply by the position of stress in the words. Some examples are given in (10):

(10)	a. xopxópa	(non-active)	'to be good-looking'
	b. xópxopa	(active)	'to pose, try to appear one's best'
	c. kshakshá	(non-active)	'to be crooked'
	d. kshákshа	(active)	'he wriggles his body about'

So far we have examined the extent to which the apparent exceptions to the stress generalization can be accounted for by relevant phonological or morphophonemic rules (such as vowel deletion, coalescence processes, and stem formation ([a]-insertion)). Although quite a few polysyllabic words with initial stress can be explained by such rules, there still remain a number of words with initial stress in which we find no motivation for assuming any kind of phonological processes that might make the surface stress opaque. This suggests that the stress is not entirely predictable but rather, at least in part, lexically determined. Let's first consider some disyllabic words for such exceptional cases, as repeated in (11):

(11)	a. máni	'to walk'
	b. ómna	'to smell'
	c. máskan[6]	'money'
	d. yámni	'three'
	e. kháte	'wind'
	f. shákpe	'six'

The words in (11) seem to be genuine exceptions. In order to account for these exceptions, as noted by Shaw, we might want to assume that these words are assigned lexical stress as in (12):

(12) Enter each in the lexicon with the initial vowel specified as [+l accent] (Shaw (1980:54))

[6] *máskan* can be decomposed into *máza* and *ská* ('white meal').

However, this assumption was rejected by Shaw herself because of the fact that stress shifts when other affixes are attached to some of the exceptional words. The rationale is that if a stress is an intrinsic lexical property, it should not shift. Relevant examples in our data are in (13):

(13) a. Hiná **máni** -pi
all walk -pl.
'They are walking'
b. Hiná **ma- 'ún - ni** -p -elo.
all *-1p.sj -walk -pl-M
'We are walking'

Note that stress shifts from the first syllable (13a) to the second syllable (13b) when *-un-* is infixed. In order to generalize the patterns, Shaw proposes that it is not the first syllable but the last syllable that is lexically marked. She argues that the last syllable is assigned [-stress] in the lexicon, so that the stress assignment rule does not apply to the last syllable. The result is that the stress falls on the first syllable. Shaw's analysis, however, still remains unsatisfactory when we consider some other cases. One such case is given in (14):

(14) a. Thaló he **ómna** washté.
meat det smell good
'The meat smells good'
b. Thaló **ó- wa -mna**.
meat *-1s.sj -smell
'I smell meat'

Stress on the first syllable (14a) does not shift to the second syllable when the overt morpheme *-wa-* is infixed (14b). This is the opposite of what we observed in (12). It would be difficult to account for why the stress remains the same in ***ó-wa-mna*** (14b) only by Shaw's claim that no stress is allowed in the last syllable. Similarly, Shaw's claim does not fit the polysyllabic exceptions as in (15):

(15) a. cík'ala 'little/small'
b. wíyuthe 'ruler'
c. íjehan 'often'
d. únshike 'poor'
e. wóshkate 'toys'
f. wówapi 'book'
g. wó'unspe 'scholar'
h. mázayajopi 'brass instrument'
i. nóngheoxloka 'hole of the ear'

All the examples in (15) have stress on the first syllable. These data suggest that some of the exceptions simply need marking on the lexicon with stress information. For example, the morpheme *wo* in (15e-g) appears to attract stress all the time. However, since quite a few words in the list are morphologically complex, we must not rule out the possibility that the complex morphological structure, which is unknown to us yet, make the surface stress patterns opaque. It is also possible that some of compounds may have secondary stress, which will be briefly addressed in section 4.

2.2. *Summary of Phonological Aspects of Stress*

So far, I have briefly reviewed some of the basic stress patterns in Lakhota and examined the extent to which the exceptions to the generalization that stress falls on the second syllable can be accounted for by Shaw (1980)'s account. A summary is as follows:

(16)
a. There are a great number of derived forms that have stress on the second syllable
b. Monosyllabic words have stress on the first syllable.
c. Some of the apparent exceptions to (a) & (b) can be accounted for by:
(i) vowel insertion to the end of underlyingly C-final stem (/shunk/→ [shúnka] 'dog'),
(ii) vowel coalescence or deletion (/wa-yúte/ → [wóte] 'to eat something'),
(iii) blocking of the general rule application across a certain type of boundaries (e.g., enclitic boundary as in *úkte* 'he is coming' or active reduplicated verb *xópxopa* 'he wriggles his body about')
d. Some of genuine exceptions suggests that the stress is at least partly lexically determined.

3. Acoustic Correlates of Stress

Stress and its acoustic correlates have been well described for such languages as English and Japanese (e.g., Beckman, 1986). In general, pitch, duration, and amplitude are known to be the primary acoustic cues for stress (e.g., Fry, 1955; 1958; Lehiste, 1970; Umeda, 1975; Crystal and House, 1988). However, which parameter plays a primary role in marking stress is language-specific. For example, Japanese has pitch as a primary cue for stress, and, for this reason, is known as 'pitch' accent system (Beckman, 1986). For Lakhota, researchers (e.g., Boas and Deloria, 1941; Shaw 1980) seem to agree that the most

salient acoustic cue of the stress is pitch. However, to my best knowledge, there seems to be no acoustic study of Lakhota stress available in the literature. In this section, I report the result of a small-scaled experiment in which three acoustic parameters (i.e., pitch, duration, and amplitude) are examined.

3.1. *Method*

A word list was designed in order to examine the stressed vs. unstressed syllables in the initial position of the following words in isolation:

(17)	a.	pápa	'dried meat'
	b.	pahá	'hill, mountain'
	c.	pháte	'to operate'
	d.	phákakse	'to behead'
	e.	phámahel	'the head covered as by a shawl
	f.	phahí	'to separate'
	g.	phahín	'porcupine'
	h.	phasú	'nose'
	i.	phaxté	'forehead'

In addition, some words given in (18) were included in the corpus in order to examine some acoustic characteristics associated with stress qualitatively.

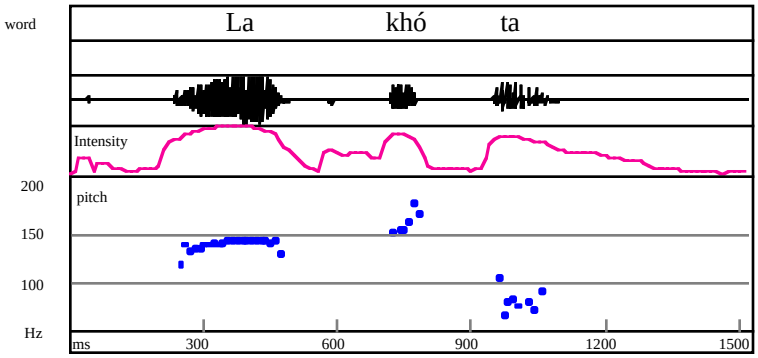
(18)	a.	lakhóta	'Lakhota'
	b.	aglágla	'shore/edge'
	c.	thaspán	'apple'
	d.	thánka	'big/large'
	e.	máza	'metal/iron'
	f.	maghá	'duck'
	g.	magháju	'rain'
	h.	kháte	'hot/warm'
	i.	khaté	'wind'
	j.	washté	'good'
	k.	washtéshte	'good(pl.)'

Each word was recorded with 4 repetitions by the Lakhota consultant Ms. Mary Iron Teeth. The recorded materials then were digitized at 12800 Hz sampling rate and analyzed using PitchWorks. Vowel duration, peak intensity and Voice Onset Time (VOT) were measured from the first syllable of the words in (17) where the first syllable starts with bilabial [ph] or [p]. Pitch was examined for all of the listed words in (17) and (18), but rather qualitatively.

3.2. *Results and discussion*

3.2.1. *Observation*

Let us first examine the acoustic correlates associated with the three syllable words. An example is given in Figure 1. This particular example tells us that the stressed vowel in fact has the shortest duration. The overall intensity is also lower than the first syllable and not necessarily greater than the last syllable. Interestingly, however, the stressed syllable is associated with the highest peak.



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gure 1. Pitch track and intensity contour of the word *Lakhota*.

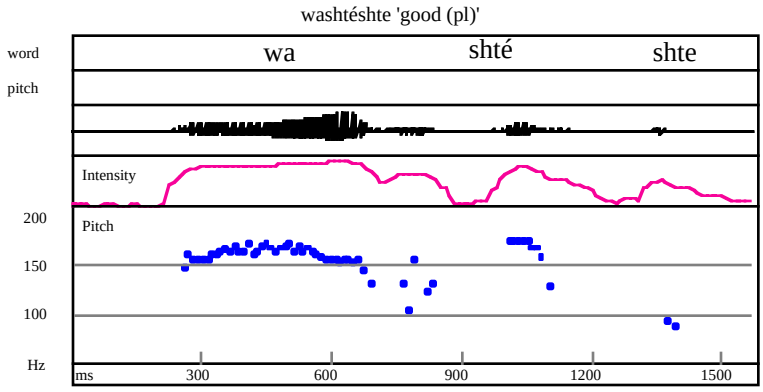

Figure 2. Pitch track and intensity contour of the word *washtéshte* 'good(pl.).'

Figure 2 shows a similar case where the stressed syllable *shté* is associated with a high pitch, but not with higher intensity. Thus, the examples in both Figure 1 and 2 show that the prominence associated with a stressed syllable is realized mainly through high pitch.

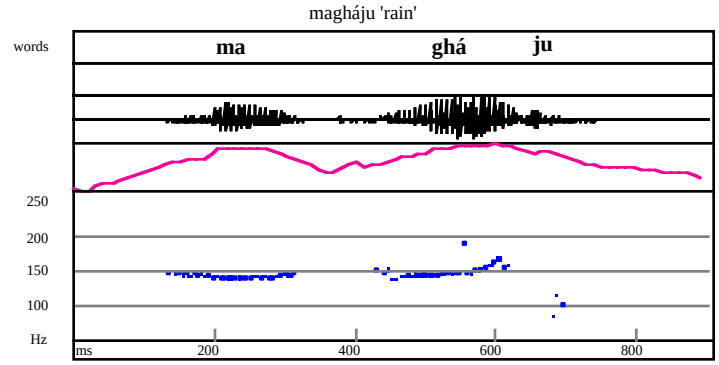

Figure 3. Pitch track and intensity contour of *magháju* 'rain'

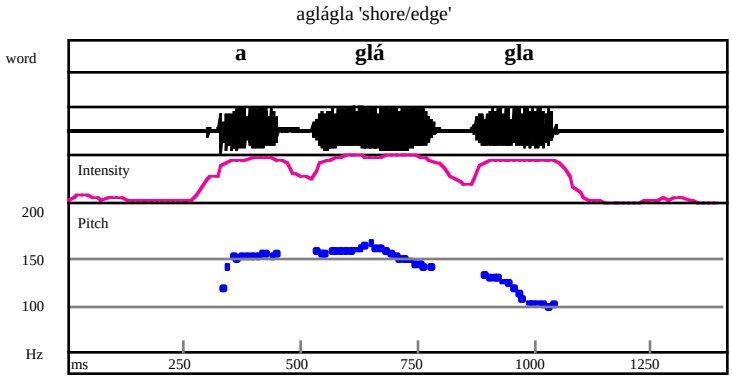

Figure 4. Pitch track and intensity contour of *aglágla* 'shore/edge'[7]

However, there are some other cases in which stressed syllables are associated with longer duration and greater intensity as well as high pitch. An example is given in Figure 3 in which the stressed syllable *ghá* is associated with not only high pitch but also relatively longer

[7] We sometimes heard *aglágla* to be pronounced with an extra schwa-like epenthetic vowel between [g] and [l]. But, this particular token does not have an apparent epenthetic vowel.

duration and greater intensity.[8] A similar case is found in Figure 4 in which the stressed syllable *lá* is associated with longer duration, greater intensity, and high pitch.

Now let us turn to disyllabic words. Examples are given in Figures 5 and 6. The most striking fact here is that the first syllable, which is supposed to be unstressed, has longer duration, higher pitch, and greater intensity. This is true in both figures. This is probably the reason why many linguists recording Lakhota are not sure about where stress occurs in words like this.

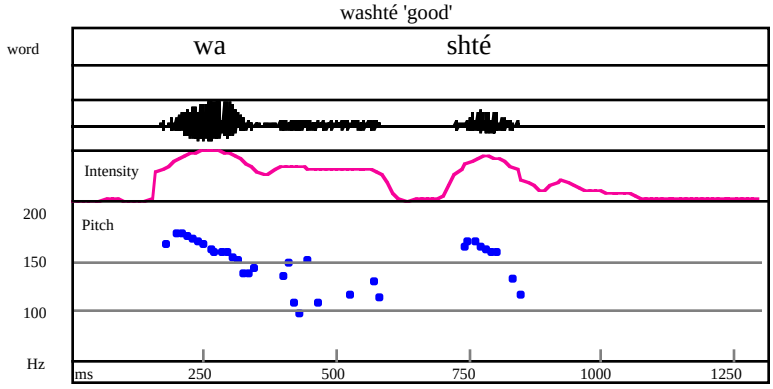

Figure 5. Pitch track and intensity contour in *washté* 'good'

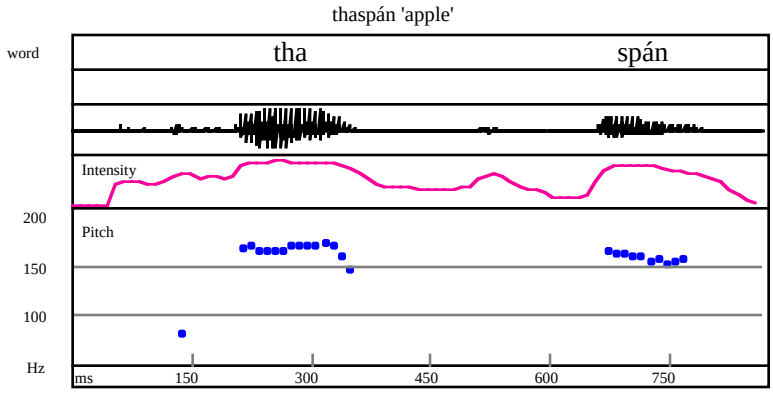

Figure 6. Pitch track and intensity contour in *thaspán* 'apple'

[8] But it should be born in mind that the observed greater intensity and longer duration, compared to cases in Figures 1 and 2, may be at least in part due to the intrinsic properties of a low vowel /a/.

Then the question is how a Lakhota speaker knows whether words like *washté* 'good' and *thaspán* 'apple' have stress on the second syllable. This can be answered by comparing examples in Figures 5 and 6 with another example, in Figure 7, where the first syllable is stressed and the second syllable is not. As can be seen in the figure, the unstressed second syllable is associated with a low pitch, resulting in a sharp fall. Speakers seem to make contrast between words with the second syllable stressed and words with the first syllable stressed by employing such a drastic fall in pitch from the stressed syllable to the unstressed second syllable. Put differently, even if the stressed second syllable does not have higher pitch than the first unstressed syllable, as we saw in Figure 5 and 6, speakers still perceive it stressed as long as there is no sharp falling for the second syllable. Figure 8 shows such distinctions for a minimal pair, *kháte* 'hot' and *khaté* 'wind.'

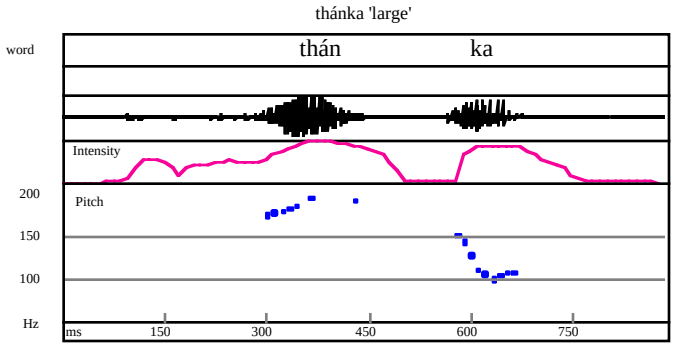

Figure 7. Pitch track and intensity contour of the word *thánka* 'large'

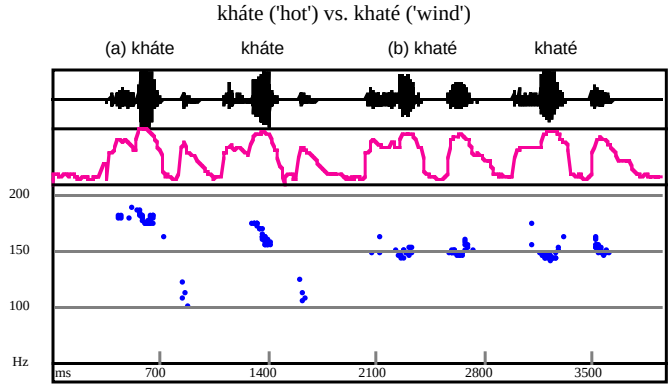

Figure 8. Comparison for the minimal pair, *kháte* ('hot') vs. *khaté* ('wind')

3.2.2. *Voice Onset Time (VOT)*
VOTs were measured for aspirated and unaspirated labial stops (*ph* and *p*) in word-initial position before stressed and unstressed vowels. (See (7) for a complete word list.) A one-way ANOVA shows that there is a significant effect of stress on VOT ($F(1, 28) = 12.403$, $p < .0001$) for the aspirated stop *ph* but not for unaspirated stop *p*. For the aspirated stop, the VOT is longer for stressed syllables than for unstressed syllables as shown in Figure 9. The greater VOT for the stressed syllable suggests that the prominence of stressed syllables is realized in part through a greater articulatory magnitude in glottal opening, because a greater opening of the glottis usually result in greater VOT (cf. Cooper, 1992; Pierrehumbert & Talkin, 1992; Jun, 1993). From this finding, we could also infer that the feature [spread glottis] that may be associated with the aspirated stop is enhanced under stress. Note, however, that this effect holds only for syllables with aspirated stops for which [spread glottis] may be a primary feature.

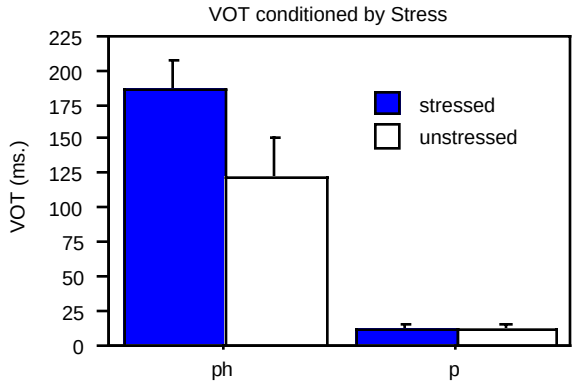

Figure 9. Voice Onset Time (VOT) in Lakhota for aspirated and unaspirated stops conditioned by stress. Error bars indicate standard deviations.

3.2.2. *Vowel Duration*
Vowel duration was measured for the vowels preceded by aspirated and unaspirated bilabial stops. The results of one-way ANOVAs show that there is no effect of stress on vowel duration, as can be seen in Figure 10.

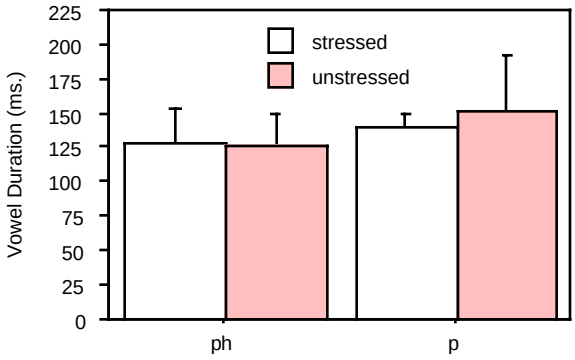

Figure 10. Vowel duration after aspirated and unaspirated stops in Lakhota. Error bars indicate standard deviations.

3.2.3. *Change in intensity (dB) from the target syllable to the following syllable*

In order to examine the intensity of stressed and unstressed vowels in the first syllables relative to following syllables, the difference in peak intensity of vowels between the first and second syllables was measured after both aspirated and unaspirated bilabial stops. As shown in Figure 11, after the aspirated stop *ph*, there is no substantial difference between the case when the first syllable is stressed and the case when the second syllable is stressed. Interestingly, however, for the unaspirated stop *p*, there is a substantial difference between the two cases — there is a greater change in intensity from the stressed syllable to the unstressed syllable than from the unstressed syllable to the stressed syllable.

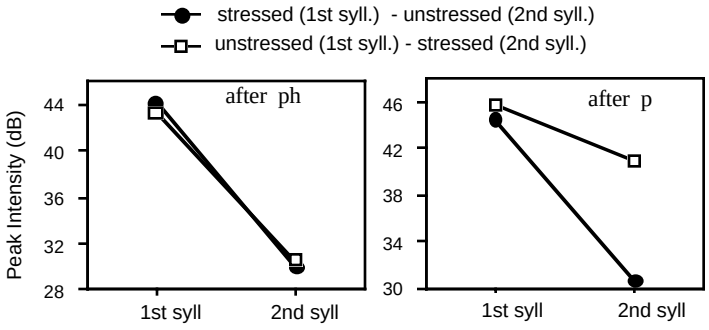

Figure 11. Change in intensity from the 1st syllable to the second syllable in Lakhota. The left panel is when the aspirated stop *ph* occurs word-initially and the right panel is when the unaspirated stop *p* occurs word-initially.

Thus far, we have observed several factors which contribute to marking the prominence associated with stress in Lakhota. First, pitch appears to be one of the most invariable factors, as discussed in section 3.2.1. Second, while there is a significant effect of stress on VOT for aspirated stops, no such effect was found for unaspirated stops. In addition, no stress-induced difference in the duration of vowels was found. Finally, the change in intensity from the first syllable to the second syllable showed that there is a greater falling in intensity when the first syllable is stressed than when the first syllable is unstressed. This effect, however, was observed only for words with initial unaspirated stops.

Though we have examined only limited data in this study, our data suggest that the speaker seem to employ different strategies in marking stress for different segmental environments in addition to making pitch difference. For a syllable with an aspirated stop as an onset, the speaker makes the VOT longer presumably to make the syllable prominent. On the other hand, for a syllable with an unaspirated stop as an onset, the speaker seems to employ change in intensity for enhancing the relative prominence.

3.3. *Factors interacting with stress*

In this section, I argue that there are some other factors that must be considered in interpreting any acoustic patterns associated with stress.

3.3.1. *Initial strengthening*

An interesting point that emerges from the previous sections is that the first syllable is almost always associated with greater intensity compared with the second syllable, regardless of the stress. Such higher intensity seems to be one of the factors that make judgment of stress difficult. The greater intensity may be accounted for by the hypothesis that the utterance-initial syllable has more strong acoustic events than the utterance-medial or final syllables. Keating, Cho, Fougeron and Hsu (1998), for example, show that utterance initial segments have stronger articulation compared to the utterance-medial ones, which is generally true cross-linguistically. In order to examine whether such initial strengthening effect is applicable to Lakhota in a systematic way, the intensity peaks of the first and second syllables of the words in (17) were compared. As shown in Figure 12, the intensity is always greater for the word-initial syllable than the following syllable. This effect holds regardless of whether the first syllable is stressed or not. Thus, Lakhota seems to exhibit initial strengthening in the domain of acoustic intensity. Note that the word-initial syllable in our data is also utterance-initial, since the test words were uttered in isolation. So, the

comparison was in fact between utterance-initial and utterance-medial positions.

Another point worth mentioning is that there is less variation in intensity for the initial syllable compared with the non-initial one, as can be seen in Figure 12. The standard deviation, as marked by dotted lines in the figure, is smaller for the initial syllable and greater for the non-initial syllable. The greater variation found for the second syllable can be accounted for by stress difference. When the second syllable is stressed, the intensity is closer to that of the first syllable. On the other hand, when the second syllable is unstressed, the intensity is further away from that of the first syllable. Such difference, however, seem to be small for the first syllable presumably due to initial strengthening.

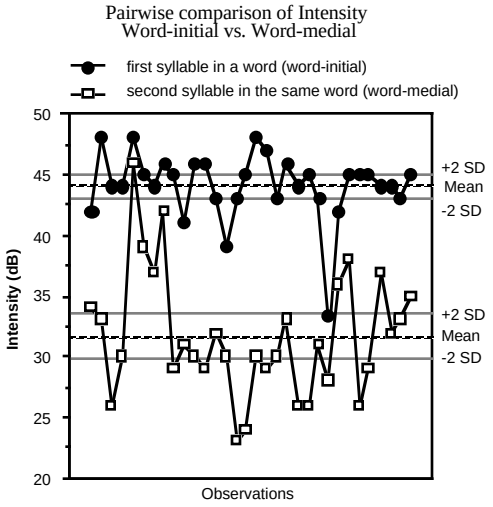

Figure 12. Pairwise comparison of Intensity between the first and second syllables in words in (17).

In order to see if initial strengthening can be extended to VOT, a small corpus was designed as in (19)[9]:

(19) a. Sentence-initial/Word-initial (=Si/Wi)
pháhmahel wanjila omna-yelo
covered head just one smell-M
as by shawl
'Just one of them smelled the head covered as by shawl'

[9] According to the consultant, the meanings of sentences in (19) are rather awkward. However, the consultant agreed that these are acceptable sentences.

b. Sentence-initial/Word-medial (=Si/Wm)
ma -**phá**su wanjila omna-yelo
1sg.Poss-nose just one smell-M
'Just one of them smelled my nose'

c. Sentence-medial/Word-initial (=Sm/Wi)
Wanjila **phá**mahel omna-yelo
just one head covered smell-M
'Just one of them smelled the covered head'

d. Sentence-medial/Word-medial (=Sm/Wm)
Wanjila ma -**phá**su omna-yelo
just one 1sg.Poss-nose smell-M
'Just one of them smelled my nose'

In (19), the stressed syllable *phá* occurs in four different prosodic positions (e.g., Sentence-initial/Word-initial, Sentence-initial/Word-medial, Sentence-medial/Word-initial, and Sentence-medial/Word-medial). Each sentence was repeated four times. The result is shown in Figure 13. Statistical analysis shows that in general, VOT in the word-initial syllable is greater than that in the word-medial syllable ($p < .0001$), regardless of the position in sentence. There is also a tendency towards greater VOTs sentence-initially than sentence-medially, though this is not statistically significant. As can be seen in the figure, the effect seems to be cumulative, in that VOT for the word-initial and at the same time sentence-initial syllable is longest while VOT for the word-medial and sentence-medial syllable is shortest. This suggests that initial strengthening may be quite a robust phenomenon in Lakhota.

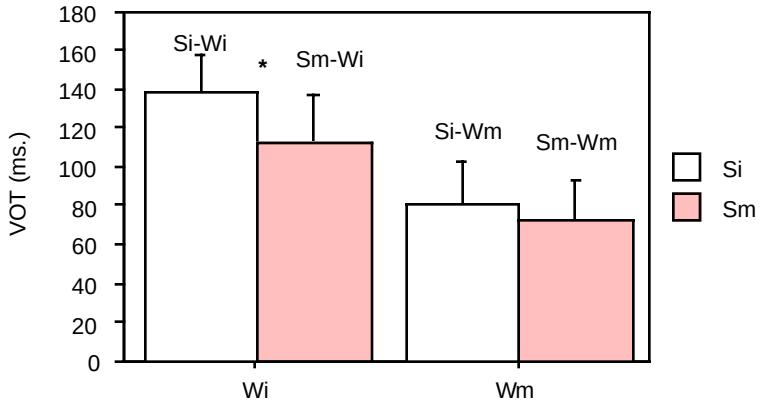

Figure 13. Variation in VOT as a function of prosodic position.

3.3.2. *Utterance-final boundary tone*

Another factor to consider is the boundary tone. It is generally agreed that certain type of tones (high, low) can characterize the edges of certain prosodic domains (e.g., Pierrehumbert, 1980; Beckman and Pierrehumbert, 1986; Pierrehumbert and Beckman 1988; Jun, 1993; Fougeron and Jun, 1997; Gordon, 1999). For example, in English the end of a statement is usually marked by a low boundary tone (L%) at the end, although such tonal marking of boundaries may differ from language to language. (Note that '%' refers to a boundary tone that occurs at edges of phrases.) Gordon (1999) shows that in Chickasaw statements are characteristically marked by a H% final boundary tone, whereas both Wh and yes/no questions are realized with a L% final boundary tone. In any event, what emerges from boundary tone phenomena across languages is that a tonal marking is generally used cross-linguistically in order to signal the end of phases.

Likewise, our data in Lakhota seem to suggest that the utterance-final syllable in statements is associated with a low boundary tone (i.e., L%). Evidence for such a low boundary tone can be found easily in utterances with non-final stress. In Figures 4, 7, and 8(a), we observe a deep tonal fall at the end of the word, which is also utterance-final since it was pronounced in isolation. Now, a more interesting question is how the utterance-final stressed syllable with a high tone is tonally realized in interaction with a boundary tone, L%. We already observed that the pitch of the stressed final syllable is not necessarily higher than that of the preceding unstressed syllable (as seen in Figures 5-6, and 8). I suggest that this is presumably because a high tone in stressed syllables seem to be suppressed by a boundary tone, L% at the end of the utterance. [10] Such interaction is schematized in Figure 14.

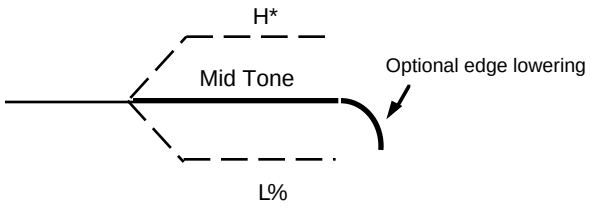

Figure 14. Interaction between high tone (H*) associated with a stressed syllable and boundary low tone (L%).

[10] Tuttle (1998) notes that intonational boundary low tone in Tanana Athabaskan is a serious potential source of confusion in testing lexical tones.

In the figure, '*' and '%" refer to the tones associated with stress and boundary tone, respectively. The dashed lines are assumed underlying tonal contours of the high tone of the stressed syllable and the low tone of the boundary. I suggest that the interaction between the opposite tones results in mid tone on the surface as marked by a thick line in the figure. The final fall in the figure, labeled as optional edge lowering, indicates that the boundary L% is optionally realized when the final syllable is long enough for it. Our data show that the speaker usually makes such a fall with creaky voice. Figure 15a shows the realization of L% with no interaction with high tone for stress. On the other hand, Figure 15b shows a surface mid tone for the most part of the final syllable due to the interaction between the two tones. This example also includes the optional edge falling toward the end of the final syllable. Note that the sharp fall was made by creaky voice.

Another evidence of the interaction between H* and L% can be found when a word with a stressed final syllable occurs in the middle of the utterance. Figure 16 shows such a case in which the word-final stressed syllable is associated with a local intonational peak as marked by a circle.[11] Note that the same syllable, *ghá*, occurring utterance-finally as in Figure 15b, does not form a peak, due to the boundary L% tone. This effect is roughly equivalent to the realization of a stable rather than rising ending in English when the phrasal tone H- is suppressed by L% (e.g., Pierrehumbert and Beckman 1988).

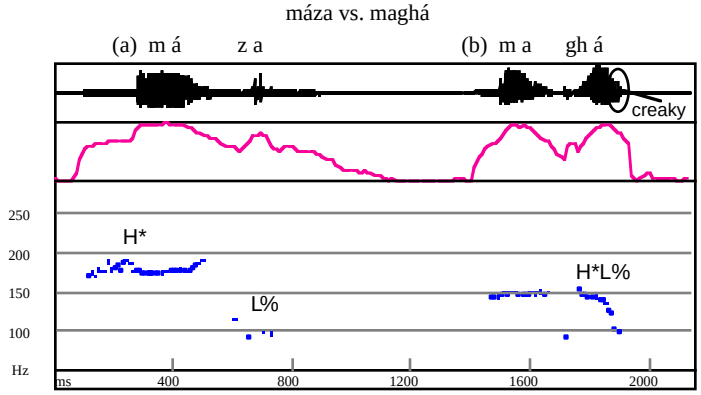

Figure 15. Interaction between high tone (H*) associated with a stressed syllable and boundary low tone (L%). (a) *máza* 'metal' and (b) *maghá* 'duck'

[11] Such a rising may be due to a high phrasal boundary tone. While this is a plausible explanation, this particular token did not have any boundary lengthening.

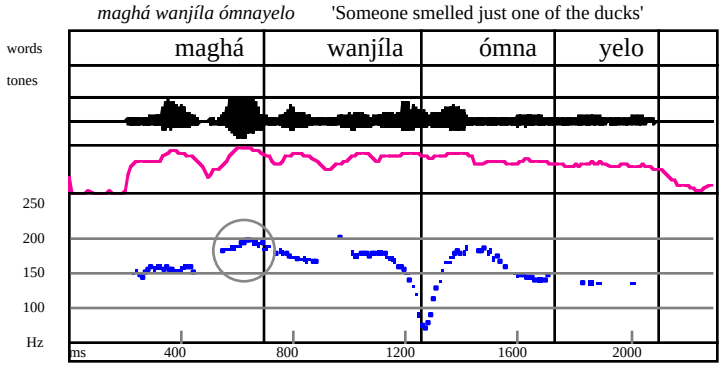

Figure 16. Pitch track of a neutral declarative sentence where the stressed syllable in *maghá* is associated with high peak as marked by a circle.

3.4. *Summary*

In this section, I have attempted to provide some acoustic correlates of stress, in part in connection with other prosodic factors such as domain-initial strengthening and utterance-final tonal phenomenon. A careful observation of the recorded tokens (using Pitchworks) suggests that the primary cue of the stress in Lakhota is relatively high pitch. Some of the data also suggested that higher intensity and greater VOT (for aspirated stops) together with higher pitch seem to enhance the prominence. However, the realization of these acoustic cues for stress often seems to be blurred due to several factors such as initial strengthening and the boundary tone phenomenon, which are prosodically conditioned. Certainly much work with systematic phonetic experiments is needed in order to better understand the stress system in Lakhota.

4. A Preliminary Look at Intonational Structure

In this section, I present a preliminary look at some intonational structure in Lakhota.

4.1. *Pitch accent*

4.1.1. *Basic pitch accent L+H**

The intonational peak with high pitch seems to fall on the stressed syllable in Lakhota. Figure 17 shows that the local intonational peak falls on the stressed syllable in each word. Following Beckman (1986)

and Beckman and Pierrehumbert (1986), I refer to these peaks as pitch accents with the diacritic '*.' I will call the syllable with pitch accent as pitch accented syllable. As can be seen in the figure, the type of pitch accent is L+H* since it is made by rising tone and its peak is realized within the stressed syllable, which is true for all three pitch accents in the figure. A similar pattern is found in Figure 18. The only difference between Figures 17 and 18 is that there is a glottal stop at the beginning of the second word *ógle* in Figure 18. This glottal stop seems to make the end of the first word *yámni* and the beginning of the second word *ógle* extremely lowered in pitch. Compare this with the pitch track in Figure 17 where the second word *míla* does not have such an effect. This extra lowering effect was also found for the beginning of the final word *ónmap* in both figures.

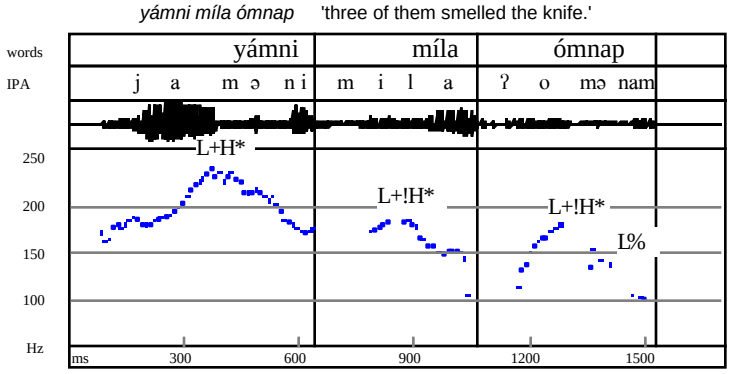

Figure 17. Pitch track of a neutral declarative sentence, *yámni míla ómnap* 'three of them smelled the knife.'

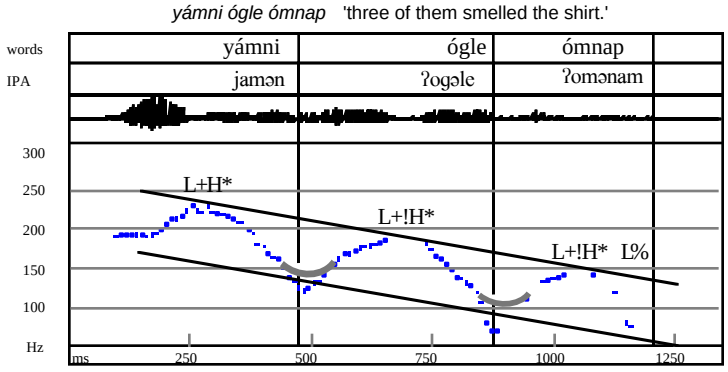

Figure 18. Pitch track of a neutral declarative sentence, *yámni ógle ómnap* 'three of them smelled the shirt.'

4.1.2. *F_0 Declination*

It is well known that F_0 (pitch) tends to decline over the course of an utterance (e.g., Pierrehumbert, 1980). Pierrehumbert hypothesizes that F_0 declination is attributable to downstepping of subsequent pitch events. This downstepping phenomenon seem to be robust in Lakhota, too, as shown in Figures 17 and 18. The lines superimposed on the pitch track in Figure 18 capture F_0 declination over the course of the utterance.[12] All the tokens examined in this study showed that the intonational peak is always highest in the first pitch accented syllable and lowest in the last pitch accented syllable in the utterance. Such a lowered peak is marked by !H*.

4.1.3. *Undershoot of L tone in L+H*

Figure 19 shows the pitch track of another neutral declarative sentence where the first word *wanjí* has stress on the final syllable on which the pitch accent falls. Since there is not enough time during the last syllable *ji* for both L+H* and falling in preparation of the following pitch accent L+H* for *míla*, the falling preparation was made in the beginning of *míla*. Note that such a falling preparation is usually made at the end of the preceding word if the last syllable of the preceding word is not stressed. Such falling in preparation for rising L+H* is another evidence that L+H* pitch accent exists in Lakhota—if there were no L tone, we would not expect lowering in pitch before the following H*. However, in many of such cases in which pitch accented syllables are adjacent to each other, the L tone seems to be *undershot*, or not realized on the surface, as shown in Figure 20, the same utterance as in Figure 19, but with L tone undershot for *míla*.

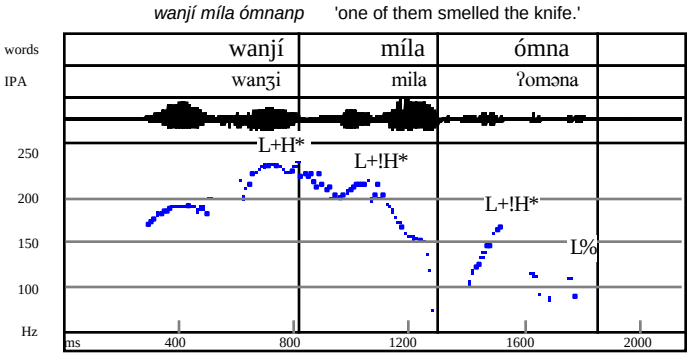

Figure 19. Pitch track of a neutral declarative sentence, *wanjí* (‘just one’) *mîla* (‘knife’) *ómna* (‘smell’) 'One of them smelled the knife.'

[12] Note that the connected thick lines at the trough in Figure 18 are drawn as estimated low valleys which might have been the cases if there were no phonetic influence of the glottal stop.

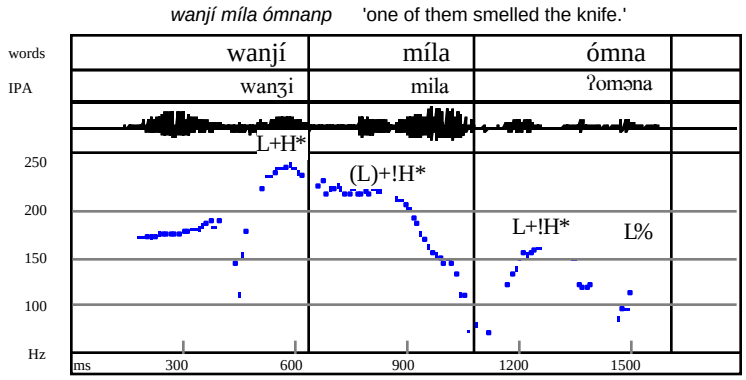

Figure 20. Pitch track of a neutral declarative sentence, *wanjí míla ómna* 'One of them smelled the knife' with L tone undershot. (L) refers to L tone undershot.

4.1.4. *Interaction between pitch accent and boundary tone on a sentence level*

In section 3.3.2., I discussed the interaction between pitch accent H* and boundary tone L% for words in isolation. Figure 21 shows the interaction on the sentence level. Note that the first part of the last syllable *há* is not associated with high pitch nor with low pitch, showing the interaction between the two opposite tones H* and L%. However, since the final syllable is relatively long (presumably because the syllable is open and has the vowel [a], which is usually intrinsically longer than other vowels), the speaker makes the L% tone at the end of the syllable with creaky voice.

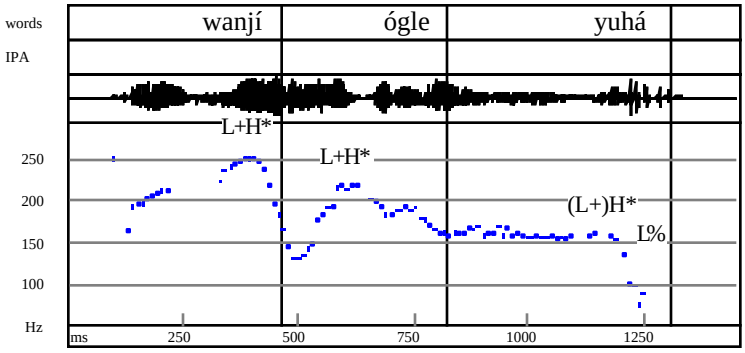

Figure 21. Pitch track of a neutral declarative sentence, *wanjí ógle yuhá* 'One of them has the shirt.'

4.2. *Realization of Secondary stress*

It has not yet known to us whether Lakhota has secondary stress or not. We sometimes observed that long words tend to have a secondary stress alternating from the main stressed syllable. In this section, I further explore such possibility based on several observations, and argue that secondary stress indeed exists in Lakhota.

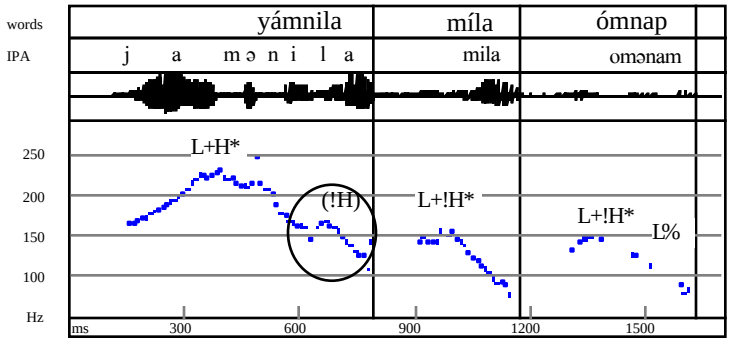

Figure 22. Pitch track of a neutral declarative sentence, *yámnila míla ómnanp* 'Just three of them smelled the knife.' The circled part indicates there is secondary stress.

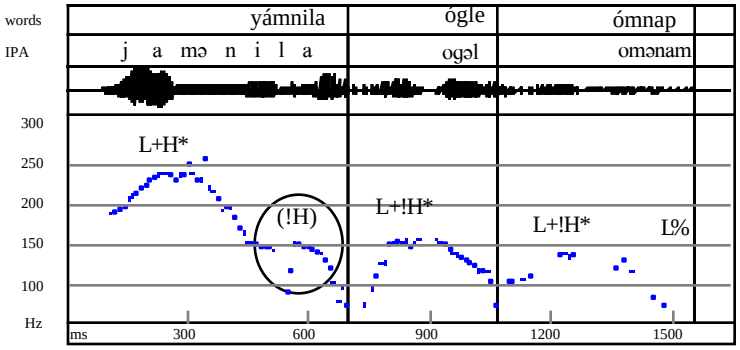

Figure 23. Pitch track of a neutral declarative sentence, *yámnila míla ómnanp* 'Just three of them smelled the shirt.' The circled part indicates that there is secondary stress.

Let us examine Figures 22 and 23 where the polysyllabic word *yámnila* 'just three' occurs. As can be seen in the figures, the final syllable *la* is associated with relatively longer duration and intensity, and a local bump in pitch (as marked by !H in the figure). Especially, the local bump in pitch resembles the L+!H* in which the L tone was

presumably not realized as was the case with Figure 20. If there were no prominence at all associated with the final syllable *la* in *yámnila*, there should be no such local pitch bump in the course of the tonal falling from H* to the following L. This tonal phenomenon seems to suggest that the secondary stress alternates after the primary stress.

However, words which seem to show apparent secondary stress are in fact morphologically complex words. For example, we know that *yámnila* is composed of *yámni +la,* and it seems that the separate morpheme *la* receives some prominence as just seen. Now the question is whether the stress simply alternates after the primary stressed syllable or whether it marks the stress on the second constituent of the morphologically complex words. While this question cannot be resolved here, we can tentatively test this by examining words with five syllables like *mázayajopi* (*máza + yajópi*) 'brass instrument' where the primary stress occurs in the first syllable followed by four syllables. If the secondary stress falls on the third syllable *yá* , we could say that the secondary stress occurs alternately after the primary stress. On the other hand, if the secondary stress falls on the fourth syllable *jo* which is the stressed syllable for *yajópi* in isolation, we could assume that the stress is maintained paradigmatically. Figures 24 and 25 indicate that the secondary stress occurs as a result of alternating the stress after the primary stressed syllable, rather than as a result of preserving the stress paradigmatically. Note that the secondary stress peaks in Figures 24 and 25 are aligned with the syllable *ya* [ja].[13]

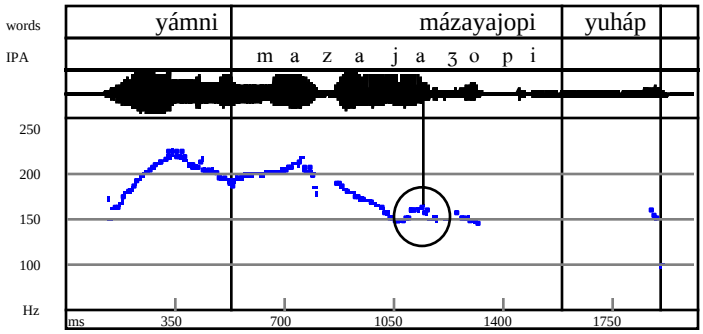

Figure 24. Pitch track of a declarative sentence, *yámni mázayajopi yuháp* 'three of them have the brass instrument.' The circle intonational event indicates the secondary stress.

[13] In addition, careful listening to the tokens lead me to suspect that there may be a tertiary stress on the sixth syllable *pi.* Such a tertiary stress may be sometimes observable as in Figure 25 where a slight rising tone is associated with the syllable *pi*.

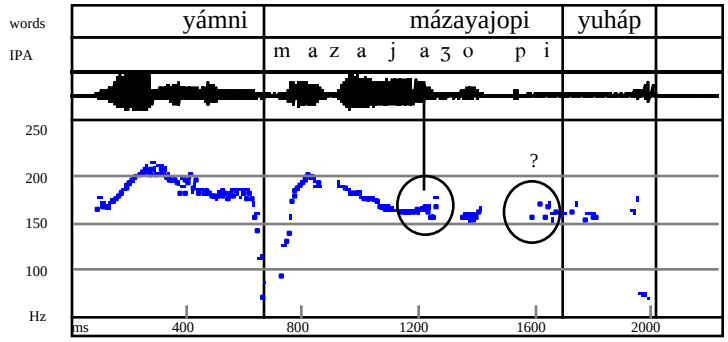

Figure 25. Pitch track of a declarative sentence, *yámni mázayajopi yuháp* 'three of them have the brass instrument.' The circled intonational events indicate the secondary stress.

So far, I have attempted to present a preliminary look at some basic intonational structures in Lakhota. Though much remains to be further explored, the intonation data suggest several points. First, intonational peak in Lakhota falls on the stressed syllable with a pattern of L+H*. When two pitch accented syllables are adjacent to each other, the L tone in L+H* tends to not be realized. Second, there is interaction between pitch accent H* and boundary tone L%, resulting in mid tone at the end of utterance. Last, for the polysyllabic words, secondary stress seems to be reliably present in Lakhota. The reason why it is not acoustically and perceptually salient is perhaps because the speaker distinguishes the syllable with secondary stress from that with primary stress, which is at the same time pitch accented syllable. Pitch accent appears to be the most perceptually salient event which marks stress and intonation at the same time.

5. Conclusion

In this paper, we have examined some phonological and phonetic properties of stress, basic intonational structures, and interaction between stress and intonation. There are quite a few prosodically conditioned factors (such as intonation, initial strengthening, final weakening, etc.) which appear to interact with the stress system of Lakhota. This paper has provided experimental work on stress and intonation for the first time in the literature. I hope this paper will serve as a basis for further development of stress and intonation system in Lakhota.

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