The Acoustic Correlates of Blackfoot Prominence

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Abstract

Blackfoot, an Algonquian language spoken in Alberta and Montana, has been described as a pitch accent language (Frantz and Russell 1989; Frantz 1991; Kaneko 1999). Pitch accent languages mark phonetic prominence with a difference in pitch on the prominent syllable. Beckman (1986) has shown that Japanese (a prototypical pitch accent language) differs from English (a prototypical stress language) in that fundamental frequency (pitch) is the *only* variable that marks prominence in Japanese, whereas several variables mark prominence in English. These variables include fundamental frequency (F_0) peak, amplitude peak, average amplitude, total amplitude and duration. Based on Beckman's analysis of Japanese, we would expect Blackfoot, as a pitch accent language, to mark prominence only with F_0, thus patterning with Japanese. However, this analysis shows that in addition to F_0, average amplitude was also correlated with prominence in Blackfoot, amplitude peak, total amplitude and duration were not. These results suggest that Blackfoot is different than Japanese in how prominence is marked. However, the results are similar enough to justify the classification of Japanese as a pitch accent language.

1. Introduction

1.1. Objectives

The purpose of this thesis is to examine the acoustic correlates of prominence in Blackfoot. Blackfoot is claimed to be a pitch accent language (Frantz and Russell 1989; Frantz 1991; Kaneko 1999), that is, a language which indicates that phonetic prominence is marked by a difference exclusively or largely in pitch on the prominent syllable. However, to my knowledge, no acoustic analysis has ever been done to determine if this is in fact how Blackfoot marks prominence. The only in-depth examination of Blackfoot pitch accent was a phonological analysis (Kaneko) apparently based on subjective interpretations of pitch changes in words spoken by Native Blackfoot speakers from the Blood reserve, which is located between Lethbridge and Cardston. She conducted an Optimality Theory analysis of accent patterns in Blackfoot nominals. Although this work greatly contributed to our knowledge of the patterns of pitch accent in Blackfoot, the conclusions were purely phonological. The present study will look at Blackfoot prominence from a phonetic point of view, focusing on how it is manifested acoustically.

1.2. Outline of the Thesis

The rest of this chapter goes over the context and methodology of data collection and information on the consultants. Chapter two reviews the phonological and phonetic attributes of different accent systems. Section 2.1 discusses the definitions of terms used throughout this thesis. Phonological prominence is discussed in §2.3, and previous research on the acoustic correlates of phonological prominence (stress and pitch accent) in other languages is discussed in §2.4. Chapter three discusses the Blackfoot language, going over the phonemic inventory in §3.1, Blackfoot syllable structure in §3.2, and the pitch accent patterns as analyzed by Kaneko in §3.3. The acoustic analysis is presented in Chapter four, with the procedures discussed in §4.1. Five variables will be analyzed: fundamental frequency, duration, amplitude peak, average amplitude and total amplitude. The results will be presented in §4.2. Chapter five presents a statistical analysis of the data, determining the significance of the results found in chapter four. Statistical procedures and their interpretations are discussed in §5.1, and the results of the statistical analysis are presented in §5.2. Chapter six discusses the results and conclusions of the acoustic and statistical analyses. §6.2 summarizes the results of this paper and §6.3 discusses the next steps that need to be taken for further research on Blackfoot prominence.

1.3. The Blackfoot Language

Blackfoot is a Native American language belonging to the Algonquian family. It is thought to be the most divergent of all Algonquian languages, suggesting that it was the first to fully split from Proto-Algonquian, (Proulx 1989). Blackfoot is spoken in Alberta and Northern Montana by the Blood, Peigan and Siksika tribes. The Siksika reserve is about one-hundred kilometers southeast of Calgary, the Blood reserve is located between Cardston and Lethbridge, the Peigan reserve is located west of Fort MacLeod, and the Blackfeet reserve is in Northern Montana. A slightly different dialect is spoken on each of these reserves. Today there are approximately 5000 Blackfoot speakers.

The language is currently undergoing a lot of change, resulting in the separate designations Old Blackfoot and Modern Blackfoot. It is likely that there is no distinct break between these two varieties, but that they represent two abstract points on a continuum of change within the language.

Most, if not all, remaining Blackfoot speakers are bilingual speakers of English. The influence of English may well be one of the reasons for the rapid change occurring within the language.

1.3. Data Collection, Methodology and Consultant Information

The data analyzed in this thesis was elicited from native speakers of Blackfoot. Most of the elicitations were done from January to April 2000 in a Field Methods class at the University of Calgary, although a small number of words were elicited in April 2001 specifically for this study. The first consultant was PB, a female who grew up on the Siksika reserve speaking Blackfoot as her first language. The second consultant was PB's older sister NB.

PB and NB made a distinction between Old and Modern Blackfoot, which is also discussed in Kaneko. The consultants often distinguished between different lexical and morphological forms used for Old and Modern Blackfoot. In citing an Old Blackfoot term, they would often suggest that this is the term an elder would use. The consultants indicated that NB spoke Old Blackfoot, while PB spoke Modern Blackfoot. However, although some of the forms elicited were different, they were similar enough to categorize them both as Modern Blackfoot. This may simply reflect the fact that each of the consultants fall along different places on a continuum from one variety to the other.

All of the data elicited in class was recorded on a Sony Professional Walkman. Transcriptions made at the time of elicitations were discussed by members of the Field Methods class and later checked with the recordings of the sessions.

2. Overview of Accent Systems

2.1. Pitch, Tone and Stress: Definitions

In the linguistics literature, the terms tone language, pitch accent, and stress accent are often used to classify languages. However, it is not always made clear what is meant by each of these terms, and different authors often seem to mean different things. In order to clarify the meanings these terms are intended to represent, I will outline the definitions I will follow throughout this thesis.

First I note that *pitch* is the perceptual correlate of the acoustic variable of fundamental frequency (F_0).

Tone languages are languages in which each word or syllable carries lexically contrastive pitch. Differences in pitch correlate with differences in meaning even when all other phonemic information is identical.

Stress will be referred to as either phonological stress or phonetic stress. *Phonological stress* is a formal method of marking one syllable in a word as more prominent than others.[1] This is usually done through modulating pitch, which is how *pitch accent languages* manifest phonological prominence.

[1] In this paper, *phonological stress* will be used interchangeably with *prominence* and *accent*.

In *stress languages,* a phonologically prominent syllable is marked through modulating phonetic stress. Phonetic stress as a method of marking prominent syllables is not as easy to define as pitch accent, as it may involve several acoustic variables. The following sections will discuss these definitions in more detail, and the acoustic variables of phonetic stress will be discussed in §2.4.

2.2. Tone Languages

As stated above, tone languages mark each word or syllable with lexically contrastive pitch. For example, in Igbo, a Niger-Congo language spoken in Africa, each syllable is marked with either a high or a low tone. Disyllabic words have four possible tone patterns, demonstrated with the minimal pairs shown in (1).

(1) a. ákwá
'crying'
b. ákwà
'cloth'
c. àkwá
'egg'
d. àkwà
'bed' (Hymen, 1975:213)

(1a) shows a high-high prominence pattern, (1b) shows a high-low pattern, (1c) shows a low-high pattern and (1d) shows a low-low pattern.

Tones can also be *contour tones*, for example, rising or falling tones. Peking Mandarin is a tone language in which three of the four tones are contour. For example, (2a) has a high level tone, (2b) has a falling tone, (2c) has a rising tone and (2d) has a falling-rising tone.

(2) a. mā
'mother'
b. mà
'scold'
c. má
'hemp'
d. mǎ
'horse' (Hymen, 1975:214).

2.3. Phonological Stress: Pitch Accent vs. Stress Accent

Languages with phonological stress employ methods of marking some syllables more phonetically prominent than others. Sometimes this prominence is lexically contrastive, as in the Japanese examples listed in (3).

(3) a. káme
'turtle'
b. kamé
'jug' (Beckman 1988:146)

I will refer to this as *lexical prominence.*

In some languages, the assignment of prominence is derived through phonological rules. For example, English nouns and unsuffixed adjectives[2] assign phonological stress to the penultimate syllable if it is heavy. (In English, heavy syllables are those with long vowels or consonants in the coda.) This pattern can be seen in the words *agénda, tomáto* and *flamíngo*. If the penultimate syllable is light (an open syllable with a short vowel), then the antepenultimate syllable is assigned phonological stress. The words *álgebra, élephant* and *béautiful* demonstrate this pattern. I will refer to this type of phonological stress as *fixed prominence.* Prominence is fixed in the sense that phonological rules determine its placement. Every relevant word has the same prominence pattern.

Both lexical and fixed prominence can be manifested phonetically in one of two ways. The first way is through pitch accent. The Japanese words in (3) are an example of lexical prominence in a pitch accent language. According to Kaneko's analysis, she suggests that Blackfoot is an example of a pitch accent language with fixed prominence.[3] However, her assertion that Blackfoot is a pitch accent language has yet to be proven phonetically, which is precisely the topic of this thesis.

Pitch accent languages modulate F_0 to mark syllabic prominence. For example, in Tokyo Japanese, the prominent syllable has a higher pitch than the syllables around it (other dialects of Japanese use a low pitch to mark the prominent syllable) (Beckman 1986). The placement of a high pitch determines the pitch patterns of the whole word. The portion of a word in Tokyo Japanese before the prominent syllable has a mid level pitch, while the portion after the high pitch of the prominent syllable has a low pitch.

The second way prominence can be manifested is through phonetic stress. An example of lexical prominence manifested as phonetic stress can be seen in the Russian words in (4).

[2] In English, different word categories show different prominence patterns.
[3] Blackfoot also has lexical prominence in some forms. The overview of Blackfoot prominence patterns in §3.3 further discusses this.

(4) a. muká
'flour'
b. múka
'torture'
c. zamók
'lock'
b. zámok
'castle' (Dobrovolsky pers. comm.)

Fixed prominence manifested as phonetic stress can be seen in the English nouns and unsuffixed affixes discussed above. Some of the acoustic variables that are modulated in languages with phonetic stress have been claimed to be pitch, amplitude, duration, and vowel quality (Fry 1958; Beckman 1986; Dobrovolsky 1999; Sluijter and van Heuven 1996). These variables will be discussed further in §2.4.

Table 1 summarizes the four types of phonological stress, giving examples of languages in each category.

Table 1

	Lexical Prominence	Fixed Prominence
Pitch Accent	Japanese	Blackfoot?
Phonetic Stress	Russian	English nouns, French, Chuvash

2.4. Acoustic Correlates of Phonetic Stress and Pitch Accent

As we have seen, in tone and pitch accent systems, prominence can be related to F_0. Phonetic stress, on the other hand, has a number of acoustic correlates. Fry (1958) suggests that there are four main acoustic correlates to the perception of stress in English. The first is the duration of syllables. The second is the intensity (or amplitude) of the sound wave, which is related to the perception of loudness. The third acoustic correlate is the frequency of the sound wave, which is perceived as pitch. The fourth correlate is variations in the formant structure of the vowels, which is related to differences in sound qualities. For example, in English, an unstressed vowel is often reduced to a schwa. This can be demonstrated in the differences in the syllables of the noun *record*, /**ˈrɛ.kəɹd**/, and the verb *record*, /**rə.ˈkɔɹd**/. Fry examined the first three of these physical correlates and determined that they all played a role in the listener's perception of prominence. He studied computer generated English noun-verb pairs listed in (5).

(5) a. ˈ**sub.jɛct** vs. **səb.ˈjɛct**
'subject:NOUN' 'subject:VERB'
b. ˈ**ab.dʒɛct** vs. **əb.ˈdʒɛct**
'object:NOUN' 'object:VERB'
c. ˈ**daj.dʒɛst** vs. **də.ˈdʒɛst**
'digest:NOUN' 'digest:VERB'
d. ˈ**kan.tɹækt** vs. **kən.ˈtɹækt**
'contract:NOUN' 'contract:VERB'
e. ˈ**pəɹ.mɪt** vs. **pəɹ.ˈmɪt**
'permit:NOUN' 'permit:VERB'

By varying the duration, intensity, and F_0 patterns he looked at which of these variables caused a shift in a listener's perception of prominence. He found that both duration and intensity played a role in the perception of prominence, although changes in intensity were not as strong of a variable because intensity changes alone never caused a complete shift in perception of prominence from one syllable to another. In both duration and intensity, the magnitude of the difference was important. When he looked at changes in F_0, he found that it also played a role in stress perception: the higher the frequency of the vowel in one syllable relative to the other, the more likely that syllable will be perceived as stressed. However, he also found that the magnitude of the frequency change was not important, it only mattered that a frequency change was present. Fry also examined listener's perceptions of words in which one syllable had a level pitch and the other syllable had a contour pitch. (Contour pitches included falling, rising, level-falling and level-rising. The contour pitches either began or ended at the same pitch as the syllable with a level pitch.) He found that the syllable with the contour pitch was perceived as prominent in two-thirds of the trials, and the level pitch was perceived as prominent in one-third of the trials. These results suggest that a change in pitch, regardless of the whether it is higher or lower, is an acoustic correlate of stress in English.

More recently, Beckman (1986) compared the acoustic correlates of Japanese pitch accent and English (phonetic) stress. Using Japanese and English as prototypes for pitch accent and phonetic stress respectively; she distinguished the acoustic differences between these two systems of marking prominence. Beckman used disyllabic minimal pairs in which the only difference was placement of the prominent syllable. For Japanese, she used the words listed in (6).

(6) a. íken
'opinion'

b. iken
'differing view'
c. íkken
'(one) house'
d. ikken
'glance'
e. kábu
'lower part'
f. kabu
'stocks'
g. káme
'turtle'
h. kamé
'jug'
i. kámi
'god'
j. kamí
'paper
k. káta
'shoulder'
l. katá
'form' (Beckman 1986:146)

For English, she used the same noun-verb pairs used by Fry listed above in (5).

Words were recorded in carrier sentences from native speakers of each language. The carrier sentence for the Japanese words is shown in (7).

(7) Sosite _______ to iimasu.
'Next I'll say _______' (Beckman 1986:145)

The carrier sentence for the English words is shown in (8).

(8) I said _______ this time. (Beckman 1986:146)

The purpose of the carrier sentence was to control for the intonation so that it would be the same for each word analyzed.

The words were then analyzed according to five variables. For each vowel she measured the F_0, the duration, the average amplitude (in dB), the amplitude peak, and the total amplitude. F_0 values were taken by measuring the third harmonic on narrow band spectrograms, and dividing the value by three. The measurement was taken at the obvious peak if there was one, if not, the measurement was taken midway through the syllable nucleus. The duration was measured on a wide band spectrogram using spectral cues such as the burst spike at the end of stop closures. The amplitude peak was the highest point of energy in dB within the vowel. The total amplitude was obtained by adding up all of the amplitude values for the vowel taken at ten millisecond intervals. This measurement takes into account both amplitude and duration. The last measurement, average amplitude, took the total amplitude values, divided by the duration, and multiplied by ten (for the ten millisecond intervals).

Beckman found that in Japanese, a prototypical pitch accent language, the only significant variable for marking prominence was the F_0. However, In English, a prototypical phonetic stress language, she found that all the variables measured were significant acoustic correlates of phonetic stress. The most significant variable was total amplitude, which is a reflection of both duration and intensity.

Dobrovolsky (1999) examined the acoustic correlates of prominence in Chuvash, a Turkic language spoken in Russia. Chuvash is a language with fixed prominence. Prominence is placed on the last full vowel of a word. If there are no full vowels (that is, if a word contains only the reduced/central vowels ĕ and ă), there is no phonological stress (Dobrovolsky 1999). The data in (9) show this pattern.

(9) a. á.dăl
'Volga'
b. i.kér.čĕ
'pancake'
c. šu.paš.kár
'Cheboksary'
d. lĕ.bĕs
'butterfly'
e. pĕ.lĕ.vĕ.mĕr
'we knew' (Dobrovolsky pers. comm.)

Dobrovolsky (1999) examined disyllabic words, comparing four word groups: words with a full vowel in the first syllable and a full vowel in the second syllable (full-full), full-reduced words, reduced-full words and reduced-reduced words. He looked at the same variables studied by Beckman to determine whether Chuvash patterned with Japanese as a pitch accent language or English as a language with phonetic stress.[4] He found that the F_0 variable was not a significant correlate of prominence in Chuvash. There were significant differences in duration and total amplitude. This suggests that Chuvash has phonetic stress, in accord with Beckman's analysis of English.

Another acoustic analysis of a language with phonetic stress was done by Sluijter and van Heuven (1996). They studied the acoustic correlates of prominence in Dutch, a language similar to English in which phonetic stress can be lexically contrastive. They examined the Dutch minimal pair shown in (10).

(10) a. ˈka:nɔn
canon
'cannon'
b. ka:ˈnɔn
kanon
'canon' (Sluijter and van Heuven 1996:2473)

They also used nonsense words in which each syllable of the target word (from (10) above) was replaced by *na*. In an attempt to separate the phonetic stress from intonation, they put each target and each nonsense word in different carrier phrases that placed the sentence intonational prominence on the target word in one instance and on a different word in another instance. They found that F_0 is not a correlate of word prominence in Dutch, but instead is a correlate of intonational prominence within a phrase.

Sluijter and van Heuven also looked at duration, vowel quality, overall intensity (in decibels) and intensity at different frequency levels. They found that the most reliable correlate of prominence in Dutch is duration, and the next most reliable correlate was what they called spectral balance, which is an increase in the intensity in the higher frequencies – above 0.5 kHz. Vowel quality and overall intensity turned out to be poor cues to phonetic stress in Dutch. Sluijter and van Heuven state that overall intensity is related to the intonational prominence of phrases, along with F_0. They suggest that this is the reason that earlier studies such as Beckman's found overall intensity to be a correlate of phonetic stress.

The present study will follow those of Beckman (1986) and Dobrovolsky (1999) and will examine F_0, duration, amplitude peak, average amplitude and total amplitude as possible correlates of prominence in Blackfoot.

[4] This was not the only purpose of this study. He also looked at whether Chuvash has left-edge default phonological and phonetic stress, that is, stress falling on the first vowel or syllable of a word with only reduced vowels, as had been claimed in earlier studies. He claimed that words with a reduced-reduced pattern did not have stress and that the apparent left-edge default stress was a result of falling word or phrase intonation found on the majority of words, irrespective of stress type.

3. An Introduction to Blackfoot[5]

3.1. Phonemic Inventory[6]

Modern Blackfoot contrasts five places of consonant articulation: bilabial, alveolar, palatal, velar and laryngeal. It also contrasts five manners of articulation: plosives, affricates, fricatives nasals and glides. The proposed phonemic inventory of the Modern Blackfoot consonants is shown in Table 2.

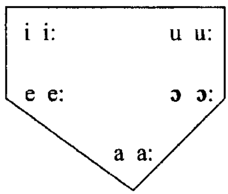
Table 2: Phonemic Inventory of Blackfoot Consonants

	Labial	Alveolar	Palatal	Velar	Glottal
Plosives	p	t		k	ʔ
Affricates	ps	ts		ks	
Fricatives	s			x	
Nasals	m	n			
Glides	w		j		

Note that these consonants also have phonemic geminate counterparts.

There are five vowels in the Modern Blackfoot phonemic inventory, shown in Table 3.

Table 3: Phonemic inventory of Blackfoot vowels



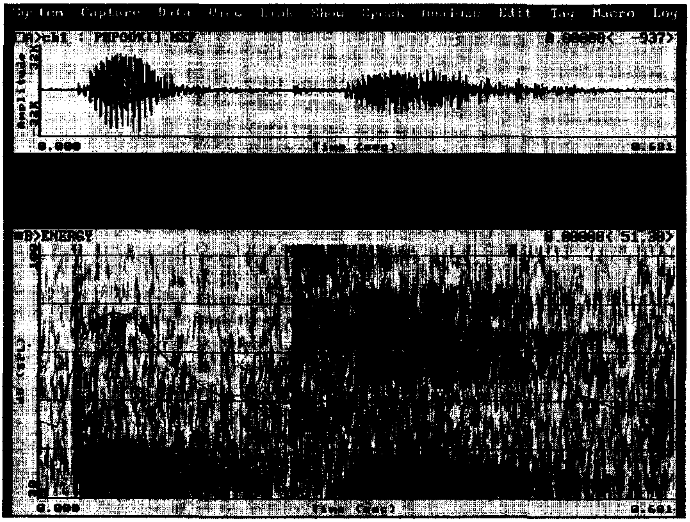
These vowels also have contrasting long counterparts. Blackfoot also has one diphthong, /oj/, but see the discussion below on the orthography for evidence of other diphthongs in other dialects of Blackfoot.

[5] For a discussion of Blackfoot Syntax, see Appendix A.

[6] For a discussion of Blackfoot phonology, see Appendix B.

Vowels are devoiced word-finally in Blackfoot. During elicitations, it seemed as if only some vowels are devoiced word-finally. However, in words that had a word-final voiced vowel, spectrographic analyses revealed that the latter half of the vowel was still devoiced. This can be seen in Figure 3-1. The line indicates intensity of the sound wave in decibels. This process of word-final devoicing may extend to the whole syllable (as discussed in §3.1). Vowels are also devoiced word-internally before [x]. Just as word-final devoicing, either the whole vowel or the first half of the vowel is devoiced. It may be that vowel devoicing is mandatory word-finally and before [x], and the cases where only half of the vowel is devoiced are underlying long vowels. This is in fact how Frantz (1991:6) orthographically represents vowels before [x]. If a vowel is voiced before [x] it is long, if it is voiceless, it is short. I propose that this analysis would be the same for word-final devoicing, except that vowel devoicing can extend to the first half of a long vowel (in fact, the whole syllable) in free variation.

Figure 1: ***pókii*****, 'small' (PB)**

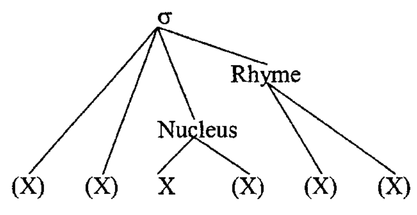


A Roman orthography was developed based on the phonological inventory of Blackfoot. Most of the consonants are written the same as their English counterparts. However, there are two phonemes that are not represented in English orthography, the velar fricative /x/ and the laryngeal stop /ʔ/. These are written as *h* and ' respectively. The three vowels, /i/, /u/ and /a/, are written with the corresponding Roman orthography *i, u* and *a*. The other two vowels, /e/ and /ɔ/, are written as the diphthongs *ai* and *ao*. Frantz (1991) suggests that some varieties of Blackfoot still pronounce these as diphthongs (from which they were historically derived). However, our elicitations showed that they were produced as monophthongs in the variety spoken by our consultants. Kaneko (1999:12-16) analyzes these sounds as diphthongs and thus has a tripartite vowel inventory with just /i/, /u/ and /a/. The consultants used in her study were from the Blood reserve, so this is likely a difference in dialect. Prominence is shown in the orthography by an acute accent over the vowel of the prominent syllable.

3.2. Syllable Structure

The simplest syllable in Blackfoot is a syllable with a short vowel and no onset or coda. Blackfoot also allows long vowels and diphthongs. Onsets and codas are also optional in Blackfoot, which allows for both simple and complex onsets and codas. Words are syllabified according to the Maximum Onset Principle, which states that intervocalic consonants and consonant clusters become onsets rather than codas as long as the consonant cluster is an allowable sequence within the language. Consonant clusters allowed in Blackfoot involve the alveolar fricative before or after stops and affricates. As earlier stated, Blackfoot also has geminate consonants, and these can also occur as part of a consonant cluster. When syllabified, geminates will generally become both the coda of the preceding syllable and the onset of the following syllable. The Maximal Syllable Template in Blackfoot is shown in (11).

(11) *Blackfoot Maximal Syllable Template (after Kaneko, 1999)*[7]



[7] This is the syllable template given by Kaneko (1999). It may be that the template should include a node for an onset. However, this issue is not relevant for the current analysis and will therefore not be discussed.

3.3. Blackfoot Prominence Patterns[8]

Kaneko did an analysis of prominence patterns in Blackfoot nouns. She suggests that Blackfoot has a mixed lexical and fixed accent system. Kaneko does not explain how the placement of the pitch accent was determined for her study. Presumably it was a subjective analysis based on what she heard during elicitations with her consultants.

Just as in Chuvash and English, Blackfoot phonological stress patterns depend on syllable weight. In Blackfoot, heavy syllables are those with a long vowel or a consonant in the coda. On mono-morphemic nouns, a heavy syllable carries prominence. This can be seen in (12a). If there is no heavy syllable, prominence is lexically specified, as in (12b) and (12c). If there is more than one heavy syllable, prominence will fall on the leftmost heavy syllable, as seen in (12d). There do not appear to be any phonological rules to predict where the prominence will fall in words with only light syllables.

(12)	a. /ˈnaa.pi/	náápi	'trickster'
	b. /ˈsto.ʔo/	stó'o	'ghost'
	c. /so.ˈpo/	sopó	'wind'
	d. /piˈksii.ksii.na/	piksííksiina	'snake' (Kaneko 1999:85-87,145)

The following patterns are proposed by Kaneko for compound nouns. The leftmost accent of the two morphemes is retained, unless the accent is on the final syllable, in which the accent moves to the juncture between the two morphemes. This can be seen in (13a) and (13b) respectively. If both morphemes of the compound noun have no lexical accent, the final syllable is marked as prominent. This is shown in (13c).

(13)	a. /piˈsat-/ + /ˈna.pi.nju.wan/	pisát- + nápinyowan	'fancy/unusual' + sugar'
	/piˈsa.tsa.pii.nju.wan/	psátsaapiinyoan	'candy'
	b. /sik/ + /ox.ˈkii/	sik- + ohkíí	'black' + 'water'
	/si.ˈkox.kii/	sikóhkii	'vanilla extract'
	c. /sik-/ + /-i.ka/	sik- + -ika	'black' + foot'
	/si.ksi.ˈkaa/	Siksika	'Blackfoot'
			(Kaneko 1999:153, 155, 156)

[8] Note that this is only a brief summary of Kaneko's (1999) analysis. In her paper, she lists many more examples and constraints than will be discussed here. See her work for a more detailed look at prominence patterns in Blackfoot nominals.

Kaneko also notes that there is a contrast found in long vowels; those with a high level pitch, those with a rising pitch and those with a falling pitch. This suggests that both timing slots of a long vowel can carry prominence, or just one can carry prominence. She claims that the words in (14) show these differences.

(14)	a. [pií.ta]	piíta	'eagle'
	b. [póo.ka]	póoka	'child'
	c. [aa.kíí]	aakíí	'woman' (Kaneko 1999: 142-143)

(14a) shows a rising pitch in the first syllable. The first syllable of (14b) shows a falling pitch. The second syllable in (14c) shows a high level pitch. In addition to examining the acoustic correlates of Blackfoot prominence, this study will test Kaneko's claim of different prominence patterns on long vowels by examining spectrograms for the above patterns of prominence. The results can be found in §6.1.1.

4. Acoustic Analysis

4.1. Procedures

The present study assesses Blackfoot phonetic accent/prominence with the same five variables calculated by Beckman (1986). The first is F_0, which is measured in Hertz (Hz). The second and third variables are the average amplitude and amplitude peak. Amplitude is measured in decibels, which is related to the perception of loudness. The fourth variable is total amplitude. This is a measurement of decibels over time. The decibel level is measured at 20ms intervals over the course of a vowel, then all of the measurements are totaled. Total amplitude thus takes into account both the amplitude and the duration of the vowel. The final variable is duration. This is measured in milliseconds (ms).

The results will also be expressed in ratios. These ratios express the results of the measurements from each word with one figure, rather than having a value for each vowel. The formulas in (15) were used to calculate the ratios.

(15) a. F_0 Peak Ratio = 17.31 ln (Hz V_2/Hz V_1)[9]
b. Duration Ratio = ln (ms V_2/ms V_1)
c. Amplitude Peak Ratio = dB Peak V_2 – dB Peak V_1
d. Average Amplitude Ratio = dB Average V_2 – dB Average V_1
e. Total Amplitude Ratio = Total Amplitude V_2 – Total Amplitude V_1

[9] This formula is used by Beckman to calculate the difference in semitones between the first and second syllable.

With these formulas, a word with a higher value of the variable being measured in the first vowel as compared to the second (falling values) will result in a negative ratio value and words with a higher value in the second vowel (rising values) will result in a positive ratio value.

Most of the data used for this study was collected over the course of four months as described in §1.2. Disyllabic words from the corpora were selected for the present study. The only disyllabic words not used were those with a glide between the vowels of the first and second syllable,[10] and words in which there was too much background noise to accurately interpret the spectrograms.

Thirty-eight words were used, 24 from speaker PB and fourteen from speaker NB. The words were elicited in isolation. The consultants were asked off-tape what the target word was, and then they were asked to repeat the word twice while being recorded. For this analysis, the first of the two words was analyzed, although there were a few instances where the word was only recorded once.

For the F_0, average amplitude and amplitude peak analyses, the words were divided into two groups. The first group consisted of words with a strong-weak prominence pattern and the second group consisted of words with a weak-strong prominence pattern. The duration and total amplitude measurements needed to be further divided because Blackfoot has a phonemic distinction between long and short vowels. For these two measurements, each group was subdivided into four more groups: words with a short vowel followed by a short vowel, words with a short vowel followed by a long vowel, words with a long vowel followed by a short vowel, and words with a long vowel followed by another long vowel. Words with different prominence patterns could then be compared between words with the same patterns of vowel length. The total number of tokens for each group can be seen in table 4.

Table 4: Number of tokens per group

	Strong-weak	Weak-strong
Short-short	10	6
Short-long	5	5
Long-short	3	2
Long-long	2	5

Comparisons will only be made in groups with a short-short or short-long length pattern due to the small number of words in the other two groups.

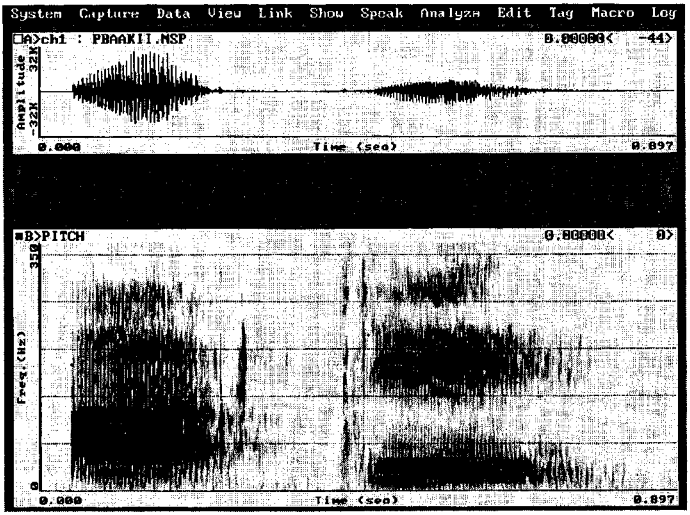
[10] The forms were eliminated because it was too difficult to determine where the first vowel of the word ends and the second vowel begins.

Vowel qualities are randomly distributed in the data. The three most common vowels, /i/, /o/ and /a/, occur in both the first and second syllable in words with a strong-weak and weak-strong prominence pattern, with the exception of /o/ in strong-weak words.

The data was analyzed on a Kay CSL model 4300, version 4.17. The words were digitized from the cassette tape at a sampling rate of 12800 Hz. Each word was examined on a broadband spectrogram with a bandwidth of 188 Hz.

The F_0 was measured by using a peak-picking algorithm that sampled the F_0 at 20 ms intervals. Figure 2 shows these pitch patterns overlaid on the broadband spectrogram. The dots are pitch peaks in Hz. The waveform is in the window above the spectrogram.

Figure 2: *aakíí*, 'woman' (PB)



In order to determine the accuracy of this algorithm, random words were checked by measuring the fifth harmonic on a narrowband spectrogram with a bandwidth of 31 Hz and dividing by five. These measurements agreed with those given by the algorithm. Figure 3 shows the wideband spectrogram of the same word in Figure 2. The arrow is pointing to the fifth harmonic. The amplitude peak and average amplitude were determined by using a peak-picking algorithm that calculated the dB level at 20 ms intervals. The amplitude can be seen in Figure 4.

Figure 3: ***aaklí*, 'woman' (PB)**

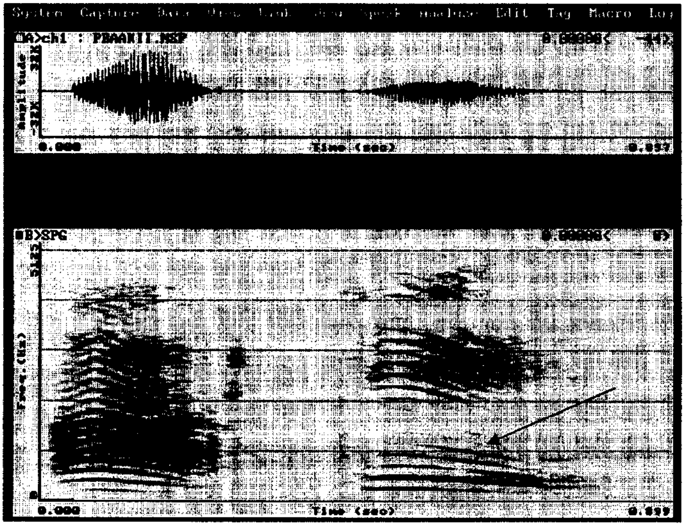
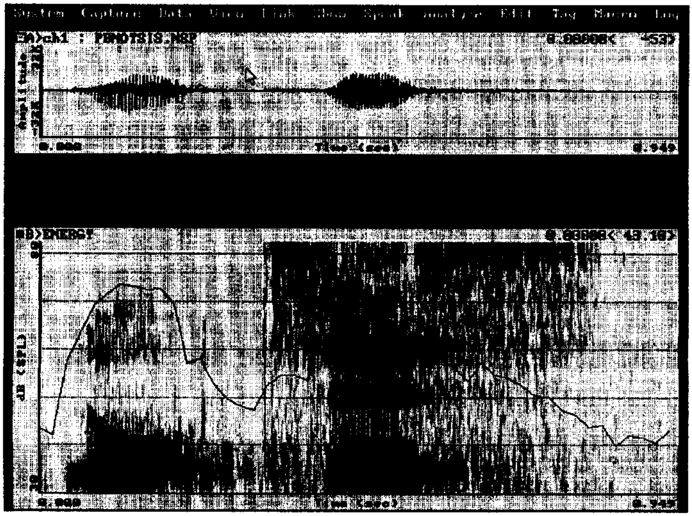


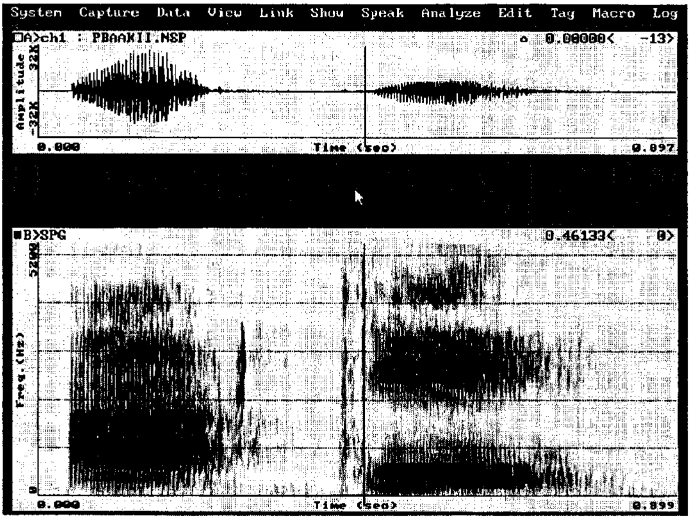
Figure 4: ***notsís*, 'my arm/hand' (PB)**



For the average amplitude, all decibel values during a value were added and then divided by the number of measurements taken. The total amplitude was the value obtained in the calculation of the average amplitude before dividing.

The duration measurement was the time in ms of the vowel. Duration measurements were made on the broadband spectrogram. The measurement of the vowel began after the burst spike of the preceding stop if it was an obstruent and after the end of the nasal murmur. This can be seen in figures 5 and 6. The vertical line in each figure indicates where the duration measurements began.

Figure 5: ***aakíí*, 'woman' (PB)**



The measurement of the end of the vowel duration was more difficult to determine. Generally, vowels end before a portion where there is no sound production (unless followed by a nasal), either as a result of the closed portion of a stop or at the end of the word. This was especially difficult when the latter half of the vowel was voiceless. Due to recording limitations, the intensity of the vowel formants is, at times, the same intensity of the background noise. Measurements were taken at the point where the formants were no longer apparent. This can be seen in Figure 7.

Figure 6: *ninàá*, 'man/chief' (PB)

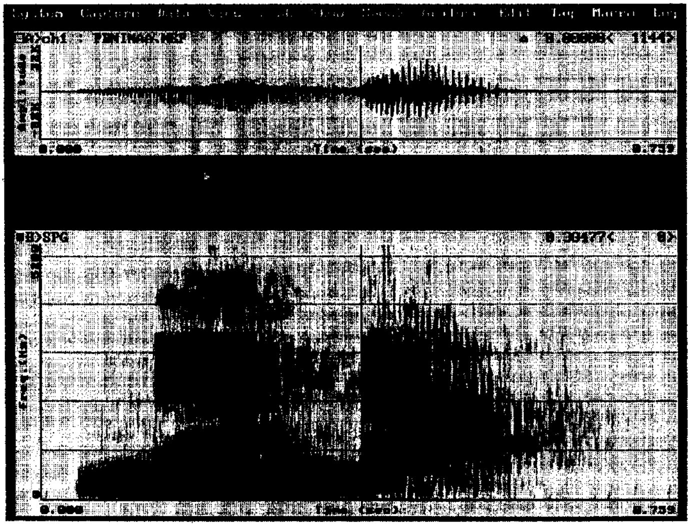
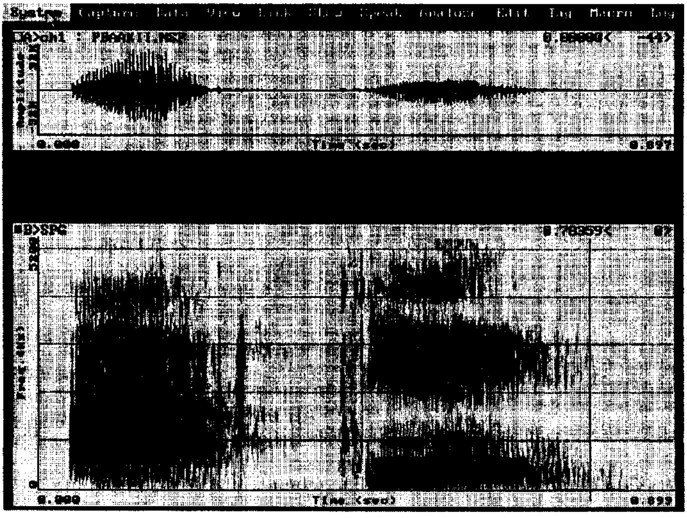


Figure 7: *áàkii*, 'woman' (PB)



4.2 Results

This section gives the results of the acoustic analysis. The different measurements for each vowel will be presented as well as the ratios discussed in §4.1. The raw data will be presented in the following sections, while the statistical analyses will be presented in Chapter 5. This will determine whether or not any differences found in the raw data are statistically significant.

The mean F_0 for the first vowel of words with a strong-weak prominence pattern is 201.30 Hz, and the mean for the second vowel is 158.15 Hz. This shows a definite drop in pitch from the first vowel to the second. Figure 8 shows this pattern. The mean F_0 for the first vowel of words with a weak-strong prominence pattern is 187.66 Hz, and the mean for the second vowel is 189.16 Hz. There does not seem to be a considerable difference in pitch between the two vowels in words with a weak-strong prominence pattern. Figure 9 shows this pattern.

The level F_0 pattern may be a result of a falling intonation overlaid on the prominence patterns of the word. A falling intonation plus a rising prominence pattern results in a general flattening of pitch from one vowel to the next. In words with a strong-weak prominence pattern, the falling pitch is augmented by the falling intonation.

Figure 8: ***píítaa*****, 'eagle' (PB)**

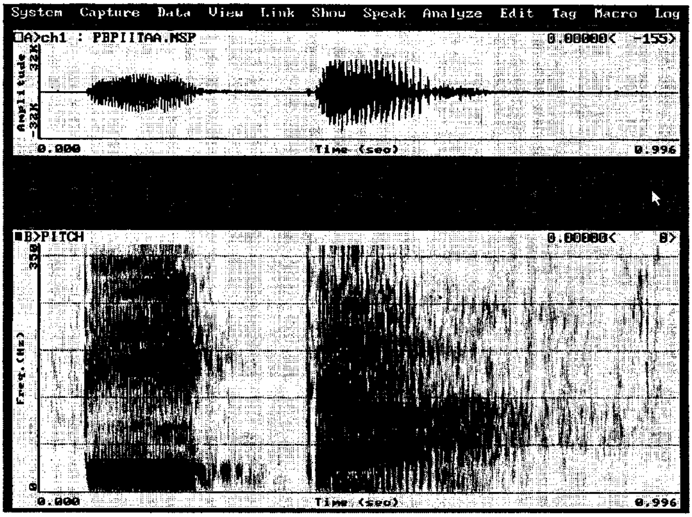
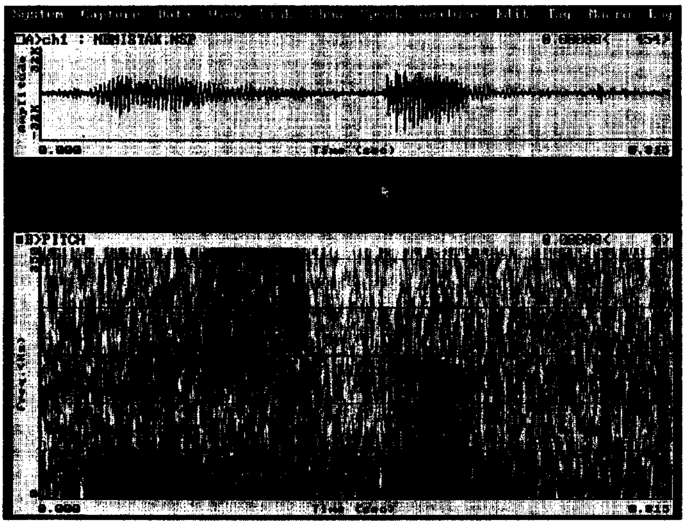
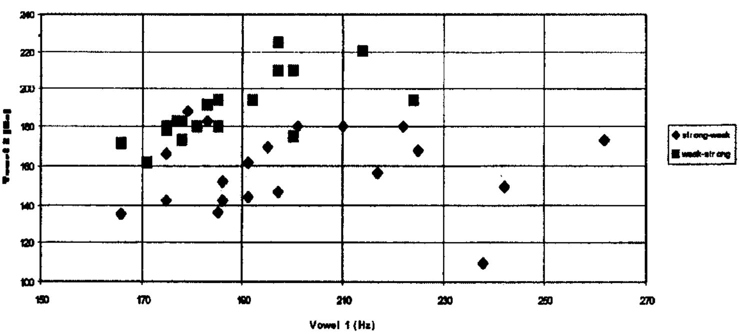


Figure 9: *misták*, 'mountain' (NB)



The results of the F_0 analysis are shown in the scatter plot in table 5.[11]

Table 5: F_0 Peak



[11] All graphs were produced with Microsoft Excel 2000.

This chart plots the F_0 peak of the first vowel against the second vowel. Words with a higher F_0 peak in the second vowel as compared with the first vowel will be closer to the top left corner of the scatter plot. You can see that the words examined follow this general pattern, with most of the words with a weak-strong prominence pattern falling to the upper left of the words with a strong-weak prominence pattern.

The average F_0 Peak Ratio for words with a strong-weak prominence pattern is -4.192 and the average for words with a weak-strong prominence pattern is 0.121. The negative ratio value indicates a falling pitch while the positive ratio value indicates a rising pitch. This demonstrates that words with a higher pitch on the first vowel correspond to words with a strong-weak prominence pattern and words with a higher pitch on the second vowel correspond to words with a weak-strong prominence pattern. The ratio value for the weak-strong words is close to zero. This reflects the fact that there was not a large difference in the F_0 of the two vowels. These results suggest that pitch is a correlate of Blackfoot prominence.

Because Blackfoot distinguishes between long and short vowels, duration measurements could not be compared between all of the words with a strong-weak prominence pattern and all of the words with a weak-strong prominence pattern. Table 6 shows the words with a short-short length pattern and Table 7 shows the words with a short-long length pattern. Words with a longer duration on the first vowel as compared to the second vowel will appear closer to the top left portion of the charts.

Figure 6: Duration in Short-Short Words

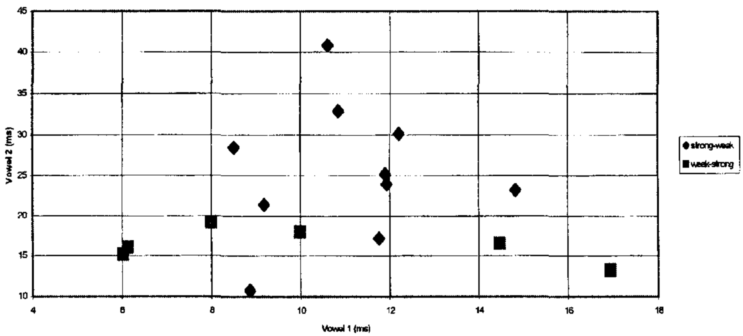
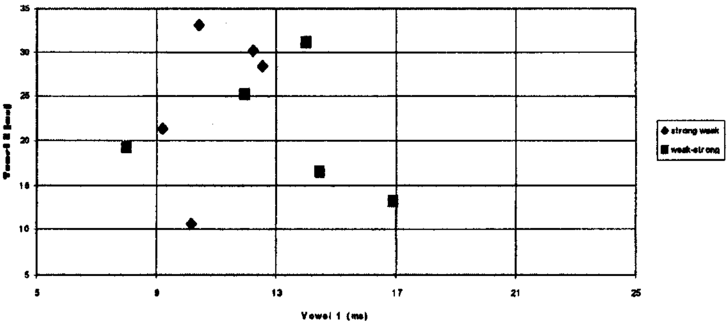


Table 7: Duration in Short-Long Words



The pattern is not as clear in duration as it seemed to be for F_0. The mean length of the first vowel in short-short words with a strong-weak pattern is 11.061 ms while the mean length of the second vowel is 25.392 ms. In short-short words with a weak-strong prominence pattern the mean length of the first vowel is 10.257 ms and the mean length of the second vowel is 16.376 ms. There is a definite lengthening of the final vowel, which is probably due to the intonational properties of phrase-final lengthening. However, the final vowel in words with a strong-weak prominence pattern is lengthened more than in words with a weak-strong prominence pattern. This can be seen in figures 10 and 11 respectively. Beckman found the prominent syllable is lengthened in English. The results of Blackfoot prominence patterns show the opposite is happening. The prominent syllable is shorter.

Figure 10: ***nitán*****, 'my daughter' (PB)**

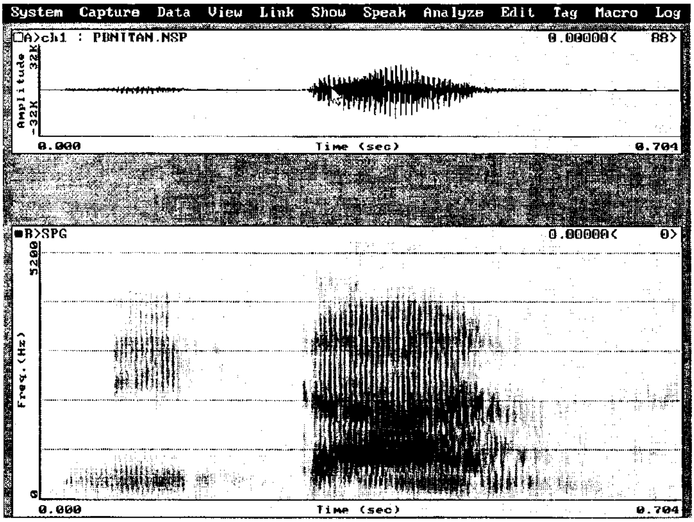
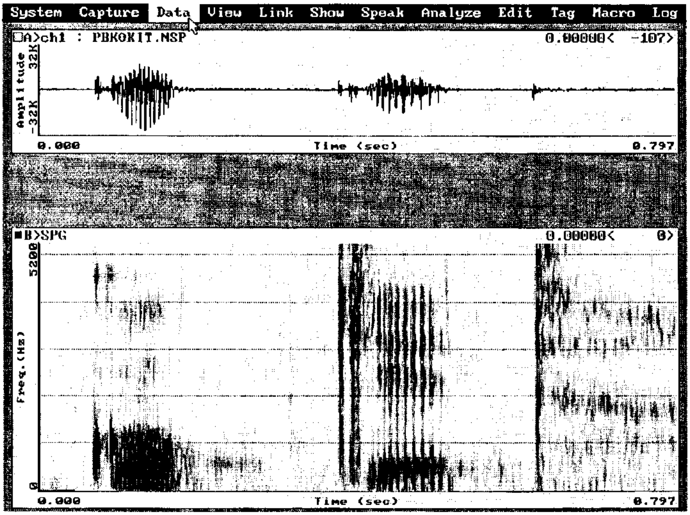


Figure 11: ***kókit*****, 'give' (PB)**



In words with a short-long length pattern, the mean duration of the first vowel of those with a strong-weak prominence pattern is 9.557 ms and the mean duration of the second vowel is 32.149 ms. In short-long words with a weak-strong pattern, the mean duration of the first vowel is 11.384 ms and the second vowel is 28.432 ms. Again, the second vowel is lengthened more in those words with a strong-weak pattern, which points to the fact that in Blackfoot, duration does not pattern in the same ways it does in languages with phonetic stress.

The average duration ratio in short-short words with a strong-weak prominence pattern is 0.597 and the average for words with a weak-strong prominence pattern is 0.623. The positive number for both word types reflects the fact that the final vowel of a word was always lengthened in the elicitations. The value is higher in words with a weak-strong prominence pattern than those with a strong-weak prominence pattern, which is what we would expect if duration were a correlate of Blackfoot prominence. A higher positive ratio value indicates a greater lengthening in the final syllable.

In short-long words with a strong-weak prominence pattern, the average duration ratio is 1.026 and the average in words with a weak-strong prominence pattern is 0.957. Contrary to the short-short words, the average duration ratio for words with a strong-weak prominence pattern is higher than the average for words with a weak-strong pattern. This is not the expected result if duration were a correlate of Blackfoot prominence.

Due to the fact that there is no clear pattern in Tables 6 and 7, and the fact that short-short and short-long words show different patterns in the duration ratio, duration is probably not a correlate of Blackfoot prominence.

The mean amplitude peak value for the first vowel in strong-weak words is 77.061 dB, and the mean for the second vowel is 74.549 dB. Figure 12 shows an example of this pattern.

In words with a weak-strong prominence pattern, the mean amplitude peak value in the first value is 75.663 dB and 77.415 in the second vowel. An example of this pattern can be seen in Figure 13. These patterns do suggest that the prominent syllable in Blackfoot has a higher amplitude peak.

Figure 12: *kókit*, 'give' (PB)

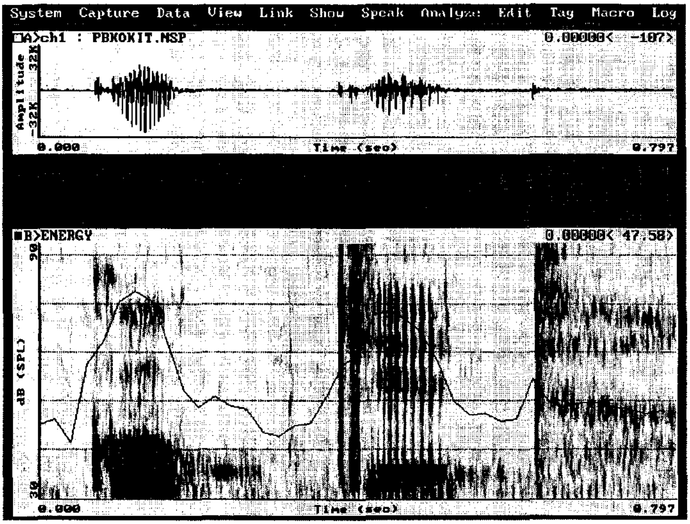


Figure 13: *notsís*, 'my arm/hand' (PB)

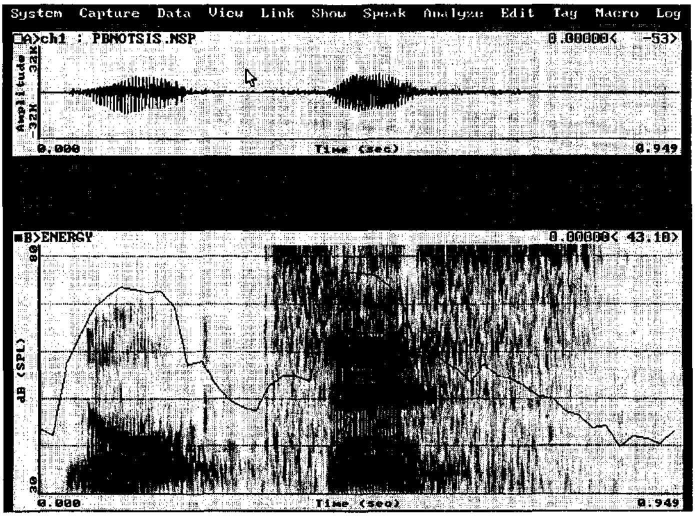
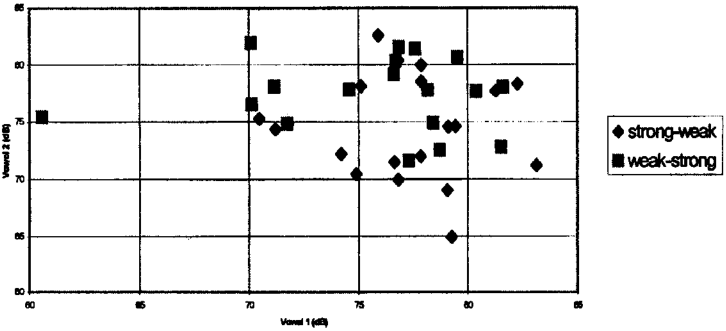


Table 8 shows the scatter plot for the amplitude peak.

Table 8: Amplitude Peak



Words with a higher amplitude peak in the second vowel will appear closer to the top left of the chart in table 8. The pattern is not as clear as the pattern in table 5 for F_0; the statistical analysis in section five discusses whether or not the difference is significant.

The mean amplitude peak ratio for words with a strong-weak prominence pattern is -2.507 and the average for words with a weak-strong prominence pattern is 1.752. This is what we would expect if amplitude peak is a correlate of Blackfoot pitch accent. Words with a higher amplitude peak on the first vowel correspond to words with a strong-weak (falling) prominence pattern and words with a higher amplitude peak on the second vowel correspond to words with a weak-strong (rising) prominence pattern.

In words with a strong-weak prominence pattern, the mean average amplitude value for the first vowel is 73.149 dB and the mean value for the second vowel is 63.844 dB. An example of this can be seen in figure 14.

In words with a weak-strong prominence pattern, the mean value for the first vowel is 70.587 dB and the mean value for the second vowel is 70.240 dB. Figure 15 shows an example of this pattern. This pattern is very similar to the pattern we saw in the F_0 values with a sharp drop in words with a strong-weak pattern and not much change in words with a weak-strong pattern. This could be due to the intonation overlay.

Figure 14: ***pókii*****, 'small' (PB)**

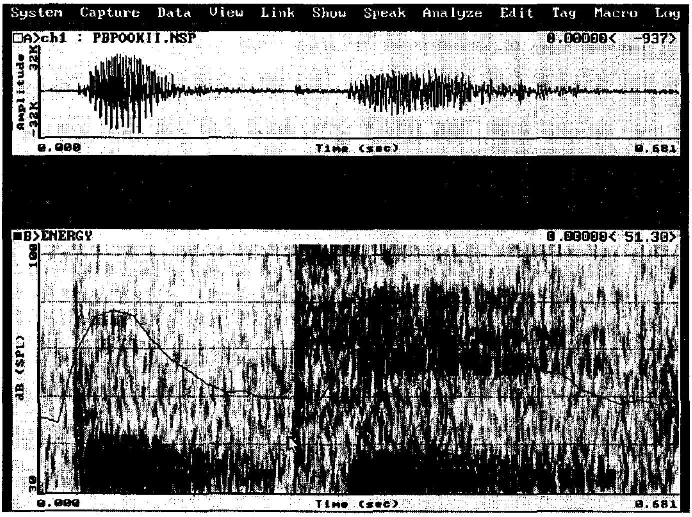


Figure 15: ***pookáá*****, 'child' (PB)**

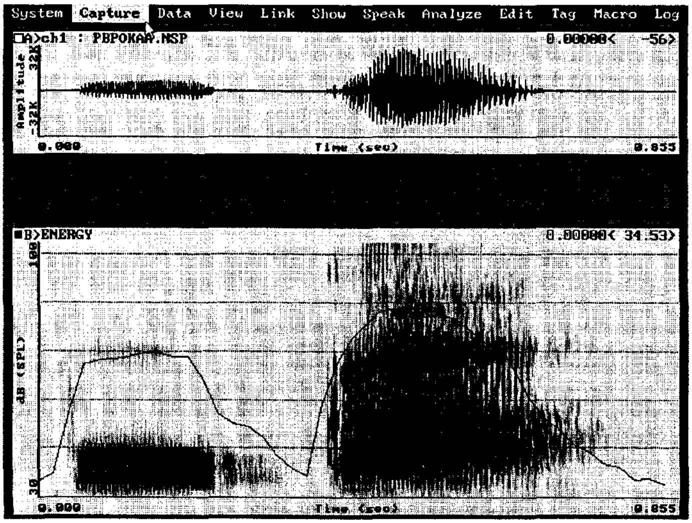
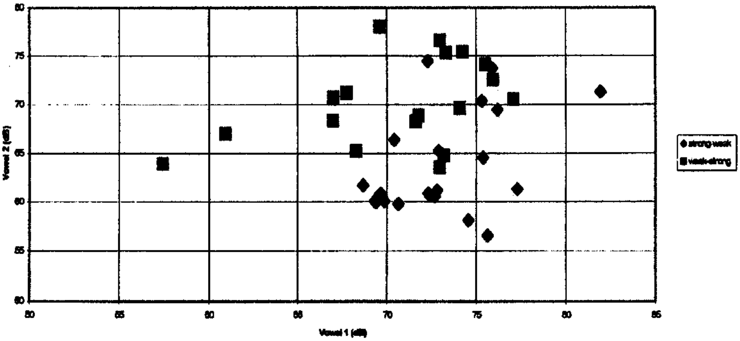


Table 9 shows the scatter plot of average amplitude values in vowel one versus vowel two.

Table 9: Average Amplitude

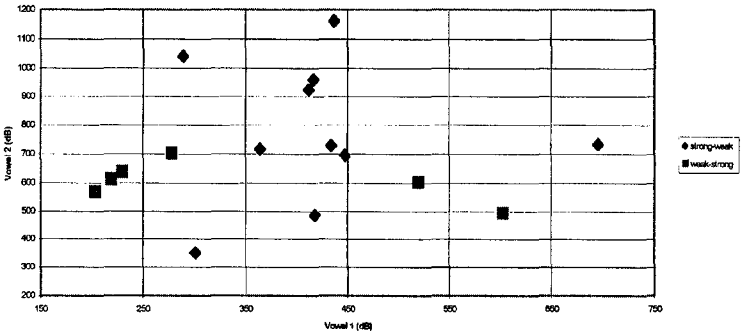


Words with a higher average amplitude value in the second vowel will be closer to the top left corner of the chart. There is a somewhat overlapping pattern of weak-strong words closer to the top left and strong-weak words closer to the bottom right.

The mean average amplitude ratio for words with a strong-weak prominence pattern is -9.292 and the average for words with a weak-strong prominence pattern is -0.345. The negative value in both prominence patterns indicates that the peak amplitude of the majority of the words elicited occurs during the first vowel. However, there is a considerable difference between the two values that corresponds to what we would expect if average amplitude is a correlate of Blackfoot pitch accent. Words with a higher average amplitude value on the first vowel correspond to words with a strong-weak prominence pattern and words with a fairly level average amplitude on the second vowel correspond to words with a weak-strong prominence pattern. The raw data suggests that average amplitude is a correlate of Blackfoot prominence.

Like duration, total amplitude values need to be looked at separately for each of the different length patterns. Words with a short-short length pattern and a strong-weak prominence pattern have a mean total amplitude of 421.447 dB for the first vowel and 781.173 dB for the second vowel. Short-short words with a weak-strong prominence pattern have a mean total amplitude of 342.116 dB for the first vowel and 603.870 dB for the second. Because total amplitude depends on duration, the lengthening of the final syllable that we saw in §4.2 will result in total amplitude values higher on the second vowel than the first. Like duration, this shows a pattern opposite to that found in English. Table 10 shows a scatter plot of these words.

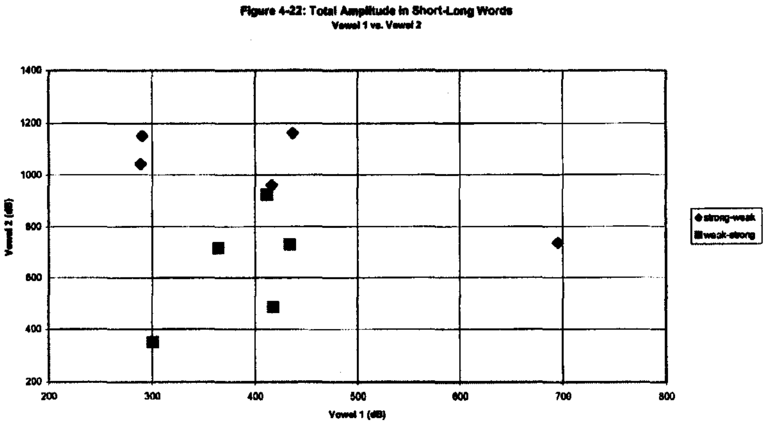
Table 10: Total Amplitude in Short-Short Words



In table 10, words with greater total amplitude on the second vowel will appear closer to the top left corner of the chart. Insofar as this chart does not seem to show any clear pattern, short-short words do not seem to be distinguished by total amplitude.

In words with a short-long length pattern and a strong-weak prominence pattern, the mean total amplitude value for the first vowel is 358.810 dB and 1101.564 dB for the second vowel. In short-long words with a weak-strong prominence pattern, the mean total amplitude value for the first vowel is 428.100 dB and 984.402 dB for the second vowel. Like the words with a short-short length pattern, these words seem to show that total amplitude does not pattern with prominence. Table 11 shows a scatter plot of the total amplitude in words with a short-long length pattern.

Table 11: Total Amplitude in Short-Long Words



As in table 10, words with greater total amplitude on the second vowel will appear closer to the top left corner of the chart. This chart seems to show the opposite pattern than one would expect in a language with phonetic stress. The total amplitude values pattern in much the same way as the duration values. This is doubtless due to the fact that duration is an important component of the total amplitude measurement. The total amplitude measurement is greater when the duration of the vowel is longer.

The average total amplitude ratio in short-short words with a strong-weak prominence pattern is 359.726 and the average for words with a weak-strong prominence pattern is 261.753. As with the values for duration ratios, the positive number for both word types reflects the fact that the final vowel of a word was always lengthened in the elicitations. The value is higher in words with a strong-weak prominence pattern than those with a weak-strong prominence pattern.

In short-long words with a strong-weak prominence pattern, the average total amplitude ratio is 742.754 and the average in words with a weak-strong prominence pattern is 556.302. Like the short-short words, the value is higher in words with a strong-weak prominence pattern than those with a weak-strong prominence pattern. This is not what we would expect if total amplitude were a correlate of Blackfoot prominence.

The next section will look at whether or not the patterns found above are statistically significant.

5. Statistical Analyses[12]

5.1. Statistical Procedures

The statistical tests used in this paper to determine the significance of the results will be discussed in this section. Statistics will be used to determine whether or not there is a significant difference in each of the five variables between the words with differing prominence patterns.

Some terms used in this section will need defining. *Sample* refers to the set of data actually observed. In this paper, this will be the data obtained in the present experiments. The *population* refers to the complete set of data. For example, for the F_0 variable measured in this study, population would refer to the F_0 of the vowels in all disyllabic words ever uttered by any Blackfoot speaker of the same dialect being studied. Thus, the sample is a subset of the population. Obviously the population is not something that can be measured, so the statistics used in this paper will be used to determine what the probability that the difference found in the sample data is actually a reflection of a difference that would be found in the population data. An *independent variable* is a variable whose selection is decided on or controlled by the experimenter with the purpose of examining their effects on other variables. In this study the independent variables are prominence and length patterns of the words. A *dependent variable* is the variable being measured. This study has five dependent variables: F_0, duration, amplitude peak, average amplitude and total amplitude.

The *null hypothesis* (H_0) is the hypothesis that is being tested by the particular statistical procedure. Scientific reasoning suggests that although we can never prove any statement about a population to be true, we can prove it to be false, (assuming we do not have access to the whole population). This is because even if we observe all of the members of a sample to have a particular property, we still cannot conclude with absolute certainty that every member of the population has that property. This is true no matter how many members of the population are observed, short of observing all members. However, it takes only one member of the population without the property to prove that a statement about the population is false. This is the basic idea behind the H_0, which is the hypothesis that there is no difference (or no relationship) between the independent and dependent variables. In this study, the null hypothesis is that the values of the

[12] The statistical procedures used in this study were learned in Psychology 312 – Experimental Methods and Design in the Fall/Winter session of 1998/1999 at the University of Calgary. Dr. Christopher Sears, one of the course instructors, also provided help with the statistics on this data, although I bear responsibility for the ultimate interpretation. The definitions follow from Howell (1999).

ratios calculated in section 4.2 will be the same in words with a weak-strong prominence pattern as the words with a strong-weak prominence pattern.

The *critical value* is the value set by the experimenter at which the H_0 will be rejected. In this study, the value that we will be looking at is the *p-value* (probability value). The p-value tells the probability that the results would occur by chance if the H_0 were true. In other words, the p-value tells us how likely it is that the difference (or relationship) found in the sample is not an actual difference that would be found in the population. The p-value is measured from zero to one, with zero meaning that it is impossible for the sample difference to be a reflection of the population difference, and one meaning that the sample difference is absolutely a reflection of the population difference. Thus, a p-value of .05 says that there is a five percent chance that the results of the sample data are not a reflection of the population data, and the difference occured by chance, or was a result of a sampling error. The critical value for this experiment will be expressed in terms of a p-value and will be set at .05. In other words, for this experiment to find a difference statistically significant, there must be a five percent chance (or less) that the difference did not occur by chance.

There will be two statistical procedures used in this study, ANOVAs and t-tests. *ANOVA*s (analysis of variance) look at the differences between groups and determine if this difference is significant by comparing it to the difference within groups. This study will use an ANOVA for two independent samples to determine whether the variance between the eight groups of different pitch and length patterns is larger than the variance within the groups. A separate ANOVA will be done for each of the five dependent variables. An ANOVA will give us a p-value to tell us the significance of the differences in the values between any of the eight groups. If the p-value is .05 or less, there will be a significant difference between at least two of the groups, but the ANOVA will not tell us which groups result in a significant difference.

To determine which groups have a significant difference between them, we turn to *t-tests*. T-tests give us the p-value for whether or not there is a significant difference between two groups. A separate t-test must be done each time you want to compare two groups. If there are five groups in an ANOVA and you want to see if there is a significant difference between each of the groups, 5! (or 120) t-tests will need to be done. Usually only a few of the t-tests will be done by the experimenter, depending on which groups are to be compared. T-tests can be one-tailed or two-tailed. A one-tailed t-test rejects the H_0 only if the sample is different from the population in one direction, (either specifically higher or specifically lower). In a two-tailed t-test it does not matter whether or not the sample is higher or lower than the population.

ANOVAs and t-tests will be done for independent samples. That is, the different groups of independent variables are not related to each other. Both

ANOVA and t-tests take into consideration the number of items in the sample data. A higher number of items in the sample data will increase the chance that a significant difference will be found if there is one.

5.2. Results

A one-way ANOVA for independent samples was performed on the F_0 peak ratios on SPSS. The ANOVA looked at the variance between the eight groups based on length and prominence patterns. The p-value obtained was .0024. This tells us that there is a 0.24% likelihood that the different F_0 peak ratio values between the eight groups is a result of chance. This is below the critical value set for this experiment.

Because the different length patterns do not affect the F_0, the data will be split into two groups instead of eight for the t-tests: those with a strong-weak prominence pattern, and those with a weak-strong prominence pattern. A two-tailed t-test for independent samples was done by hand.[13] The result was a p-value less than .001. This tells us that there is less than a 0.1% chance that the different F_0 peak ratio values between strong-weak and weak-strong word occurred by chance. This is below our critical value of .05, thus we can say that F_0 is a significant correlate of prominence in Blackfoot. We can therefore conclude that Blackfoot speakers manipulate pitch deliberately in the marking of a prominent syllable.

A one-way ANOVA for independent groups was run for duration between the eight groups of differing length and prominence patterns. The p-value obtained was .0016. There is less than 0.16% likelihood that the differences in duration are a result of a sampling error. This is below our critical value of .05.

Unlike F_0, length patterns are relevant for the duration ratio measurements. T-tests will have to be performed between the two prominence patterns within the same length patterns. Short-short and short-long words were tested, as the other two length patterns have such small sample sizes. A two-tailed t-test for independent samples on words with a short-short pattern gives a p-value greater than .50. This says that there is over 50% likelihood that differences in total amplitude ratios between strong-weak and weak-strong words are due to chance. This is much higher than our critical value of .05. The H_0 that there is no difference in duration between the two prominence patterns in short-short words cannot be rejected, and thus duration cannot be said to be a correlate of Blackfoot prominence in these words.

A two-tailed t-test for independent samples on words with a short-long length pattern resulted in a p-value greater than .50. Again, this is much higher than our critical value of .05. The results of the t-tests suggest that there are no

[13] T-tests were not done on SPSS, they were calculated by hand. Exact p-values could not be determined, although ranges are given.

differences in the duration ratios between groups with different prominence patterns. The difference found in the ANOVA is likely due to the fact that Blackfoot has phonemic length. It would seem obvious that there would be difference between groups with different length patterns. Again, the H_0 cannot be rejected and according to these results, duration cannot be said to be a correlate of Blackfoot prominence in short-long words.

A one-way ANOVA for independent samples was run on the amplitude peak ratios of the eight groups, and a p-value of .1390 was obtained. This says that there is a 13.90% likelihood that the difference in the sample ratios is not a reflection of an actual difference in the population ratios. This is above our critical value of .05, and we cannot reject the null hypothesis that states that there is no difference in peak amplitude between the eight groups. That is to say that we cannot conclude a difference in peak amplitude between any of the eight groups. No further tests are needed because the ANOVA tells us that we would not find a significant value between any of the groups. We cannot conclude that peak amplitude is a correlate of prominence in Blackfoot.

The results of a one-way ANOVA for independent variables on the average amplitude ratios between the eight groups give a p-value of .0001. This is below our critical value of .05, and suggests that there is a difference between some of the groups. To determine which groups show different average amplitude ratio values, we must turn to t-tests.

A two-tailed t-test for independent samples was performed (like F_0, the length patterns are not relevant to average amplitude, therefore the data was split only into two groups, those with weak-strong and strong-weak prominence patterns). The p-value found was less than .001. This is well below the critical value of .05. This tells us that there is a less than 0.1% likelihood that the difference in average amplitude between the words with different prominence patterns is due to chance. Average amplitude is a significant correlate of prominence in Blackfoot. A prominent syllable in Blackfoot is deliberately marked with a higher average amplitude value; that is, it is louder overall than a syllable that is not prominent.

A one-way ANOVA for independent samples was done on the total amplitude ratios between the eight groups with different length and prominence patterns. The p-value obtained was .0027, which tells us that there is less than a 0.27% likelihood that variability found in the ratios between the eight groups is due to chance. This is below the critical p-value of .05, so t-tests will be done to see if the significant values are between groups with different prominence patterns.

Like duration, length patterns are relevant for total amplitude since duration is a factor in its measurement. T-tests were performed between the two prominence patterns within the same length patterns (short-short and short-long).

A two-tailed t-test for independent samples on words with a short-short pattern gives a p-value between .20 and .30. This says that there is between 20% and 30% likelihood that differences in total amplitude ratios between strong-weak and weak-strong words are due to chance. This is much higher than our critical value of .05.

A two-tailed t-test for independent samples on words with a short-long length pattern resulted in a p-value between .40 and .50. Again, this is much higher than our critical value of .05.

We know that a smaller sample size makes it less likely that a significant p-value will be found. It is a reasonable question to ask whether it is the difference in sample size in the total amplitude and duration t-tests that resulted in higher p-values as compared to those found in the F_0 and average amplitude ratios (because the total amplitude sample had to be split into groups with smaller sample sizes based on length patterns). To determine this, t-tests were run for the F_0 and average amplitude ratios between the prominence patterns of short-short and short-long words. Two-tailed t-tests on words with a short-long length pattern for the F_0 peak ratio and average amplitude ratio both produced p-values between .10 and .20. This is much lower than the duration value above .50, and also lower than the total amplitude value between .30 and .40. Although it is still not significant, we did find a significant value between strong-weak and weak-strong words when length patterns were not taken into consideration.

Two-tailed t-tests on words with a short-long length pattern for the F_0 peak ratio and average amplitude ratio were less than .01 and .001 respectively. This is much lower than the value obtained for duration that was above .50, and the value obtained for total amplitude that fell between .20 and .30.

These results show us that the difference in sample size in both the duration and total amplitude t-tests that resulted in higher p-values as compared to those found in the F_0 and average amplitude ratios is not a result of sample size. The null hypothesis that there is no difference in duration and total amplitude values in words with a strong-weak compared to a weak-strong prominence pattern cannot be rejected. Neither duration nor total amplitude can be said to be a correlate of Blackfoot prominence.

The results of the statistical analyses show that F_0, and average amplitude are correlates of Blackfoot prominence. That is, pitch and loudness over the whole syllable are deliberately manipulated as markers of word prominence by Blackfoot speakers. Table 12 is a summary table of the statistical results. The values that are not significant are shaded in.

Table 12: Results of statistical analyses[14]

	ANOVA	T-tests		
		All groups	Short-Short	Short-Long
F_0	$p = .0024$	$p < .001$	[illegible]	$p < .01$
Duration	$p = .0016$	n/a	[illegible]	[illegible]
Amp Peak	[illegible]	n/a	n/a	n/a
Ave Amp	$p < .0001$	$p < .001$	[illegible]	$p < .001$
Tot Amp	$p = .0027$	n/a	[illegible]	[illegible]

6. General Discussion and Conclusions

6.1. Results of Acoustic and Statistical Analyses

The results of the analyses in this study suggest that F_0 peak and average amplitude are both correlated with prominence in Modern Blackfoot, while duration, amplitude peak and total amplitude are not. The correlation of the F_0 peak supports the assertion by Frantz (1989, 1991) and Kaneko that Blackfoot is a pitch accent language. This corresponds to Beckman's analysis of pitch accent in Japanese. As stated in §2.4, Beckman found F_0 peak was correlated with pitch accent in Japanese and all of the variables, primarily total amplitude, to be correlated with phonetic stress in English. The absence of a correlation to duration, average amplitude and total amplitude is similar to the Japanese results found by Beckman, but the correlation of amplitude peak differs. According to Beckman, amplitude peak is a correlation of phonetic stress and not pitch accent.

As discussed in §2.4, Sluijter and van Heuven say that amplitude is not a correlate of phonetic stress, suggesting that in Beckman's study, increases in amplitude were a result of the intonational contours overlaid on the phonetic stress. Sluijter and van Heuven also suggest that increases in amplitude associated with phonetic stress are a result of higher intensities at higher frequencies, while intensities at lower frequencies are affected very little. They found this to be a strong correlate of phonetic stress in Dutch, which was second only to duration.

It is difficult to determine what the reasons are for the correlations to prominence found in this study with average amplitude. Because this was one of the correlates Beckman found to phonetic stress, it could be suggested that Blackfoot has some characteristics of phonetic stress. Before coming to this conclusion, we must remember that Blackfoot was not found to have Beckman's most important cue of phonetic stress, total amplitude, or Sluijter and van Heuven's most important cue – duration. We must also remember that pitch,

[14] Shading indicates values that are not significant.

which was found to be a correlation of prominence in Blackfoot might not be a correlate of phonetic stress, but simply a result of intonation according to Sluijter and van Heuven. The results on Chuvash prominence found by Dobrovolsky (1999) also support this assertion. Because the words in this study were not elicited in a carrier phrase, it is difficult to determine what role intonation played on the dependent variables.

It may also be that Blackfoot is not like Japanese, as a prototypical pitch accent language, or English and Dutch, as prototypical phonetic stress accent languages, but falls somewhere in between the two methods of marking prominence. The patterns in §4.2.1 and §4.2.4 suggest that this is the case. Both variables show higher values on the first vowel in words with a strong-weak prominence pattern and similar values for the two words with a low high prominence pattern. This suggests that they are both correlates of word prominence, but also that they are both interacting with intonation. It would be interesting to see if the changes in amplitude peak in Blackfoot are a result of changes in Sluijter and van Heuven's spectral balance.

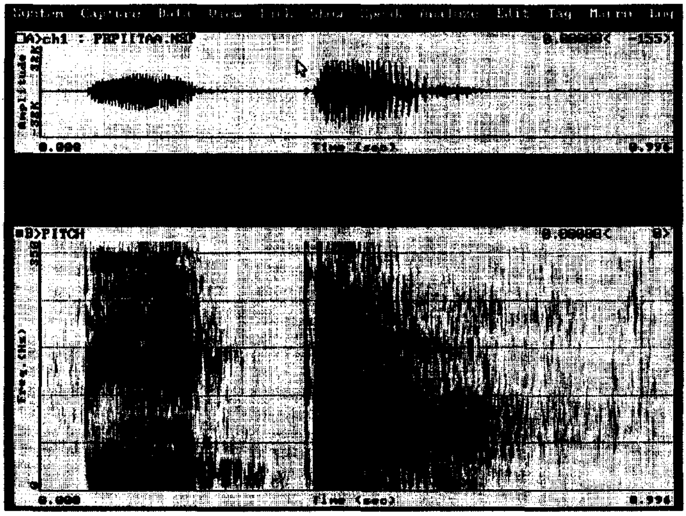
As discussed in §3.3, Kaneko claims that there are three different prominence patterns found in long vowels, those with a rising pitch, those with a falling pitch, and those with a high level pitch. Examples of these three different patterns were given in (14), restated here as (16).

(16)	a. [pií.ta]	piíta	'eagle'
	b. [póo.ka]	póoka	'child'
	c. [aa.kíí]	aakíí	'woman' (Kaneko 1999: 142-143)

All three of the above words were examined in this study. As we have already seen, pitch is a correlate of prominence in Blackfoot, so we will look at the pitch patterns in these three words to test Kaneko's claim. Figure 16 shows the word *piítaa*[15] as given in (16a).

[15] The different length patterns in the vowels may be due to dialectal differences.

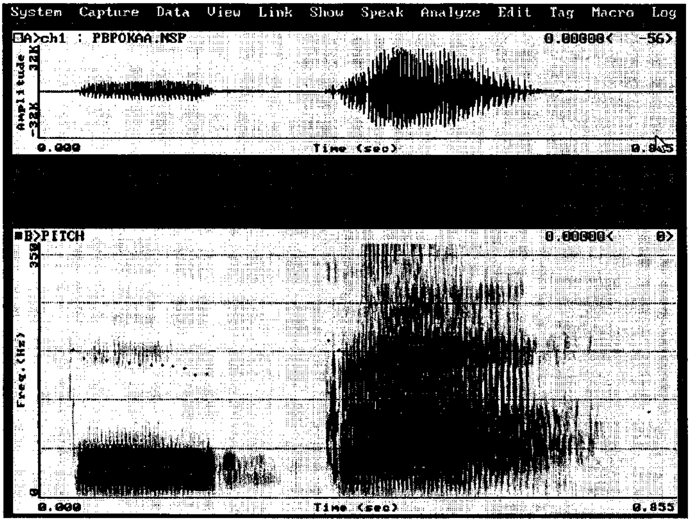
Figure 16: ***piítaa*, 'eagle' (PB)**



You can see a definite rising pitch in the first syllable of *piítaa*, which is what was expected according to the form seen in (16a). This rising pitch in the first syllable goes against the falling pitch found in the syllables of all the other words. This was the only word examined in this study that displayed this rising pattern.

Figure 17 shows the pitch patterns for the word *póokaa*.

Figure 17: ***póokaa*, 'child' (PB)**

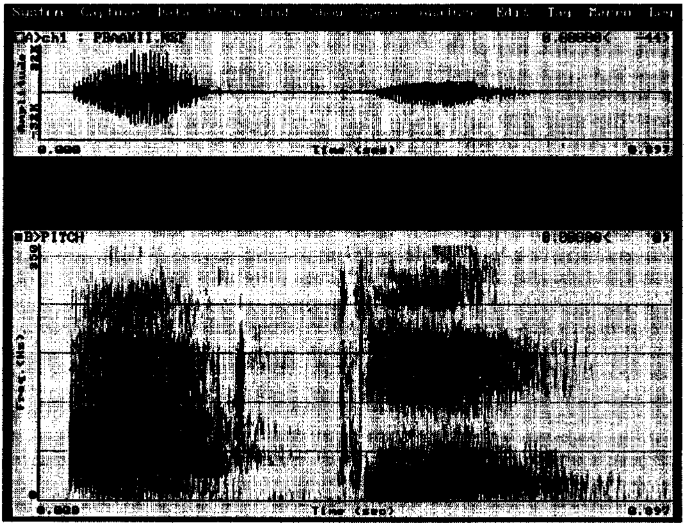


Although there is a slight falling pattern in the first vowel of *póokaa,* this is similar to the falling pattern found in almost all syllables (see Figure 2 in §4.1). It is not obvious that there is a falling pattern of prominence in *póokaa.* It is difficult to determine if there is an actual falling word prominence on any of the long vowels examined in this study as all syllables (except for the first syllable of *piítaa*) showed a falling pattern.

The pitch patterns for (16c), *aakíí,* can be seen in Figure 18. According to Kaneko, *aakíí* should have a level pitch on the final syllable. Although there is a falling pitch pattern, the actual word prominence is likely level throughout the long vowel. The falling pitch is due to the phrase final intonation. This pattern of falling pitch was found in all words looked at, regardless of vowel length.

All of the words with prominent long vowels (there were a total of fifteen) had a level or slightly falling pitch on the prominent syllable except for *piítaa.* Unfortunately, one word is not enough to give us evidence of different pitch patterns in long vowels. It may be that a level pitch pattern is much more frequent, while the rising and falling pitch patterns are not common. This could explain why only one word out of fifteen showed a definite contour pitch. Further analysis of pitch patterns in Blackfoot long prominent vowels is needed before this can be determined.

Figure 18: *aakíí*, 'woman' (PB)



6.2. Summary

The results from this study indicate that Frantz' (1989, 1991) and Kaneko's assertions that Blackfoot is a pitch accent language are correct. The acoustic evidence in this paper support this view. Pitch is a strong correlate of prominence in Blackfoot, just as it is in Japanese. The appearance of average amplitude as a correlate may be a result of intonation, or it may be that it is used as a cue for word prominence in Blackfoot. This latter possibility would suggest that Blackfoot pitch accent has acoustic differences from Japanese pitch accent, but I do not believe that it should constitute a different classification of prominence marking for Blackfoot.

6.3. Suggestions for Further Research

Further analyses would be useful on how amplitude patterns with word prominence and intonation in Blackfoot. Eliciting minimal pairs in carrier phrases as Sluijter and van Heuven did with Dutch would be useful in separating the intonation patterns from the pitch accent. An analysis of amplitude at higher frequencies would be useful in determining whether or not spectral balance is a correlate of prominence in Blackfoot. Elicitations of more words with a prominent syllable on a long vowel would give more evidence as to whether or not Blackfoot long vowels have different pitch patterns.

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I would like to thank my supervisor, Michael Dobrovolsky for his patience, guidance and suggestions. I would also like to thank my second reader, John Archibald for his helpful comments. Thanks also to Suzanne Urbanczyk for introducing me to the Blackfoot language. And a special thanks to Pat and Noreen Breaker for sharing their language.

Appendix A: Blackfoot Syntax and Morphology
Blackfoot is a polysynthetic language with complex verbal and noun morphology. Verbs are inflected for subject, object and tense. Subject and object inflections show up as agreement morphology on the verb, and as a result, the pronouns they agree with may be omitted.

Nouns are inflected for number. Old Blackfoot[16] distinguished between animate and inanimate nouns, but this distinction seems to be being lost in Modern Blackfoot. For example, Frantz (1991:8) notes,

> A singular animate gender noun has -wa[5], and plural animate gender has -iksi
>
> [5] Certain speakers omit the suffix -wa under as yet undetermined conditions. And many young speakers never seem to use it.

This quotation shows that omitting *-wa* as a gender marker was already in process during Frantz' work. This is likely a result of a phonological phenomenon that is occurring in Blackfoot. Often the last syllable of a Blackfoot lexeme is devoiced, and sometimes deleted completely. This process will be discussed further in §3.1.2. Sometimes the same lexical item would be spoken both with a devoiced final syllable and again with the same syllable deleted completely. In fact, speaker B sometimes used the suffix *-wa*, although she indicated that it made no difference to the meaning when it was used. This may indicate that there are still some traces of gender distinction within Modern Blackfoot. In fact, when eliciting the form for "What is it?" speaker B said that there was a difference dependent upon whether or not the object was animate or inanimate. In this case, the gender is within an object agreement marker on the verb and is not the final syllable of the lexeme. This demonstrates how a phonological phenomenon is affecting the morphology and ultimately word classes within the language.

Modern Blackfoot has a basic SVO word order; however, there are some exceptions. The transitivity of the main verb within a Blackfoot sentence has a

[16] For simplicity, in this section only, Old Blackfoot will refer to the variety described by Frantz (1991) and Frantz & Russell (1989), and Modern Blackfoot will refer to the variety spoken by the consultants. This is the distinction used by the consultants when asked about the differences between the forms.

large affect on the morphology and syntax of a Blackfoot phrase. In some instances the word or morpheme order is changed as a result.

Appendix B: Blackfoot Phonology

There is a relationship between the oral stops /t k/ and the corresponding affricates. The phoneme /t/ never occurs before the high-front vowel /i/, while /ts/ is very common in this environment. The affricate [ts] seems to be an allophone of /t/; /t/ becomes [ts] before /i/. However, this affricate also occurs in all of the environments that /t/ occurs in, which is why it is included in the phonemic inventory. The velar stop /k/ can occur before /i/, but it may change from [k] to [ks] in the same environment. This can be seen in (17).

(17)	/sik-/ + /-i.ka/	sik- + -ika	'black' + 'foot'
	/si.ksi.ˈkaa/	Siksika	'Blackfoot' (Kaneko 1999: 156)

This affrication may be due to an analogy with the relationship between [t] and [ts]. Because /t/ is realized as [ts] before /i/, /k/ may be realized as [ks] in the same environment.

It also appears that there is a phonological relationship between [x] and [k]. [x] only occurs in a coda position, and quite often it occurs before a [k]. Kaneko suggests that [x] is an allophone of /k/, and does not include /x/ in her phonemic inventory of Blackfoot. She gives convincing arguments for her proposal. She states that a single [k] never occurs in a coda position. This suggests that [x] and [k] are in complementary distribution and are allophones of a single phoneme /k/. However, one has to wonder what Kaneko means when she says that a *single* [k] never occurs in a coda position. Presumably, this is opposed to a geminate [k]. However, in geminates, the second half of the geminate would be syllabified as the onset of the following syllable while the first half remains in the coda position of the preceding syllable. In this sense, there is a single [k] in the coda. This can be seen in the data in (18) from Kaneko.

(18)	a. [ni.ˈtak.kaa]	nitákkaa	'my friend'
	b. [ˈpak.kiip]	pákkiip	'choke cherry' (Kaneko, 1999:20)

A similar pattern can be seen in (19), which shows data elicited from the consultants in this study. The gemination of the stop portion of the affricate /ks/ results in a /k/ in the coda.

(19)	[ˈksɪk.ksɪ.naa.tsi]	/ˈksik.ksi.naa.tsi/	ksíkksinaatsi	'white' (PB)

In addition, elicitations with PB produced words with [k] in a word final coda position in a cluster before /s/. This is demonstrated in (20).

(20)	[po.ˈkʊ.nɪks]	/po.ˈko.niks/	pokóniks	'balls' (PB)

The absence of [k] in the coda position in environments other than gemination may at first seem to support Kaneko's view that [x], which frequently occurs in the coda position, is an allophone of /k/. However, the distribution of [t] and [p] is similar to that of [k]. They also do not occur in the coda position, except in environments similar to those found in (18) to (20). This may be due to constraints on the coda position in Blackfoot. It may also be that these phonemes can occur in Blackfoot codas, but only in low frequency due to the rules of syllabification in Blackfoot. If a non-geminate stop is intervocalic, it will be syllabified as an onset of the following syllable. If a stop is followed by an /s/, it will also be syllabified as part of the onset of the following syllable, reanalyzing the /ks/, /ts/ or /ps/ sequence as an affricate, which are phonemes of Blackfoot.

Although /x/ and /k/ do not seem to be allophones of the same phoneme, there does still appear to be some relationship between them. /x/ frequently appears in the coda position of syllables preceding a /k/ in the onset. The words in (21) demonstrate this pattern.

(21)	a. [ˈum.**ʔ**ʌ̥x.kiː.na]	/ˈum.**ʔax**.kiː.na/	ómahkiina	'old man' (PB)
	b. [ˈsʌx.ko.maa.pi]	/ˈsaax.**ko**.maa.pi/	sááhkomaapi	'boy' (PB, NB)

I could not find evidence of /x/ occurring as an onset. Kaneko's analysis of /k/ becoming [x] in the syllable coda suggests that her data also showed no evidence of [x] in the syllable onset position. I propose that a /k/ is inserted after an intervocalic /x/ in order to satisfy a constraint against /x/ in an onset position. A more thorough analysis of the distribution of these phonemes is needed to determine if this is truly the case. Until then, the relationship between /k/ and /x/ remains an issue that warrants further investigation.

There is one consonant in Kaneko's phonemic inventory that I have not included in my analysis, the glottal fricative /h/. She states that its distribution is very restricted, only occurring at the beginning of a few interjections. This phoneme was never encountered during elicitations with our native speakers. However, this may simply be a result of its limited distribution.

Appendix C: Word List

Weak-Strong Long-Long

/aa.ˈkii/	aakíí	'woman'	(PB & NB)
/ii.ˈnii/	iiníí	'buffalo'	(PB)
/poo.ˈkaa/	pookáá	'child'	(PB & NB)

Weak-Strong Short-Long

/ma.ˈmii/	mamíí	'fish'	(PB & NB)
/ox.ˈkii/	ohkíí	'water'	(PB & NB)
/piʔ.ˈksii/	pi'ksíí	'bird'	(PB)

Weak-Strong Short-Short

/ki.ˈtsim/	kitsím	'door'	(PB)
/ni.ˈtan/	nitán	'my daughter	(PB)
/noʔ.ˈtsis/	no'tsís	'my arm/hand'	(PB & NB)
/po.ˈkon/	pokón	'ball'	(PB & NB)

Weak-Strong Long-Short

/miis.ˈtak/	miisták	'mountain'	(NB)
/aa.ˈksin/	aaksín	'bed'	(PB)

Strong-Weak Long-Long

/ˈpii.taa/	piítaa	'eagle'	(PB & NB)

Strong-Weak Short-Long

/ˈni.naa/	nínaa	'man/chief'	(PB & NB)
/ˈpo.kii/	pókii	'child'	(PB & NB)
/ˈspi.taa/	spítaa	'tall'	(PB)

Strong-Weak Long-Short

/ˈkoo.si/	kóósi	‘cup’	(PB)
/ˈnaa.ma/	nááma	‘gun’	(NB)
/ˈnoo.ma/	nóóma	‘my husband’	(PB)

Strong-Weak Short-Short

/ˈes.spi/	áísspi	‘to dance (durative)’	(PB)
/ˈejnx.ki/	áíynhki	‘to sing (durative)’	(PB)
/ˈaps.si/	ápssi	‘an arrow’	(NB)
/ˈis.ska/	ísska	‘pail’	(PB)
/ˈko.kit/	kókit	‘to give’	(PB)
/ˈnin.na/	nínna	‘my father’	(PB & NB)
/ˈnin.sta/	nínsta	‘my sister’	(PB)
/ˈox.ki/	óhki	‘it’s barking’	(NB)
/ˈok.je/	ókyai	‘hello’	(PB)

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