Contrast, phonological features, and phonetic implementation: Aspiration in Blackfoot

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Abstract

Blackfoot is generally regarded as lacking phonological contrasts based on laryngeal settings; it is typically analyzed as lacking aspiration, voiced obstruents, and the segment [h] (see Elfner 2006 or Frantz 2009). The simple fact that Blackfoot sonorants appear as voiced and obstruents as voiceless could be the result of redundancy rules (cf. Stanley 1967) or phonetic implementation rather than phonological contrast (Keyser & Stevens 2006; Stevens & Keyser 2010). However, at the end of an orthographic word, vowels in Blackfoot typically devoice such that "there can be no contrast between short and long vowels at the end of a word" (Frantz 2009:5, see also Gick *et al* 2012).

In this study, I examine whether Blackfoot final vowel devoicing —what I argue is better characterized as aspiration— is the result of phonological specification or phonetic implementation. I argue that the laryngeal feature [SPREAD GLOTTIS] is contrastive in Blackfoot and that the phonetic implementation of this feature leads to phonological opacity and a near-merger of phonemically short and long vowels in a phonological phrase-final position such that they are perceptually identical (Frantz & Russell 1995).

1. Introduction[*]

In Blackfoot, it is commonly observed that vowels devoice at the right edge of a phonological phrase (φ)[1] (Frantz & Russell 1995; Frantz 2009; Bliss 2013, see also Gick *et al* 2012). Blackfoot is suggested to lose vowel length contrasts in final position due to this devoicing rule which makes long and short vowels indistinguishable from one another (Frantz & Russell 1995:441; Frantz 2009:5):

(1) Vowel length contrasts

a. *Áakokaawa* [aːk**o**kaːʍḁ]
yáak-okaa-wa
FUT-rope.AI-3.SG
'(s)he will rope'

b. *Áakookaawa* [aːk**oː**kaːʍḁ]
yáak-ookaa-wa
FUT-sponsor.sundance.AI-3.SG
'(s)he will sponsor a Sundance'[2]

c. *Nitopi* [nitop**i̥**]
nit-opi
1.SG-possess.archery.equipment.AI
'I had a bow and arrow'

d. *Nitopii* [nitop**i̥ː**]
nit-opii
1.SG-sit.AI
'I sat/stayed'

(*cf.* *Opiiwa* [op**iː**ʍḁ]
opii-wa
sit.AI-3.SG
'(s)he sat/stayed')

As can be seen in examples (1a) and (1b), vowel length contrasts signal meaningful differences in Blackfoot. Despite a meaningful contrast between the forms in (1c) and (1d), however, vowel devoicing in final position is reported to neutralize the perceptual phonetic cues to this contrast (Frantz & Russell 1995). The fact that the contrast does exist at the level

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The author would like to thank his Blackfoot teachers and language consultants for their invaluable and ongoing contributions to this research. *Piitaikiihtsipiimi, Aistanskiaki, Issapoiloan, kii Ainootaa, nitsíniiyi'takihpinnaan*. Unless otherwise stated, examples in this article come from elicitation sessions with these speakers.

[1] The literature typically denotes the environment as "the end of a word" which describes a word-sized unit in the orthographic convention. A full analysis of the prosodic constituency of Blackfoot is beyond the scope of the present article. I assume, here, that Blackfoot follows the same pattern as the related Algonquian language, Cree, in that "the units of Cree which are usually called "words" are in fact phrases at the phonological level" (Russell & Reinholtz 1997:447). See Windsor (to appear) for a detailed analysis in support of this assumption.

[2] This verb is translated in Frantz & Russell (1995:168) as "sponsor the primary religious ceremony associated with the Sundance." I use the abbreviated translation for simplicity (*cf.* Frantz 2009:2, from which examples 1a-b are adapted).

of the input can be observed through the addition of morphology to shift the vowel away from the right edge, such as the 3.SG suffix, –*wa* (Frantz 2009:5).

A second common assumption about Blackfoot is that stop consonants in the language generally lack aspiration (Frantz & Russell 1995; Elfner 2006; Frantz 2009). In fact, Blackfoot is typically analyzed as lacking laryngeal contrasts all together allowing the fact that —with the exception of the above mentioned vowel devoicing facts— sonorants are realized as voiced and obstruents as voiceless via redundancy rules (cf. Stanley 1967). This can be seen by the commonly assumed phonemic inventory of Blackfoot provided below.

(2) The commonly assumed Blackfoot phonemic inventory (Elfner 2006:12)

	Labial	Coronal	Dorsal	Glottal
Stops	p pː	t tː	k kː	ʔ
Fricatives		s sː	x	
Affricates		ts tːs	ks kːs	
Nasals	m mː	n nː		
Glides	w	j		

Vowels	
i iː	
	o oː
a aː	

From the above inventory, there is no reason to assume that any of the laryngeal features, [VOICE], [SPREAD GLOTTIS] ([SG]), or [CONSTRICTED GLOTTIS], are active in Blackfoot at all; there is no glottal contrast between /h/ and /ʔ/, there are no contrasts that depend solely on voicing, and obstruents are typically regarded as lacking aspiration.

Combining these two common assumptions about the Blackfoot sound system, one is left wondering what would cause final vowel devoicing in a language which lacks laryngeal contrasts and whether or not this is actually a phonological rule, or simply a language-specific phonetic implementation rule. In this article I argue that Blackfoot phonology does, in fact, make a meaningful contrast with respect to the feature [SG]; that it marks the right edge of φs by epenthesising the feature there; and, that this phonological process is obscured by variation in the phonetic implementation of the [SG] feature.

This article proceeds as follows: I provide evidence for the unified treatment of vowel devoicing and consonant aspiration in Section 2. In Section 3 I discuss the possible phonetic vs. phonological causes of aspiration based on contrast, and I conclude in Section 4 with directions for future research.

2. Aspiration and the edge

Although Blackfoot is typically analyzed as lacking aspiration following consonants, aspiration does appear in one environment – the same environment as final vowel devoicing. In this section, I provide a phonetic analysis of final-vowel devoicing and final-consonant aspiration each in turn. I then argue that these seemingly separate processes have a common phonological source – the feature [SG] which is phonetically realized in different ways depending on the segmental host which that feature is epenthesized to.

2.1. Vowel devoicing

Vowel devoicing can be observed in several locations in the Blackfoot utterance such as the right edge of a demonstrative, the verbal complex, or the nominal complex:

(3)			
	[án:iksi̥	ákɛ́:maxkiçkinɛ̱ksi̥	inókiʍḁ]
	Ánniksi	*ákaímahkihkinaiksi*	*inókiwa*
	ann-iksi	áka-íímahkihkinaa-iksi	ino-okiwa
	DEM-ANIM.PL	old-sheep-ANIM.PL	see.TA.21.PRO
	'those old sheep see us'		

Frequently, the environment for this devoicing lines up with an orthographic word as can be seen above. This gives rise to the descriptive statement in the literature that vowels are typically voiceless at the end of a word (Frantz & Russell 1995; Frantz 2009; Bliss 2013). However, as can be seen in 4, this is not always the case:

(4)			
	[pɔɪnaps:i	an:ḁ	pokɛ́n:ɔkɔmita:ʍḁ]
	poinapssi	*anna*	*pokáinnaokomitaa*
	poinapssi	ann-wa	poka-innoka-imitaa-wa
	Frenzied.VB	DEM.ANIM.SG	stunted-elk-dog.ANIM.SG
	'that colt is frenzied'		

These data suggest that if a target noun can be elicited both in and out of a devoicing environment (such as *pííta* 'eagle' in 5a, b), then the amount of devoicing can be contrasted between the two positions to better understand the effect that this process has on the vowel and see if a length distinction is maintained in production. In order to answer these questions, I elicited a series of sentences with a target noun[3] in sentence-final (5a) or sentence-medial (5b) position from three native Blackfoot speakers.

(5) Elicitation sentence examples (animate nouns)[4]

a.	*Ámo anistápssiwa*	*pííta*		< noun in devoicing environment
	amo anistápssi-wa	pííta-wa		
	DEM be.AI-3.SG	eagle.ANIM.SG		
	'this is an eagle'			
b.	*Ámo*	*píta*	*nitsináán*	< noun outside of devoicing environment
	ámo	pitta-wa	n-itsináán-yi	
	DEM	eagle.ANIM.SG	1.SG-possession-OBV	
	'this eagle is my pet'			

[3] It should be noted that all nouns in Blackfoot end in a vowel due to required morphological endings.

[4] This study was originally part of a collaborative effort first reported in Windsor & Cobler 2013 which I expand upon and update here where possible.

Using a Welch two-sample t-test with 56 tokens in final position and 60 tokens in medial position, it was found that the amount of devoicing in final position was significantly greater than those in medial position: [t(91.207) = –6.0408; $p < 0.001$].[5] Particularly interesting for the present analysis is that when the noun did not appear in final position, its final vowel was almost entirely voiced with very few exceptions. When the noun appeared in final position it was found to devoice approximately the final ⅓ of the overall vowel regardless of phonemic length (between 27%-44%) when averaged across speakers.[6]

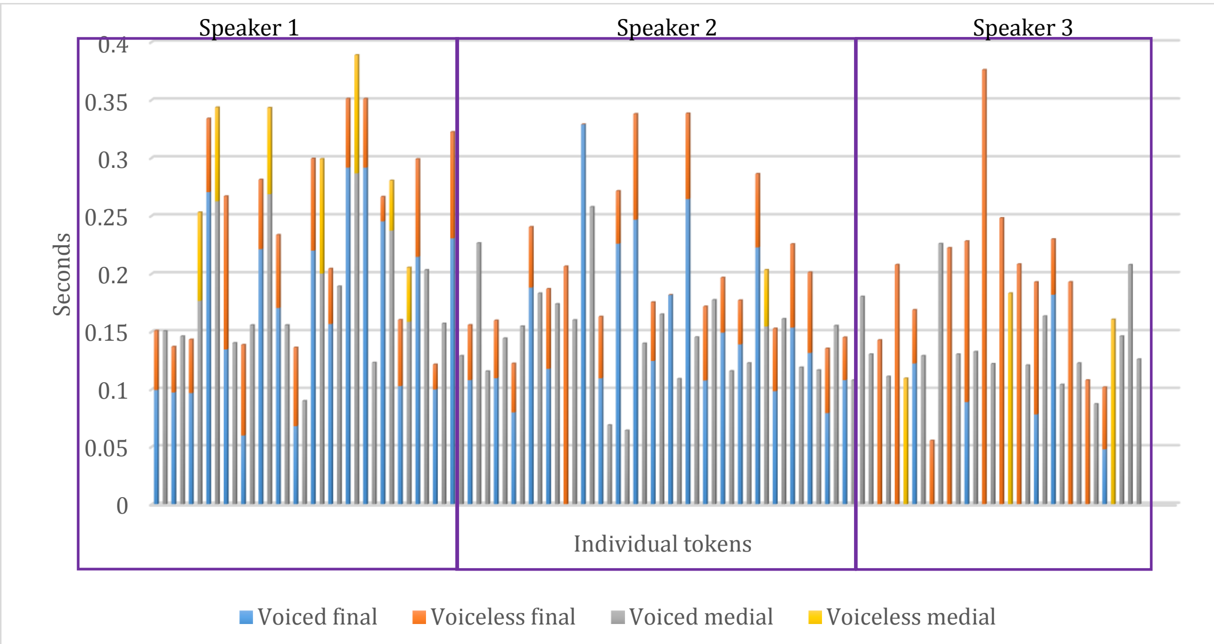

Figure 1: Devoicing by sentence position (Windsor & Cobler 2013)

Figure 1 above shows that, despite some inter-speaker/inter-generational variability, the observed pattern is robust. The blue and orange columns show a combined total of vowel length, per token, in utterance final position with the orange portion representing the devoiced portion of the vowel. The grey and yellow columns show a combined total of vowel length, per token, in medial position with the yellow portion representing the devoiced portion of the vowel. As provided above, the amount of devoicing by utterance position is significant ($p < 0.001$).

A second finding of this study is that, while Frantz & Russell (1995) and Frantz (2009) are undoubtedly correct that devoicing eliminates a perceptual contrast between long and short vowels in this position, the articulatory phonetic/phonological contrast is maintained.

[5] Only tokens in sentences which were syntactically identical to the carrier sentence were used in this test (n=116).

[6] It should be noted that Speaker 3 has a condition which affects his respiratory system and, therefore, his ability to produce voiced sounds. Despite this, the same pattern of voicing by position was found for this speaker as well.

Across speakers, when position within the utterance is not considered, the average length of a phonemically long vowel was found to be 0.27 seconds and the average length of a phonemically short vowel was 0.12 seconds. This shows that even in a devoicing environment, those vowels which have a reduction of phonation do maintain their phonemic length, and thus maintain their phonological/articulatory contrast.

The next logical question in this study is whether devoicing is something that happens to vowels, or if it affects consonants as well. I address this question in the next section.

2.2. Consonant aspiration

Probably all modern Blackfoot speakers are at least bi-lingual, additionally speaking English, and the two language phonologies' remain largely separate. English speakers often produce word-initial /p/, /t/, and /k/ with accompanying aspiration. This is not done in Blackfoot which, according to Frantz (2009:4), causes English speakers to perceive these sounds as [b], [d], and [g] respectively. This, in addition to the fact that all sonorants are voiced and all obstruents are voiceless, supports the analysis of Elfner (2006:11), who states that "Blackfoot lacks voicing or aspiration contrasts; all of its obstruents are voiceless with little or no aspiration[.]" However, it seems that there is positional variability with regards to how much aspiration is found on an obstruent in Blackfoot.

In the original study summarized in the previous section, Windsor & Cobler (2013) additionally collected utterances with imperative verbs ending in the final morpheme *–t* (IMP.SG) as a control to see if this phenomenon was the result of a rule/constraint which targeted vowels, or if there was an edge effect which applied regardless of the segment in final position.[7] We elicited a small control group of utterances (n=14) which consisted solely of an imperative verb (6a), and with the same verb removed from the right edge by the addition of a direct object (6b).

(6) Elicitation sentence examples (imperative verbs)

a. *Matoííkskimaa<u>t</u>!*
mato-ííksimaa-t
go.to.do-hunt.game.AI-IMP.SG
'go <u>hunt</u>!'

b. *Matoííškimaa<u>t</u>* *áwakaasii!*
mato-ííksimaa-t áwakaasii-yi
go.to.do-hunt-game.AI-IMP.SG deer.OBV
'go <u>hunt</u> deer!'

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[7] Word final consonants in Blackfoot are almost exclusively limited to the morphological markers, *-t* 'IMP.SG' and *–k* 'IMP.PL'. Other apparent instances of word final consonants such as the 'we.excl' ("we exclusive" – we but not you) suffix *–hpinnaan* is actually *–hpinnaana* but sometimes written without the final <a> due to the fact that "the final <u>a</u> of [these morphemes] is a predictable addition after an otherwise word-final consonant, rather than part of these morphemes per se" (Frantz 2009:23). The same is true for other final morphemes such as final *–hp* transitive inanimate marker for 1st/2nd person singular or the various final [w]s or final [n]s of the transitive animate verbal paradigm.

Similar to the main study of vowel devoicing, we found that, in final position, consonants displayed an average of 9.7x the length of aspiration and 2.7x the length of closure duration over their phrase-medial comparators.

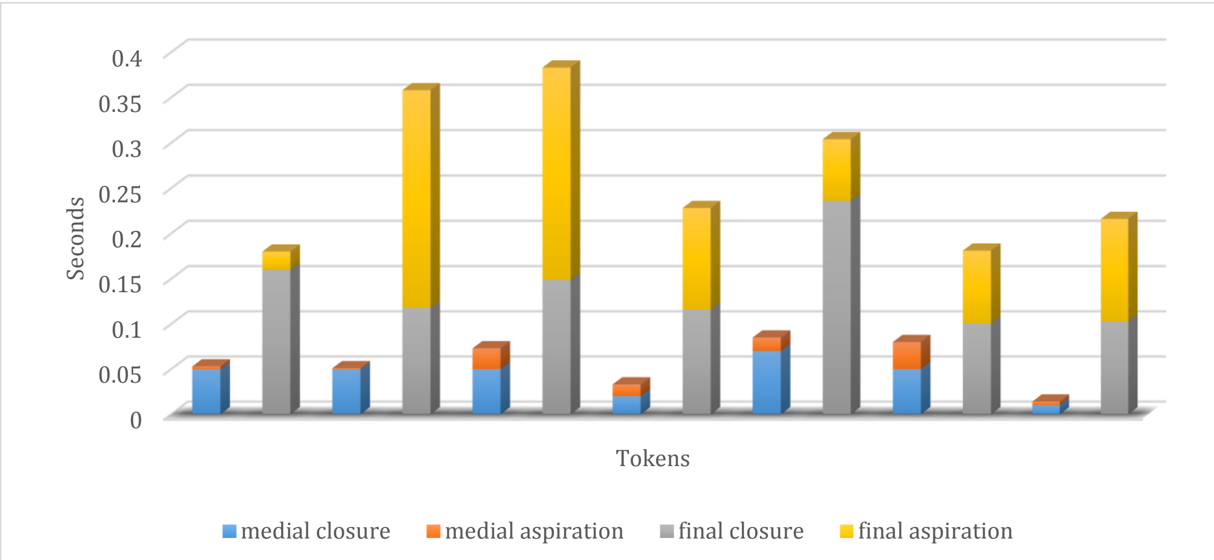


Figure 2: Duration of stop closure and aspiration by position (Windsor & Cobler 2013)

The results of this small control suggest that in final position, the closure duration of consonants lengthens while the air pressure builds and the vocal folds abduct which is realized as aspiration on the consonant when the stop is released. The question now is how do consonantal aspiration and vowel devoicing relate to one another, if they do at all. This is the subject of the next section in which I argue that a single process underlies both of these realizations.

2.3. Phonological specification and phonetic implementation

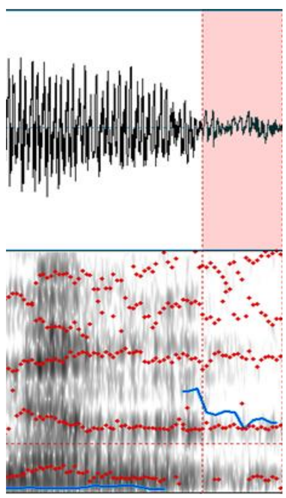
The fact that vowel devoicing and consonant aspiration in Blackfoot occur in the same environment suggests that there is a unified explanation for the two seemingly separate processes. Here, I argue that the cause of both vowel devoicing and consonant aspiration is the epenthesis of the feature [SG] to mark the edge of a prosodic domain.[8] To do this, we will first consider the phonetic implementation of aspiration.

To achieve aspiration on final consonants, as discussed above, there needs to be a supra-glottal constriction in the vocal tract to build up sub-glottal pressure. When the vocal folds are abducted, air is released past the obstruction and the consonant is produced with an additional burst of turbulent noise. For example, if the tongue tip contacts the alveolar ridge and, at the time of release, the vocal folds are abducted, the result is a [t^h]. Similar to

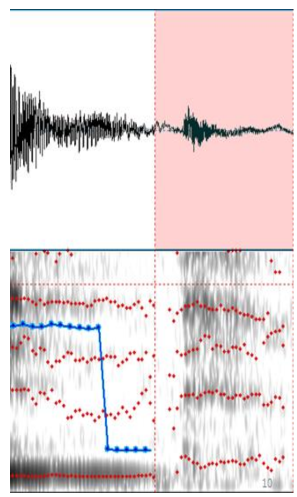
[8] I assume here the domain for [SG]-epenthesis is at right edge of a phonological phrase (φ); however, for reasons of space, I will not provide the arguments for this here – see footnote 1.

this, in order to devoice a vowel, the vocal folds must again be abducted to prevent phonation. In terms of the articulatory mechanisms, these two processes are only differentiated by the oral articulators; for consonants, aspiration follows the release of the articulatory gesture and results in high frequency noise which is visible in the spectrogram, similar to [h]; for vowels, the oral gesture remains but some voicing is lost. This difference can be seen in the following two images of a Blackfoot final vowel (7a) and final consonant (7b).

(7) a. Spectrogram of vowel devoicing   b. Spectrogram of consonant aspiration



*Apasstamiinaamm**a*** 'apple'



*Pii**t**!* 'enter!'

In (7a), the final portion of the /a/ vowel in *apasstamiinaamma* 'apple' is selected on the right. As can be seen in the spectrogram, although faint, the formants of the /a/ persist even though phonation has ceased. Crucially, there is no high frequency noise on this segment. Contrastively, in (7b), we see the occlusion and release burst of the final /t/ segment in *píít* 'enter' which is accompanied with high frequency noise resulting from the aspiration of this segment.[9]

Although the articulatory gesture that aspiration follows may differ, causing the differences in realization, both consonantal aspiration and vowel devoicing is achieved through vocal fold abduction. Vocal fold abduction is arguably the physical realization of the phonological feature [SG].

Beyond the physiological similarities between aspiration and devoicing and the fact that they occur in the same environments, one final piece of evidence that these two seemingly separate processes are underlyingly the same comes from duration. One could argue that if the same process is effecting consonants, short vowels, and long vowels, then

[9] Oberly (2008:125), discussing Southern Ute, states that it is possible to detect a devoiced vowel by the aspiration which appears where the first and second formants would have appeared if the vowels were voiced. I am grateful to one of my reviewers for pointing out this reference to me.

the length of the effect (duration of devoicing/aspiration) should be similar across all three types of segments found at the right edge. This prediction is, in fact, borne out.

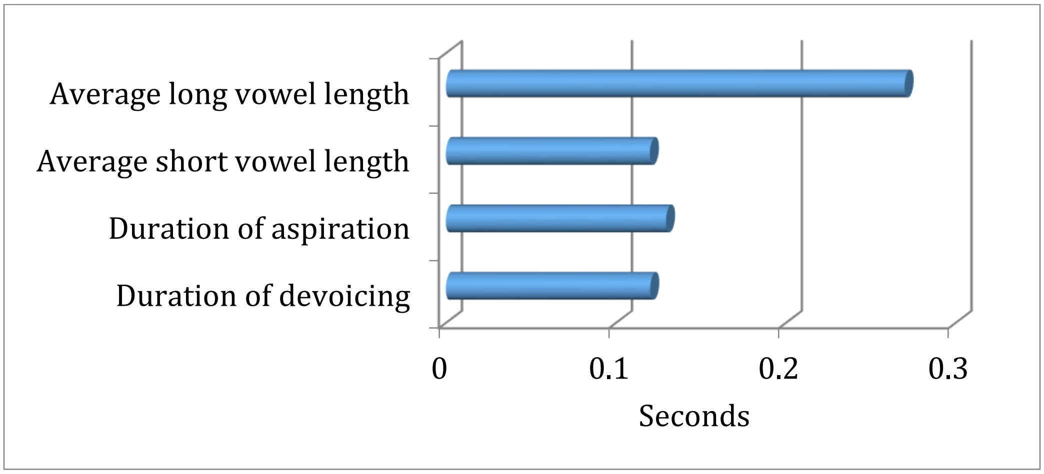


Figure 3: Average aspiration durations

Windsor & Cobler (2013) provide the above figure as a comparison between the average duration between consonant aspiration and vowel devoicing using utterance final vowels and consonants from a single speaker. This shows that the average duration of vowel devoicing in this environment is 0.1202 seconds and the average duration of aspiration is a strikingly similar 0.1295 seconds. These preliminary results —combined with the similarity in environment for the sound change and articulatory processes— provide evidence that there is a single underlying phonological process which has multiple phonetic realizations.[10] If this analysis is accurate, then we can explain the multiple phonetic realizations of [SG] based on the segment affected. Under this analysis, the phonological component would epenthesise a [SG] feature to the right edge of a φ to overtly demarcate that edge. This feature is realized on whichever segment is aligned with the edge of the φ, whether it is a vowel or a consonant. For the purposes of the present discussion, I will use the descriptive constraint ENHANCE-Rφ to describe this process. The phonetic component then interprets the phonological output by attaching aspiration to consonants and devoicing vowels.

(8) ENHANCE-Rφ (Windsor 2012)
Overtly demarcate the right edge of a prosodic phrase (φ) by epenthesising a [SPREAD GLOTTIS] feature to the segment aligned with that prosodic boundary (Align [SG] with the right edge of a φ)

[10] See Zsiga 2000; Kiparsky 2006; deLacy 2006; Blevins 2006a, b; Keyser & Stevens 2006; or Stevens & Keyser 2010, for discussion of the variable phonetic realizations of phonological specification.

(9) Derivation of Blackfoot phrases

Input	/…iːʔn**iː**/ 'buffalo'	/…piːt**a**/ 'eagle'	/piː**t**/ 'enter!'
ENHANCE-Rφ	[iːʔniːʰ]φ	[piːtaʰ]φ	[piːtʰ]φ
Phonetic realization	⟦iːʔni͡i̥⟧	⟦piːtḁ⟧	⟦piːtʰ⟧

The analysis provided above shows how the phonetic component instantiates a single phonological feature —[SG]— in different, but regular and predictable ways. It has the advantage of explaining why vowels and consonants are both affected by a process which requires abduction of the vocal folds; why these processes are triggered in the same prosodic environment, and why the length of aspiration and devoicing are similar. The only remaining problem is how does a language which is typically analyzed as lacking any laryngeal features utilize [SG] as an active prosodic boundary marker. This is the subject of the next section.

3. Contrast

The Contrastive Hierarchy (Dresher 2009) is a theory of segmental phonology which contends that a feature which does not contrast within a language is not active within the phonology of that language. This theory is built off of the long standing view originally expressed by Saussure in 1916 (*qtd. in* Dresher 2009:1) that the "sound of a word is not in itself important, but the phonetic contrasts which allow us to distinguish that word from any other." Dresher expands upon that notion by recognizing that phonemes cannot merely be categorized by what they sound like, but also what they contrast with. Thus, we might look up a feature matrix for the sound [p] and learn that it, among other features, is traditionally viewed as being specified for [–VOICE] as opposed to an [m] which is traditionally viewed as being specified for [+VOICE]. In Welsh where [p] contrasts with [b], and [m] can alternate with [m̥], this analysis seems correct. However, given that there are no voicing contrasts in the Blackfoot consonant series, this means that it is highly unlikely that Blackfoot [m] is actually specified for [VOICE] at all. This raises the question that, in a language which is not traditionally considered to make a contrast on the feature [SG], such as Blackfoot, what evidence is there for phonological epenthesis of [+SG][11] at the right edge of a φ rather than relegation of the explanation of Blackfoot aspiration to the phonetic implementation of a phonological category?

From a phonetic standpoint, one could make the case —contra what was argued in the previous section— that vowel devoicing and aspiration are decidedly different phonetic processes taking place in a single environment – the edge of a phonological category. Because [SG] does not seem to be contrastive anywhere else in the language, there is good reason to doubt an analysis that relies on [SG] as a phonological feature. If we look at the

[11] I remain agnostic on whether phonological features are privative or binary, but will largely treat them as binary in this section for consistency with the Contrastive Hierarchy method that I am assuming here.

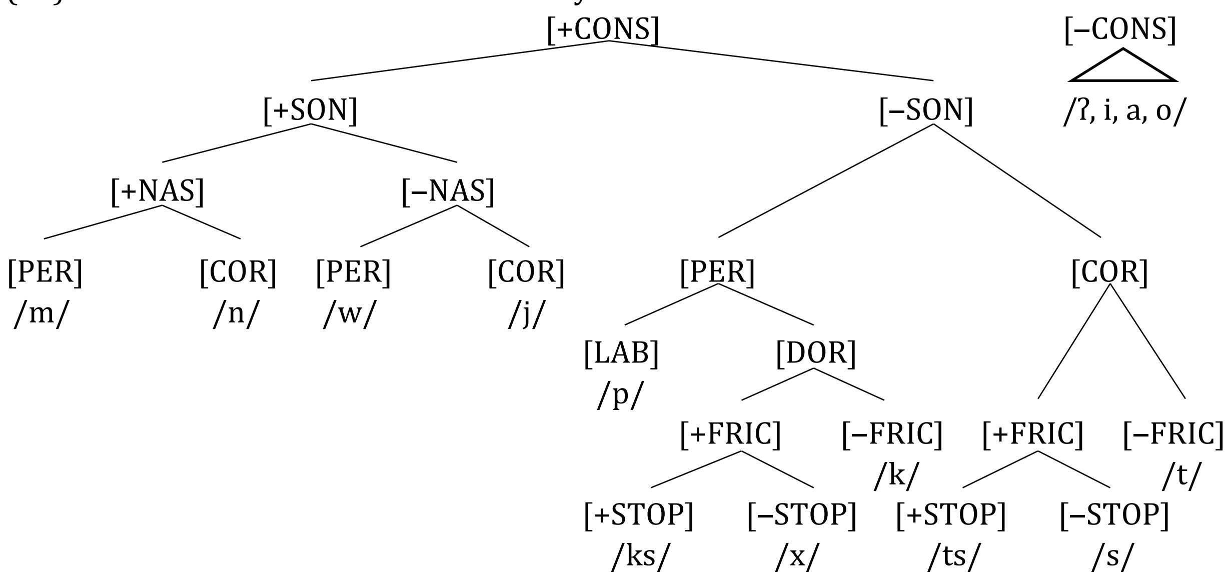
phonemic inventory of Blackfoot, we can then divide these phonemes out based on featural contrastiveness (length will be dealt with separately). I repeat the commonly assumed phonemic inventory of Blackfoot provided in (2) here as (10) for convenience.

(10) The commonly assumed Blackfoot phonemic inventory (Elfner 2006:12)

	Labial	Coronal	Dorsal	Glottal
Stops	p pː	t tː	k kː	ʔ
Fricatives		s sː	x	
Affricates		ts tːs	ks kːs	
Nasals	m mː	n nː		
Glides	w	j		

Vowels
i iː
o oː
a aː

(11) The Blackfoot contrastive hierarchy[12]



At first glance, this contrastive hierarchy seems reasonably satisfactory; segments contrast in whether or not they are consonantal, the consonantal segments contrast for sonority (we can reasonably assume a constraint prevents non-sonorous sounds from being contrastive in nasality (*i.e.*, *[−SON], [NAS])), and then location —peripheral or coronal, with peripheral then contrasting between labial and dorsal specifications— followed by a contrast for frication, and finally for a stop feature. Thus, the phoneme /m/ would only be specified as a [PERIPHERAL, NASAL, SONORANT, CONSONANT] segment, but the affricate /ks/ would be specified as a [STOP, FRICATIVE, DORSAL, PERIPHERAL, NON-SONORANT, CONSONANT] segment. This hierarchy successfully divides all of the phonemes assumed in Elfner (2006) and crucially does not require any laryngeal features to do so – specifically [SG]. From here,

[12] Because the contrast between singleton consonants and geminates relies on moraic structure, not phonological features, geminates are not included as part of this division algorithm.

so-called redundancy rules achieve the fact that sonorant consonants are voiced and non-sonorants are voiceless. This achieves the descriptive fact given by Elfner (2006:11) who states that "Blackfoot lacks voicing or aspiration contrasts; all of its obstruents are voiceless with little or no aspiration, and all of its sonorants are voiced." In fact, the only reason to be suspicious of this hierarchy is because of the distribution of the velar fricative. The fact that [x] is the only non-sonorant consonant which cannot appear as long may make it suspect, but this is not damning evidence in and of itself. A proponent of this hierarchy could also point out that the glides and glottal stop likewise cannot appear as long, and that must first be explained. First, we will consider glottal stop.

One thing that should be immediately taken into consideration is the fact that glottal stop patterns in various ways across languages: Glottal stop has a tendency to pattern with approximants in some languages, stops in others, and as an unspecified epenthetic consonant in yet others still. Windsor (2012) discusses how glottal stop and schwa —as the least specified segments— alternate with Ø in French (*cf*. Côté 2008).[13] Kavitskaya (2002: §3.3.1) discusses the wide range of possible /ʔ/ phonologies. She discusses how Clements (1990) refines Catford's (1977) definition of approximants as lacking turbulence in the oral cavity, thus making /ʔ/ an approximant by definition. She shows how this is borne out in Karok (Bright 1957) where /ʔ/ patterns with glides as the set of consonants which cannot be geminated. However, in Kwakwala (Zec 1988, 1995), /ʔ/ patterns with stops in that coda-/ʔ/ does not attract stress. In fact, Kavitskaya cites personal correspondence with Keren Rice who suggests that in Proto-Athapaskan, the /ʔ/ is the only non-moraic coda. Finally, she gives an example from Ladefoged & Maddieson (1996) who describe a Papa New Guinea language, Gimi, as having a contrast between approximant-/ʔ/ and stop-/ʔ/. So, how does /ʔ/ pattern in Blackfoot? Immediately, one can see the descriptive similarities between Karok and Blackfoot – that /ʔ/ patterns with the glide series as a set of non-geminable consonants (Kavitskaya 2002:87). However, according to Frantz (2009) glides and /ʔ/ partake in different phonological rules. Though there are rules that govern both semivowel (glide) and /ʔ/ loss/reduction, there are additional rules that show /ʔ/-assimilation and /ʔ/-metathesis which the other approximants do not participate in. Strikingly, on this point, Frantz (2009:156-7) describes the phonological rules of semivowel and glottal reduction:[14]

(12) Semivowel reduction: G → Ø/_+G
kitanistawaaw + yináyi → kitánistawaayináyi 'you$_{2p}$ said to him$_{4s}$'

(13) Glottal reduction: ' → Ø/_'
(á' + o'tooyiniki → áo''tooyiiki)[15] áo''tooyiniki → áó'tooyiniki[16] 'when you arrive'

[13] See also Shaw *et al* (1999:12 and references therein) for a discussion of this lack of specification on schwa and glottal stop in Salish, and van Oostendorp (2000) for a discussion of these segments in Dutch.
[14] Where G = glide and ' = [ʔ]
[15] After the effects of the glottal metathesis rule which applies for maximal feeding (Frantz 2009:157).
[16] After the effects of the accent spread rule.

However, [ʔ] and glides can occur in adjacency in Blackfoot:

(14) [ʔ]-G adjacency

a. aʔpiksík:aʔjiwa 'stroke/he walked' (Eflner 2006:51)
b. ikoxpiʔwa 'it swelled' (Elfner 2006:51)

Glottal stop in Blackfoot also seems to be unlike the majority of Blackfoot obstruents in that, according to Elfner (2006), it and [x] are the only singleton consonants which can occupy coda position. The difference between these two segments is that [x] is found exclusively in post-vocalic, pre-consonantal position, and [ʔ] is normally found in coda position before vowels, glides, and any consonant other than another glottal stop. So it seems that [ʔ] is simply a segment which, like in Rice's Proto-Athapaskan analysis cited above in Kavitskaya (2002), is simply a consonant which cannot project a mora, which means it can appear in coda position without causing a gemination to occur – but it is not restricted solely to codas (although it is most frequently found there), unlike [x].

It is a theoretical possibility that even though [ʔ] does not pattern with glides in Blackfoot, [x] does. However, as we shall see, such an analysis would be difficult to maintain. According to Catford's (1977) definition of approximants (given in Kavitskaya 2002:87) as having the airstream become turbulent when they are voiceless, it is possible that [x] patterns with the approximants in Blackfoot, which is why it cannot appear as long. Elfner (2006) gives a possible historical reason for [x]'s distribution in Blackfoot, suggesting that it may have arisen through a process where codas were neutralized to [x] before obstruents. This would explain why the distribution of [x] is limited to post-vocalic, pre-obstruent position in modern Blackfoot. Approximants on the other hand, are found exclusively in onset position (phonemically), and are deleted word-initially or following a consonant that is not [ʔ] (Frantz 2009). Further, [x] does not participate in any of the reduction or deletion rules that the approximants of Blackfoot do. From an Evolutionary Phonology standpoint (Blevins 2006), this distribution could be the result of, ultimately, historical accident, which merely puts [x] in complementary distribution with the approximants [w] and [j]. I contend that this gives us reason to re-examine what the actual nature of [x] is in modern Blackfoot and see if there is another principled phonological reason for its distribution.

Reis Silva (2008) argued quite convincingly that what is traditionally considered to be a velar fricative in the Blackfoot literature is more accurately described as a slight frication at the end of a vowel resulting from the pre-aspiration of a following consonant. The slight frication, typically transcribed as [x] or [ç] (depending on the adjacent vowel), can be explained by the fact that pre-aspiration typically presents with an oral constriction which is "fricative in nature" (Silverman 2003 *qtd in* Reis Silva 2008:7). This interpretation of the slight frication found (post)vocalically and pre-obstruent in Blackfoot allows us to make a meaningful contrast between singleton unaspirated consonants, geminate unaspirated consonants, and pre-aspirated consonants:

(15) Three-way aspiration distinction in Blackfoot (Reis Silva 2008:9)[17]

	SR	Written form	Gloss
a.	[mʊ**ʊ̥^{xw}t**ʊːkis]	mohtóókis	'ear'
b.	[mʊ**t**ʊʊkis]	mótookis	'kidney'
c.	[mʊ**tː**ʊksis]	mottoksis	'knee'
d.	[mʊ**ʊ̥^{xw}k**in]	mohkín	'necklace'
e.	[mʊʊ**k**ʊan]	móókoan	'stomach'
f.	[mʊ**kː**ʊis]	mókkoyis	'animal fur'
g.	[apatʊ**ʊ̥^{xw}ts**i̥]	apatohtsi	'back'
h.	[mʊː**ts**iss]	mo'tsís	'hand/arm'
i.	[mʊ**ʊ̥^{xw}ks**is]	mohksisís	'nose'
j.	[ʊːkʊʔsi**ks**i̥]	oko'siksi	'her children'

In the above example, forms a, d, g, and i show pre-aspirated stops/affricates, b and e show unaspirated singleton consonants, h and j show unaspirated affricates, and c and f show unaspirated geminates. If we take as fact that [SG] is contrastive in Blackfoot, we can then revisit the contrastive hierarchy given for the language and see if that resolves the problem of [x]:

(16) The revised Blackfoot phonemic inventory

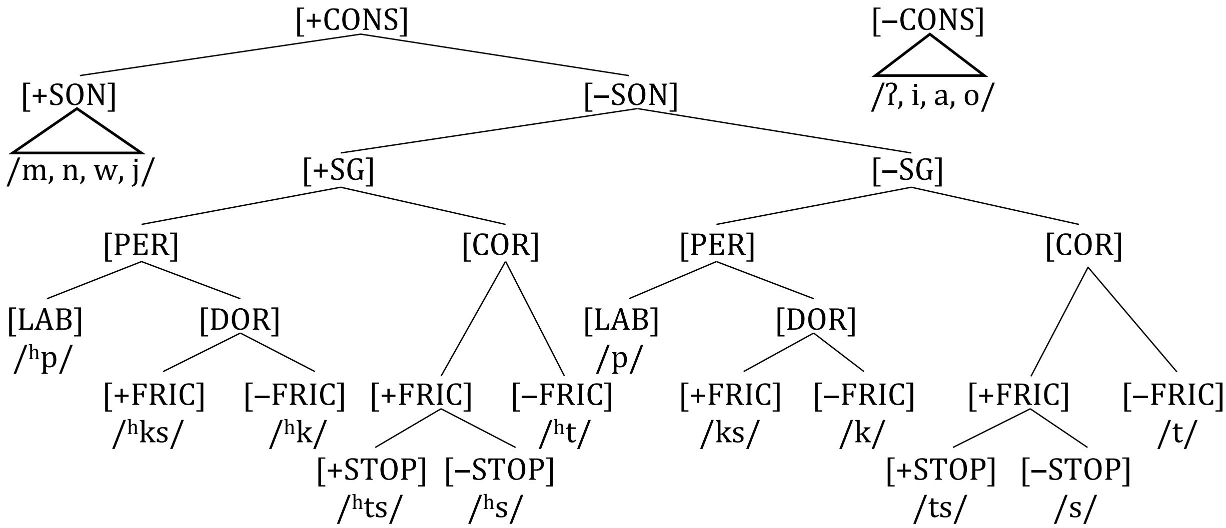
	Labial	Coronal	Dorsal	Glottal
Stops	p **^{h}p** pː	t **^{h}t** tː	k **^{h}k** kː	ʔ
Fricatives		s **^{h}s** sː	x	
Affricates		ts **^{h}ts** tːs	ks **^{h}ks** kːs	
Nasals	m mː	n nː		
Glides	w	j		

Vowels		
i iː		
		o oː
	a aː	

In this revised phonemic inventory, the pre-aspirate series has been added to the non-sonorant stops/affricates and fricatives (appearing as bold in the above diagram), and the velar fricative has been removed (appearing as greyed out in the above diagram). Crucially, this inventory can still be achieved by computing a contrastive hierarchy (Dresher 2009). The revised contrastive hierarchy, however, has better explanatory power in that it better explains the distribution of the geminates, the patterning of [ʔ], and predicts the realization of the affricate series.

[17] The SR of these forms are phonetic outputs. I am unaware of anyone who argues labialization is a contrastive feature in Blackfoot, and would likely exist on these forms only as overlap gestures from the preceding rounded vowel. Reis Silva uses a superscript [^{x}] to indicate pre-aspiration. An example using /s/ contrasting with /^{h}s/ can be seen in *aaasi* 'be a mile' [aːasi] and *aaahs* 'elder relation' [aːa^{h}s] (*cf. maaahsi* 'her paternal aunt' [maːa^{h}si]).

(17) The Blackfoot contrastive hierarchy revised for [±SG]



In the above diagram, I truncate the hierarchy of the sonorant consonants for reasons of space, I do not see any reason to alter the hierarchy given for these phonemes from the diagram which appeared in (11). This hierarchy makes use of two redundancy rules, one which was used in the hierarchy given in (11); that [−SON] consonants are not contrastive for [NAS] (*[−SON], [NAS]), and that [+SON] phonemes are not contrastive for [SG] (*[+SON], [SG]). Under this hierarchy, there are no unanswered questions based on exceptional phonemes. Any phoneme which may appear as a coda —and is capable of associating with a mora— may appear as geminate. As argued above, there are languages where glottal stop is the only consonant not able to associate with a mora, and Blackfoot seems to fall into that category – therefore, we do not expect geminate glottal stops, especially given the rule that in a sequence of two adjacent glottal stops, one deletes (Frantz 2009). Further to that, since glides in Blackfoot cannot appear in coda position, we understand why they cannot appear as long. Finally, this analysis of Blackfoot has the additional advantage of explaining why the dorsal affricate in the language is [ks] and not [kx] – which would be expected if velar fricatives were phonemically available in the language.

The one final argument one might give for not accepting the phonological treatment of consonants being specified as [+SG] in Blackfoot is the idea that they seem to be restricted to word-medial positions. Since word-final consonants in Blackfoot are largely restricted to a small set of morphological endings (i.e., *−t/−k* 'imperative.sg/.pl') we would not expect to necessarily find pre-aspirates in this position, but why can they not appear in word-initial onset position? Of course, this raises the question of perceptibility – how wold you recognize a word-initial pre-aspirate if you had no preceding vowel by which to gauge the pre-aspiration? In large part, I would argue that that perceptual explanation provides an adequate answer to the question, however there is at least one dialect of Blackfoot where pre-aspirates may appear in word initial position. One of my consultants consistently produces the words for 'soup' and 'chair' with an initial pre-aspirate, epenthesising a vowel to the beginning of the word in order to make the contrast perceptible:

(18) Word-initial pre-aspirates Blackfoot[18]

	Written form	Pronunciation 1	Pronunciation 2	gloss
a.	*(a)koopi(si)*	[ko:pi]	[ḁʰko:pi]	'soup'
b.	*(a)sóópa'tsis(i)*	[so:paʔtsis]	[ḁʰso:paʔtsis]	'chair'

I take this as evidence that pre-aspirates are not restricted to word-medial position, though they may be rare in initial position due to the relative lack of salient cues that a word-initial consonant is pre-aspirated. The above examples provide one repair strategy to allow word-initial pre-aspirates to be recognised. Given the salience of such an item, and the relative infrequency of the words it appears on, however, it is not surprising that this pattern is found mainly among older speakers of the language. Nevertheless, this does provide evidence for [SG] as a contrastive feature in Blackfoot.

Since we understand [SG] to be contrastive in Blackfoot, then we are not forced to relegate phrase-final aspiration to phonetic implementation. This is a feature that the phonological component of Blackfoot has access to, and can make use of.

4. Conclusion

In this article I have provided evidence that the feature [SPREAD GLOTTIS] is active and contrastive in the phonology of Blackfoot. This evidence comes from the fact that phrase-final phenomenon which devoices vowels targets all segments, and has different phonetic implementations depending on the segment associated with the edge; that aspiration and vowel devoicing share the same articulatory gestures and phonetic length; and, that assuming aspiration is phonetic implementation rather than phonological specification fails to predict the distribution of what has been previously analyzed as the velar fricative, /x/.

There are three important contributions from this article: i. That the articulatory gesture for short and long vowels in final position remains contrastive, ii. an explanation for why vowels in final position devoice, and iii. evidence for the reconfiguration of the Blackfoot phonemic inventory based on contrast. This analysis crucially makes use of the Contrastive Hierarchy (Dresher 2009) as a method for discovering phonologically contrastive/active features in a language. Together with evidence presented in Reis Silva (2008) that Blackfoot contains pre-aspirates, the contrastive hierarchy allows me to show ample evidence that [SG] is active in Blackfoot. This explains why vowel devoicing and consonant aspiration occur in the same environment and use the same articulatory process without relying on historical accident. Finally, this analysis also adds to the existing literature on phrase-final glottal

[18] Frantz (2009) lists other possible forms which fit this pattern (with an optional initial <a>) such as *(a)sootsímaan* 'parfleche' or *(a)sottoan* 'knife-scabbard'.

insertion, providing typological validation of these studies (see Blevins 2008 or Watters 2010 and references therein).

4.1. Directions for future research

The research presented here offers both theoretical and experimental evidence for the conclusions reached. However, some of the experimental evidence stems from what amounts to preliminary or pilot studies thus far. Further experimentation is still needed to confirm the results of these preliminary studies such as eliciting and analyzing equal tokens of final short vowels, long vowels, and consonants with a consistent syntax in order to provide enough data for meaningful statistical analysis of these tokens.

Additionally, Understanding the prosodic constituency of Blackfoot and how this relates to the syntax (as used for elicitations) is the subject of ongoing research. I have suggested here that the environment for [SG] epenthesis in Blackfoot is the right edge of a phonological phrase, but I have provided no evidence that the correct environment is not the right edge of the utterance in the current article. However, preliminary results from utterance medial elements such as demonstratives and adjectives suggest that neither utterance nor phonological word boundaries are the environment for aspiration.

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