Duration and Sonority in Blackfoot Syllable Structure

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ABSTRACT

Blackfoot, an Algonquian language spoken in northern Montana and Southern Alberta, reveals mechanisms of syllabification not well-described in Linguistic literature. The Blackfoot alveolar fricative /s/ can occupy any syllable position based on its duration [1]. Blackfoot's back fricative /x/ has a center of gravity based on the preceding vowel and always closes a syllable [2, 3]. Singleton plosives, affricates, nasals, and glides form syllable onsets – glottal plosives can also be codas. Geminates also form part of the nucleus of preceding syllables [2, 3]. Nasals, glides, and vowels all have the same amplitude and duration, but only the vowels form as tautosyllabic nuclei. The production-based mechanism that distinguishes vowels from nasals and glides must therefore include other information, which may be any of acoustical salience, vocal tract constriction, or visible mouth/jaw opening. Taken together, Blackfoot syllables appear to be constructed through an interaction of duration and continuant frication with vocal tract openness.

Keywords: Syllable Structure, Sonority, Duration, Multi-modal speech, Blackfoot

1. INTRODUCTION

One goal of phonology is to describe and explain cross-linguistic syllable structure. Two major theories of syllable organization are known as the 'Sonority Sequencing Principle (SSP)' [4] and the 'Syllable Contact Law (SCL)' [4-6]. These theories use a sonority scale [4, 7], which categorizes speech sounds in terms of how easily people can hear them and is acoustically correlated with acoustic energy [8-10], relative resonance [4], and segmental duration [11]. In Clements' version of the sonority scale, sound classes are ranked from least to most sonorous in the order: *Obstruents (e.g. /p/) < Nasals (e.g. /n/) < Liquids (e.g. /l/,/r/) < Glides (e.g. /w/,/j/) < Vowels (e.g. /a/, /i/)* [4].

According to the SSP, segments are syllabified in such a way that sonority, or perceptible distinctiveness, increases from the syllable margin to the peak. According to the SCL, in a sequence of syllables, the coda on the first syllable is more sonorous than the onset on the second syllable [4]. For example, the word "grandpa" [gɹæm.pɑ] has two syllables. According to the SSP, [g] is less sonorous than [r], and [r] is less sonorous than [æ], and according to the SCL, the coda [m] of the first syllable is more sonorous than onset [p] of second syllable.

While SSP and SCL are described as universal principles, only one sound class division within SSP and SCL conforms to syllable organization cross-linguistically: *Non-sonorants* (sounds produced with interrupted or turbulent air-flow) versus *sonorants* (sounds produced with continuous and non-turbulent air-flow) [12]. Other sound class divisions in the SSP and SCL are violated by many languages [12]. These violations have frustrated Linguists so much that many resorted to descriptions based on sequences that do and do not appear in the relevant language – distributional evidence [13-15]. Distributional evidence describes the facts but explains none of them.

As a good example, Blackfoot, an Algonquian language spoken in northern Montana and Southern Alberta, partially violates even the supposedly universal non-sonorant vs. sonorant SSP, sometimes treating voiceless fricatives like sonorants (e.g. [ʔiː.kʊ́m.<u>ʔsː</u>.pi.kaʔ.<u>ps</u>.si], *iikó<u>mssp</u>ika'<u>pss</u>i*, 'he is hard to take care of', where it does so twice).

Here I examine segmental intensity, duration, formant position, as well as discussing unmeasured visual and tactile speech, to identify and describe the phonetic basis of syllabification in Blackfoot as an example of how to address the limitations of the analysis techniques used to describe and generate sonority theory (SSP and SCL).

1.1. Blackfoot Phonetics and Syllable Structure

Blackfoot has 21 contrastive consonants, including plosives /p, pː, t, tː, k, kː, ʔ/, fricatives /s, sː, x/, affricates /t͡s, t͡ːs, k͡s/, nasals /m, mː, n, nː/, glides /w, j/, and the marginal pre-assibilants / ˢt, ˢtː/. Blackfoot also has 5 long /iː, ɛː, aː, ɔː, oː/ and 3 short /i, a, o/ vowels, along with several predictable variants /ɪ, ɐ, ʊ/ along with rising /jV/ and falling /Vj/ diphthongs.

Any consonant may form a Blackfoot onset except for the dorsal fricative /x/, which obligatorily closes a syllable.

Vowel nuclei may be a short vowel, long vowel, or diphthong. Nuclei may also be voiceless fricatives. The consonants /s/, along with /x/ (realized as [ç], [x], or [xʷ]) can act as vowels and are the only consonants which can occur between consonants. The /s/ can be short or long, whereas the /x/ is always short, coalescing with a preceding short vowel [16], forming the whole nucleus, or the second mora in a long syllable nucleus (eg [ʔiç.po.kʊ́n.ʔsˑ.kaː], *iihpokónsskaa*, ‘he has gotten the ball’).

A coda consonant may be /s/, /x/, a glottal plosive /ʔ/, the first half of a geminate consonant, or a nasal before glottal stop.

1.1.1. Syllabification of Blackfoot /s/

Blackfoot /s/ can occupy any position and length in a syllable, including: 1) short interconsonantal [CsC] ([ʔá.ps.pi.niːk͡s], *ápspiniiksi,* ‘geese’); 2) short word-initial [#sC] ([s.pɐ́.t͡sɪ.ko], *spátsiko,* ‘sand’); 3) short intervocalic [(V)sV] ([niː.síp.po], *niisíppo*, ‘forty’); 4) long postconsonantal [CsːV] ([pi.sɐ́.ts.sɛs.ki], *pisátssaisski*, ‘flower’); 5) long preconsonantal [VsC] ([ʔɪs.pʊ́m.ʔç.taːt], *isspómmihtaat,* ‘help out!’); 6) long interconsonantal [CsːC] ([mo.wɐ́.psː.pɪn], *mowápsspin*, ‘eye’); 7) short word-final [Vs#] ([moxʷ.kín.ʔsː.t͡sɪs], *moohkínsstsis*, ‘elbow’); 8) long intervocalic [VsːV] ([nɪs.sísː], *nissíss*, ‘my yng’r sibling’ (of fem.)); 9) superlong postconsonantal [CsːːV] ([ní.tsː.soʔ.toː.kḁ], *nítssso’tooka*, ‘he felt me (up)’). As well as being part of an 10) affricate ([ʔiː.t͡síʔ.ts.ks.o.ji, *iitsí’tsksoyi*, ‘picnic’) or 11) pre-assibilant ([miː.ˢt͡s.ís], *miistsís*, ‘tree’) [17]

1.2. Hypothesis

Given these distributional patterns of syllabification in Blackfoot, the hypothesis is that Blackfoot syllabification requires not only intensity, but also duration and vocal tract openness information to be describable through speech production outputs. The predictions tested here are: 1) Blackfoot /s/ syllable position is dependent on duration and segment adjacency, but not amplitude differences. 2) Blackfoot /x/ combines with acoustical information from the underlying preceding vowel identifiable through center-of-gravity. This information, along with its obligatory distribution before a stop or fricative, ensures it always closes a syllable. 3) Blackfoot vowels have the same amplitude and duration as glides and nasals, and so if production-based information explains their distribution, it must come from another source such as visual speech or acoustic information on vocal tract constriction as identified through air flow stoppage (for nasals) or 4) formant position (for glides).

2. METHODS

2.1. Participant

One native speaker of Blackfoot language consultant (XXX) provided all of the data. They spoke the “new Blackfoot” Káínai dialect and was recorded when they were in their 60s. The consultant was literate in the Blackfoot orthography written by Franz and Russel and originally published in 1978 [18]. This data is currently part of Blackfoot Illustration under review [19].

2.2. Materials

Recordings were completed using a Marantz 660 solid-state recorder with a countryman (phantom power) wired lapel microphone.

2.3. Procedure

The participant was seated in a sound-attenuated booth, and the wired label microphone was clipped on to their shirt collar. They were then verbally given English glosses and asked to translate the gloss and repeat it 3 times. If the consultant translated differently from what the source material suggested, a second recording of 3 repetitions was completed after they read the translation provided in the Blackfoot dictionary [18].

2.4. Analysis

Measurements were transcribed using PRAAT [20], and duration, amplitude, and center of gravity were extracted using automatic settings with a PRAAT script. Analysis was completed using R [21]. All statistical analyses were completed with simple linear models using R’s built-in linear model predictor tools.

3. RESULTS

The results of the measurements are presented in order of the predictions to be tested.

3.1. Blackfoot /s/ syllable position

Comparison of the durations of Blackfoot /s/ show that /s/ duration falls into five groups (Figure 1), which are statistically significant (Table 1): A) pre-assibilation and affrication are of similar duration; B) all the short /s/ except for word-final /s/ form a bigger group, including the two tautosyllabic short syllable nuclei /s/; C) all the long /s/ except long intervocalic, including the tautosyllabic long nuclei /s/ (long interconsonental), and the short nucleus + following onset (long postconsonantal); D) the short word final and long intervocalic /s/, which syllabifies as the other geminates do; E) the superlong postconsonantal /s/, which forms a long syllable nucleus and a following syllable onset.

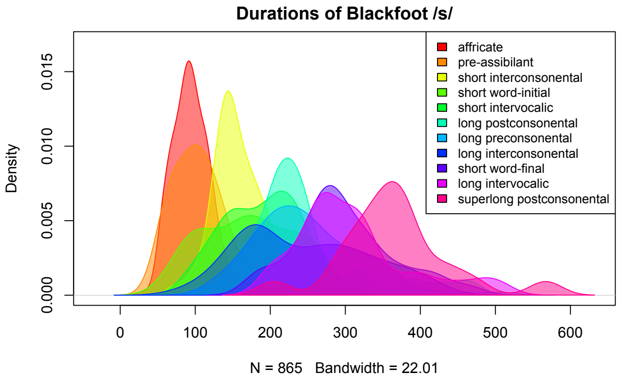

Figure 1: Duration of Blackfoot /s/ by syllable position and segment adjacency

Position	Dur (ms) Med (SD)	t-value	Group
Affricates	93 (13.4)	N/A	A
Pre-assibilant	103 (40.9)	1.5	A
Short interconsonantal	150 (32.8)	9.0	B
Short word-initial	173 (59.8)	6.4	B
Short intervocalic	191 (50.0)	12.0	B
Long postconsonantal	225 (7.3)	19.6	C
Long preconsonantal	241 (70.7)	21.0	C
Long interconsonantal	245 (84.4)	23.5	C
Short word-final	287 (66.3)	18.8	D
Long intervocalic	292 (76.7)	18.8	D
Superlong postconsonantal	368 (74.7)	20.3	E

Table 1: Duration groupings for /s/: Dur = duration, ms = milliseconds, Med = median, SD = standard deviation.

In contrast, the intensity of Blackfoot /s/ is much more difficult to group or interpret. Blackfoot /s/ intensities shows extreme overlap that do not relate well to syllable structure or duration, as seen in Figure 2.

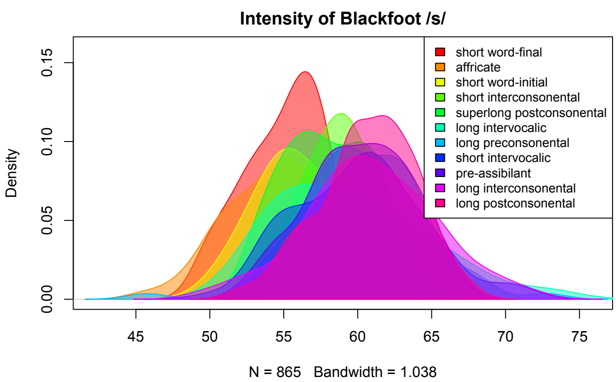

Figure 2: Intensity of Blackfoot /s/ by syllable position and segment adjacency

3.2. Blackfoot /x/ center of gravity

Blackfoot /x/ center of gravity is much higher for the fricative [ç] that follows /i/ than for the [x] that follows [a] and [o] and the [xʷ] that follows [o] and [ɔ], as seen in Figure 3.

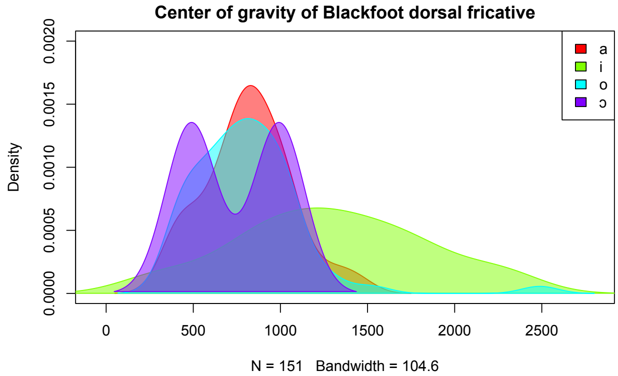

Figure 3: Center of gravity for Blackfoot /x/ variant

The differences between [ç] and the rest are significant, as seen in table 2.

Position	COG (ms) Med (SD)	t-value	Group
[x] ‘ax’	825 (247)	N/A	A
[ç] ‘ix’	1269 (538)	5.79	B
[x/xʷ] ‘ox’	787 (320)	-0.13	A
[xʷ] ‘ɔx’	741 (357)	-0.28	A

Table 2: Center of gravity groupings for /x/. COG = center of gravity.

3.3. Blackfoot segment intensity

Short segments are shown because there are no short glides in Blackfoot, but results are similar for long segments. Blackfoot vowels, glides, and nasals have similar amplitudes, with fricatives having lower amplitudes, and stops having the lowest amplitude, as seen in Figure 4.

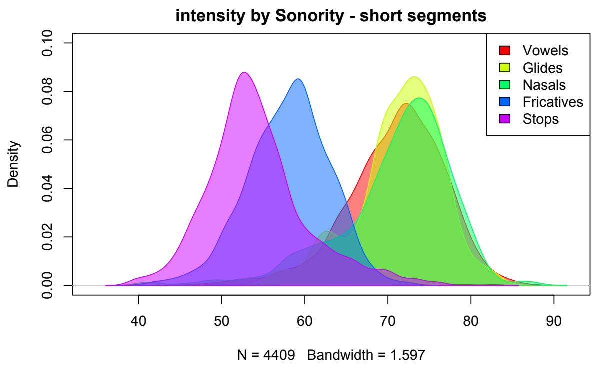

Figure 4: Blackfoot segment intensity by type

The differences between the three observable groups in Figure 4 are statistically significant, forming the three groups seen in Table 3.

Position	Int (dB) Med (SD)	t-value	Group
Vowels	71.6 (5.73)	NA	A
Glides	72.3 (5.13)	0.7	A
Nasals	71.8 (6.54)	-0.9	A
Fricatives	58.3 (4.96)	-62.1	B
Stops	53.2 (6.06)	-86.1	C

Table 3: Center-of-gravity groupings for /x/. Int = intensity, dB = decibels.

Duration distribution can be seen in Figure 5.

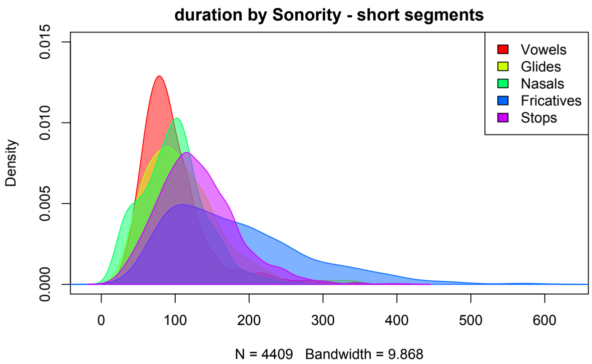

Figure 5: Blackfoot segment duration by type

Vowels and nasals are the shortest (group A), followed by glides (group B), stops (group C), and fricatives (group D), as seen in Table 4.

Position	Int (dB) Med (SD)	t-value	Group
Vowels	88 (47.1)	NA	A
Nasals	98 (43.2)	0.10	A
Glides	100 (52.3)	2.08	B
Stops	123 (53.5)	13.0	C
Fricatives	163 (94.1)	33.4	D

Table 4: Center-of-gravity groupings for /x/. Int = intensity, dB = decibels.

3.4. Blackfoot glide formants

Blackfoot glides have different formants than their related vowels (the vowel [i] for [j], and the vowel [o] for [w]), as seen in Figure 6.

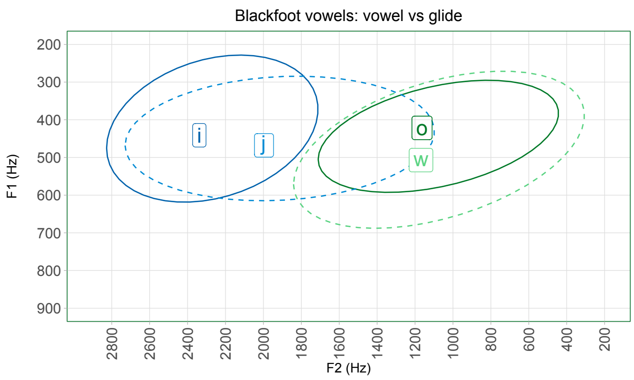

Figure 6: Formants Blackfoot glides vs vowels

4. DISCUSSION

The results show support for prediction 1, that /s/ duration, when combined with information about adjacent segments (vowels, consonants, or a word boundaries) to provide sufficient information to identify the syllable position of the given /s/ segment. In contrast, /s/ intensity does not provide enough information to aid in identifying syllable position.

The results partially support prediction 2 in that the center of gravity for [ç] are distinguishable from those for [x] and $[x^w]$. However, center of gravity alone does not provide sufficient information to distinguish all of the underlying vowels from each other. Nevertheless, when listening to this dataset, it is relatively easy to hear the effects of the specific merged vowel, so information from speech production is sufficient. This acoustic information, combined with the distributional evidence, identifies the dorsal fricative /x/ as a segment that always closes syllables.

The results support prediction 3 in that intensity of vowels, glides, and nasals are similar in Blackfoot, and while the duration of all three are not quite identical, it is hard to imagine that intensity differences provide enough to explain why nasals and glides cannot form syllable nuclei when vowels can. Instead, nasals stop airflow from leaving the mouth – they are stops – which provides its own production-based distinction between nasals and vowels. Similarly, in support of prediction 4, glides have differing formant values and are distributed before vowels.

Blackfoot also sometimes ends words in nearly inaudible voiceless vowels; speakers who notice mispronunciations may ask learners to watch them speak [22]. This behaviour suggests native Blackfoot speakers learn their syllable structure rules in part through visual, rather than acoustic, cues. This additional acoustic and visual information provides the information needed to improve our understanding of the connection between multi-modal speech production and syllable structure.

Taken together, the results show that Blackfoot syllables are constructed through an interaction of segment adjacency, duration for /s/, and the degree of oral vocal tract openness for voiced continuants.

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