PHRASE-FINAL VOWEL ALTERNATIONS IN CROW

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Abstract

In the Siouan language Crow, only a particular set of vowel structures are observed at the end of the phonological phrase. Phrase-internally, monomoraic vowels, bimoraic vowels and bimoraic diphthongs with a non-moraic off-glide are observed in free distribution. In inputs ending in a single-vowel sequence, only bimoraic mid vowels and bimoraic diphthongs are observed phase-finally in the output. To prevent marked vowel structures from appearing phrase-finally, Crow vowels undergo processes of lengthening, neutralization and diphthongization. Vowel sequences in Crow are also restricted phonotactically. Sequences of consecutive long vowels or long vowels following short vowels are prohibited. Marked sequences undergo processes of shortening and height dissimilation in order to satisfy these sequence restrictions. In cases where vowel sequences are phrase-final, restrictions on possible vowel sequences and possible phrase-final structures conflict. The result is that structures are observed in the output which are prohibited by phrase-final restrictions in single vowel sequences. This interaction gives insight into how phonotactic processes interact and shows that in Crow, phrase-final restrictions are violable in order to satisfy vowel sequence restrictions, which are undominated in the data. In my analysis, formulated in Optimality Theory, I model these restrictions and associated processes by introducing positional markedness constraints and ranking them with respect to faithfulness constraints. My constraints and analysis provide a model for how the phonotactic restrictions in Crow are motivated and give insight into the interaction and conflict that takes place when both sets of restrictions target the same structure.

I. Introduction

Crow, or *Apsaalookanqi*, is a Siouan language spoken primarily on the Crow Agency in Montana. The language displays many morphological and syntactic similarities to other Siouan languages, especially Hidatsa. In Crow, an asymmetry in the distribution of vowels in phrase-internal vs. phrase-final positions is observed. Phrase-internally, Crow words can end with any of the short vowels *a, i* or *u,* long vowels *aa, ii, uu, ee* or *oo,* or diphthongs *iiə* or *uuə* (Graczyk 2007). Phrase-internal distribution of vowels is completely free, meaning that any vowel represented in the vowel inventory of Crow (1) can be found phrase-internally. However, in phrase-final position, there are restrictions on which vowels can appear in the output. For inputs ending in a single vowel, only the bimoraic mid vowels *ee* and *oo,* as well as the diphthongs *iiə* and *uuə* are observed phrase-finally in the output. This process is complicated when vowel sequences are found in the phrase-final position. Vowel sequences themselves are subjected to a unique set of phonotactic restrictions which prevents certain marked sequences from appearing in the output. When vowel sequences are phase-final, restrictions on phrase-final segments conflict with restrictions on vowel sequences, leading to complex interactions.

In this paper, I will take a step-by-step approach to explaining how these processes act on phrase-final segments in Crow. First, I will present an analysis for how the full range of single vowel phrase-endings is restricted to only the well-formed phrase endings described above. Next, I will examine vowel sequence restrictions in Crow by introducing and analyzing the plural morpheme, which has three possible allomorphs that are phonologically conditioned according to vowel sequence restrictions. Finally, I will analyze the interaction that takes place when the plural morpheme is observed phrase-finally, resulting in a two vowel sequence at the

end of a phrase. I will be presenting an analysis of these phenomena within the framework of Optimality Theory (Prince and Smolensky 1993/2004).

II. Background information

Before moving into an analysis of these alternations, some background information will provide helpful context into some structural elements of Crow. The following table provides a phonemic vowel inventory in lieu of a full phonemic inventory due to the fact that the relevant alternations target only vowels and are uninfluenced by environmental consonants.

(1) Vowel inventory

	[-ROUND]			[+ROUND]		
	SHORT	LONG	DIPHTHONG	SHORT	LONG	DIPHTHONG
HIGH	*i*	*ii*	*iiə*	*u*	*uu*	*uuə*
MID		*ee*			*oo*	
LOW	*a*	*aa*				

Vowels represented by double orthography in these data (e.g. *aa, ii* etc.) are long vowels in Crow. In the existing literature on Crow and for the purposes of this analysis, long vowels are analyzed as bimoraic (Graczyk 2007). The bimoraic vowels *aa*, *ii* and *uu* contrast on a phonemic level with the monomoraic *a, i* and *u* respectively. This distinction is illustrated by the difference in meaning between the words *baalaa* (‘winter’) and *balaa* (‘money’). Similar such examples exist for the *ii, i* and *uu, u* correspondences as well (Lowrie 1960). The mid-vowels *ee* and *oo* are phonemically bimoraic, with the monomoraic vowels *e* and *o* being phonologically conditioned allophones. This assumption is supported by the absence of observed minimal or

near-mininal pairs in Crow where short and long *ee* and *oo* contrast (Grazyck 2007). Two high diphthongs are also observed: *iiə* and *uuə*. Existing scholarship on Crow and Hidatsa analyzes these diphthongs as bimoraic high vowels followed by non-moraic schwa off-glides (Graczyk 2007, Bowers 1996). This analysis is consistent with the generalization that tri-moraic syllables are typically not observed cross-linguistically (Goldsmith et al. 2011).

The basic syllable structure of Crow is CVC. CV and CVC with either monomoraic or bimoraic vowel nuclei are the most commonly observed syllable structures in Crow, while syllables consisting of just a vowel are only found in exceptional circumstances. The following structures are observed:

(2) Crow syllable structures

CVC	CVC	CV	CV	VC	VC	V
|	||	|	||	|	||	|
μ	μμ	μ	μμ	μ	μμ	μ

It is worth noting that CVC syllables are observed phrase-finally quite frequently and neither final consonants nor the vowel nuclei in phrase final CVC syllables undergo phonological changes. Vowel sequences are restricted by Crow phonotactics. Due to the maximal CVC structure, sequences of multiple vowels are only observed at morpheme boundaries. The only allowable sequences of three consecutive vowel morae are a short vowel following a long vowel across a syllable boundary. Consecutive long vowels are not observed, nor are sequences of a long vowel following a short vowel. Additionally, consecutive high vowels are not observed in Crow. An analysis of these patterns is found in (IV), where vowel sequence phonotactics and restrictions are discussed at length.

Due to the relevance of the concept of a 'phrase' to my analysis, an explanatory note on the nature of a phrase in Crow is in order. The status of the word and the phrase in Siouan languages can be opaque. Crow is both polysynthetic and incorporating, meaning words can be composed both of multiple morphemes and multiple lexemes. This incorporation leads to long sequences which are treated as a single phonological entity. To illustrate, example (3) shows the incorporation of an entire clause into a single noun phrase (Dixon et al. 2002).

(3) *iisaaksheilliadaxxoxxuuk*
iisaakshe illiia daxxoxx-uu-k
young.men tipi-poles peel-PL-DECL
"The young men are peeling the tipi poles" (lit. Engagement in the activity of peeling poles by young men.")

To avoid confusion, when I use the term 'phrase' in this analysis, I refer exclusively to the *phonological phrase*.

III. Single vowel phrase-final inputs

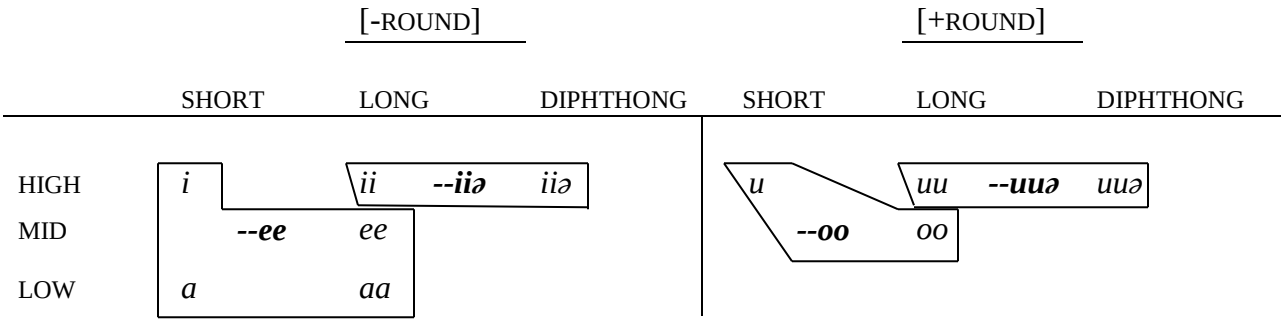
In Crow, only specific segments are observed phrase-finally. Phrase-internally, the distribution of vowels is entirely free. This means that phrase internally, words can end with any of the short vowels *a, i, u*; the long vowels *aa, ii, uu, ee, oo* or the diphthongs *iiə, uuə*. In other words, the full range of vowels is found word-internally. In single vowel phrase-final input sequences, the endings lengthen and undergo height neutralization, while the [+/- round] distinction is preserved. The following data shows the alternations between phrase-internal and phrase-final endings.

(4) Phrase-internal vs. phrase-final vowel distribution

Phrase-internal	Phrase-final	
apa	apee	‘nose’
aachi	aachee	‘breast’
chiaxxu	chiaxxoo	‘five’
ehchee	ehchee	‘know’
bachee	bachee	‘man’
akbinnawoo	akbinnawoo	‘scholar’
daaxoo	daaxoo	‘lung’
baalaa	baalee	‘man’
bitchii	bitchiiə	‘knife’
awuu	awuuə	‘inside’
biia	biiə	‘woman’
buua	buuə	‘fish’

I assume the input and output to be identical for the phrase-internal forms, due to the fact that these forms display the full range of possible vowel endings. Phrase-final endings are more limited and can be seen to be in systematic alternation with corresponding phrase-internal endings. These corresponding alternations can be seen more clearly in the following tables. In (5) internal endings are grouped by corresponding phrase-final endings. In (6) correspondences are grouped by phonological processes which are observed.

(5) Phrase-internal and phrase-final vowel correspondence



(6) Phrase-final vowel alternations

(6a) Lengthening

-a	*-ee*	*-i*	*-ee*
--u	*-oo*		

(6b) Neutralizatiion

-a	*-ee*	*-i*	*-ee*
-u	*-oo*	*-aa*	*-ee*

(6c) Diphthongization

-ii	*-iiə*	*-uu*	*-uuə*

(6d) No change

-ee	*-ee*	*-oo*	*-oo*
-iiə	*-iiə*	*-uuə*	*-uuə*

The first observation that can be made is that monomoraic vowels are not found in the phrase final position. These endings can be seen in (6a). Since monomoraic vowels are found word-finally in corresponding phrase-internal words, it is clear that some phonotactic restriction on phrase final vowels is preventing phrase-final monomoraic vowels in the input from remaining monomoraic in the output. Final lengthening is a commonly observed phenomenon cross-

linguistically, observed in languages from a wide variety of genetic groupings (Goldsmith et al., 2011). The generalization that monomoraic vowels are not found in world-final outputs can be modeled in OT by ranking a markedness constraint which prohibits phrase-final monomoraic vowels is over the faithfulness constraint IDENT(μ). In an analysis of French syllables, Fery (2003) posits the markedness constraint FinalLength, which states that final syllables are bimoraic. While Fery's constraint is positively formulated to ensure well-formed syllables, my constraint FINALLENGTHV is negatively formulated, prohibiting marked structures from appearing in the output:

- FINALLENGTHV: monomoraic vowels are not found phrase-finally. Assign one violation mark for each monomoraic output vowel in a phrase-final position.
- IDENT(μ): output segments are equal to corresponding input segments in number of morae. Assign one violation mark for each output segment which differs in number of morae from corresponding input segment.

(7) FINALLENGTHV >> IDENT(μ)

daxxoo 'lung'

	/daxxo/ | μ	FINALLENGTHV	IDENT(μ)
	[daxxo]$_{phrase}$ | μ	*!	
→	[daxxoo]$_{phrase}$ | | μ μ		*

This tableau shows that in Crow, it is acceptable to violate the faithfulness constraint IDENT(μ) in order to avoid a violation of FINALLENGTHV. This constraint ranking serves as an OT model of

the generalization that in Crow, it is preferable to have output segments which differ in moraic quality from corresponding input segments in order to avoid having a monomoraic vowel in the phrase final position.

The next observation that can be made is that phrase-final single vowel sequences are constrained to a particular set of vowels - mid vowels and diphthongs. I will treat the mid vowel endings first. Underlying short vowels as well as the long vowel -aa undergo height neutralization phrase-finally. The vowels all become bimoraic mid vowels, while retaining their [+/- round] distinction. Refer to (5) for an explicit representation of these alternations. The phenomenon of phrase-final vowel neutralization is not exclusive to Crow and has been observed in many American language families as well as being prominently featured in many Dravidian languages (Barnes 2006). Neutralization in Crow involves peripheral vowels becoming mid vowels. I use the term 'peripheral vowel' to mean any non-mid vowel, i.e. those which have a positive value for either [high] or [low]. The generalization can be made that phrase-final vowels will undergo a change in height rather than remain peripheral with respect to height. This generalization can be modeled in OT by ranking a markedness constraint preventing phrase-final peripheral vowels over the faithfulness constraint IDENT(height). I propose another markedness constraint, NOFINALPERIPH.

- NOFINALPERIPH: Peripheral vowels are not found phrase-finally. Assign one violation mark for each phrase final vowel with a positive value for [hi] or [low]
- IDENT(height): Output segments have identical values for [high] and [low] as corresponding input segments. Assign one violation mark for each output segment which differs with corresponding input segment in value for [hi] or [low]

(8) NOFINALPERIPH >> IDENT(height)

balee ‘man’

	/balaa/	NOFINALPERIPH	IDENT(height)
	[balaa]$_{phrase}$	*!	
→	[balee]$_{phrase}$		*

This tableau shows that in Crow, a violation of the constraint IDENT(height) is allowable in order to avoid violations of NOFINALPERIPH. This constraint ranking is an OT model of the generalization that it is preferable to change the height of a vowel in order to prevent a peripheral vowel from appearing phrase finally. Like lengthening, final neutralization and positional neutralization are phenomena that are observed in many languages. Cross-linguistically, neutralization is most commonly found in weak positions (Walker 2011). Additionally, Barnes (2006) contends that final neutralization serves the purpose of marking the end of a word or phrase. These observations both give support to the argument that this alternation in Crow is motivated by phrase-final neutralization.

The vowel lengthening and neutralization phenomena described above explain only the incidence of *ee* and *oo* as phrase-final vowels. Also observed phrase-finally are the high diphthongs *iie* and *uue.* Recall that these diphthongs are bimoraic high vowels followed by a non-moraic schwa off-glide. It makes sense that words ending in *iiə* and *uuə* surface faithfully phrase-finally, as they are protected from NOFINALPERIPH by the non-moraic off-glide which appears phrase finally. Due to the presence of this segment in the diphthongs, no violation of NOFINALPERIPH, which prohibits only phrase-final peripheral vowels, is incurred when a

diphthong is in a phrase-final position. The existence of the phrase-final off-glide prevents the bimoraic high segment from undergoing neutralization. Additionally, this off-glide is not targeted by FINALLENGTHV, as the constraint is formulated only to prohibit phrase-final monomoraic vowels. This explains the faithful phrase-final output representations of words which end in either of the high diphthongs. The fact that input word-final *ii* and *uu* are represented in the output as *iiə* and *uuə* rather than *ee* and *oo* respectively presents a more interesting puzzle. The bimoraic high vowels *ii* and *uu* are the only non-diphthong vowels which do not undergo neutralization to become *ee* or *oo*. This process of diphthongization has the same motivations as the neutralization seen above, namely a means of avoiding violations of NOFINALPERIPH. The epenthesis that occurs with phrase-final *ii* and *uu* indicates that in Crow, it is preferable to insert a schwa to make a diphthong than to change vowel height. To model this generalization in OT, I rank the previously discussed faithfulness constraint IDENT(height) over the anti-epenthesis constraint DEP. This ranking prevents the height change seen in the neutralization cases above.

- DEP: All output segments have corresponding input segments. Assign one violation mark for every output segment with no corresponding input segment.

(9) IDENT(height) >> DEP

awuuə 'inside'

	/awuu/	IDENT(height)	DEP
→	$[awuuə]_{phrase}$		*
	$[awoo]_{phrase}$	*!	

This tableau shows that to avoid a peripheral vowel phrase-finally, Crow inserts a schwa off-glide to create a diphthong rather than changing vowel height.

Because this process of diphthongization is preferable to height neutralization, it is important to state why neutralization is observed at all. The answer lies in the nature of Crow diphthongs. As previously stated, *iiə* and *uuə* are the only diphthongs which are found in Crow. This suggests the existence of some context-independent markedness constraint which prevents other diphthongs from appearing. I propose the markedness constraint HIGHDIPHTHONG.

- HIGHDIPHTHONG: In diphthongs, the bimoraic segment must be high. Assign one violation mark for every diphthong in which the bimoraic segment is [-high].

(10) HIGHDIPHTHONG >> IDENT(height) >> DEP

baalee 'man'

	/baalaa/	HIGHDIPHTHONG	IDENT(height)	DEP
	$[baalaaə]_{phrase}$	*!		*
→	$[baalee]_{phrase}$		*	

This tableau and constraint ranking ensure that my analysis for the process of diphthongization in (9) does not wrongly overextend to other vowels. In Crow, the schwa off-glide is only found as a constituent segment of the two observed high diphthongs. Without this ranking, diphthongization would predict diphthong endings which are not found in Crow. This leaves us with the following constraint hierarchy, which I believe to be sufficient in phrase-internal/phrase-final alternations:

(10) Constraint ranking for phrase-final single vowel sequences

HIGHDIPHTHONG, FINALLENGTHV, NOFINALPERIPH

||

IDENT(μ), IDENT(height)

||

DEP

This constraint hierarchy is sufficient for describing the phrase-final lengthening, neutralization and diphthongization in Crow. FINALLENGTHV is undominated thus far, meaning that no phrase-final vowel endings are monomoraic. Crow responds to this constraint through the process of vowel lengthening. Additionally, NOFINALPERIPH is undominated thus far, meaning that high and low vowels are not found phrase-finally. Crow ensures that these peripheral vowels are not found phrase-finally through the process of diphthongization or, in the cases where diphthongization would result in a violation of the undominated HIGHDIPHTHONG, through the process of neutralization. However, this picture of phrase-final vowel structures will be complicated with the introduction of vowel sequences into the phrase-final environment.

IV. Vowel sequence phonotactics: plural formation

As we have seen, only certain vowel sequences are observed in Crow. Due to restrictions on syllable structure, sequences of vowels only occur at morpheme boundaries. When input vowel sequences are ill-formed according to sequence restrictions, vowels undergo changes in moraic quality to appear well-formed in the output. I will use the plural morpheme, which is *–uu* in the input, as a paradigm through which to analyze these vowel sequence restrictions. In Crow, the plural surfaces phrase-internally as one of three allomorphs: *–uu*, *–u* or *–o*. Which allomorph surfaces depends on which stem vowel the morpheme attaches to. The distribution of the plural

allomorph phrase-internally is seen in (12). When forming plurals phrase-internaly for words ending in short vowels, the word final short vowel is deleted and *–uu* is added (12a). For stems ending in the long vowels *–aa* and *–oo*, *–u* is added as the plural marker (12b). For stems ending in the long vowels *ii*, *ee* and *uu*, the suffix *–o* is added as the plural marker. For stems ending in the diphthongs *–iiə* and *–uuə*, the final schwa off-glide is deleted and *–o* is again added as the plural marker (12c). Before examining how plural formation interacts with the phrase-final restrictions described in (III), I will present an analysis of the plural marker as it appears phrase-internally.

The data sets below show that the alternations described above are in complementary distribution, which means they are motivated by phonological considerations. I will posit *–uu* as the underlying input plural marker. This hypothesis is strongly supported by the fact that the plural marker is universally observed as *–uu* when attached to roots ending in a consonant. An example of such an occurrence can be seen in the following noun phrase (Grazcyk 2007):

shikaaka-m xapiik-uu-sh
boy-DET lost-PL-DET
"The boy that they lost."

Under my analysis, the monomoraic allomorphs of *–uu* are due to positional markedness constraints which take vowel length and vowel height into consideration. Specifically, long vowels appear to shorten when following other vowels and consecutive high vowels dissimilate. The following data represents these alternations:

(12) Phrase-internal plural allomorphs

(12a) –*uu* plural morpheme

Singular	plural	
bala	*bal-uu*	'woods'
baalu	*baal-uu*	'beads'
aaciwi	*aaciw-uu*	'climb'
apusa	*apus-uu*	'cuts'
alaxxu	*alax-uu*	'friends'
aliisi	*aliis-uu*	'hungry'
aci	*at-uu*	'heat'

(12b) –*u* plural morpheme

singular	plural	
biilaa	*biilaa-u*	'geese'
akbinnawoo	*akbinnawoo-u*	'scientists'
duuxaa	*duuxaa-u*	'spread out'

(12c) –*o* plural morpheme

singular	plural	
ii	*ii-o*	'mouths'
iiə	*ii-o*	'wear'
duuə	*duu-o*	'lift up'
chii	*chii-o*	'pack'
kuluu	*kuluu-o*	'piled up'
paapii	*paapii-o*	'stir'
axuuə	*axuu-o*	'body'
biliiə	*bilii-o*	'door'

(13) Phrase-internal plural morpheme correspondences

Stem ending	Plural allomorph
–a	*–uu*
–i	
–u	
–ee	*–u*
–oo	
–aa	
–ii	*–o*
–uu	
–uuə	
–iiə	

As mentioned above, I assume *–uu* to be the input plural morpheme. This means there two alternations to account for, changes in moraic quality and height. First, I will address the *–u* alternation seen in (12b). In order for this allomorph to appear in the output, there must be some motivation for a change in the moraic quality of the morpheme. Recall from my earlier discussion on phonotactics that sequences of two consecutive long vowels or short vowels followed by long vowels are not observed in Crow. An OT analysis of this generalization will produce an undominated markedness constraint prohibiting a long vowel from following any other vowel. This markedness constraint is required to outrank the faithfulness constraint IDENT(μ) in order to account for the monomoraic allomorph *–u* which is seen in words like *biilaa-u*. This markedness constraint is *VVː, which prevents a long vowel from appearing in any postvocalic position.

- *VVː : No post-vocalic long vowels. Assign one violation mark for every long vowel which occurs after a vowel.

(14) *VV: >> IDENT(μ)

biilaa-u *'geese'*

	/biilaa-uu/ | | μ μ	*VV:	IDENT(μ)
	[biilaauu] | | μ μ	*!	
→	[biilaau] | μ		*

This ranking tableau shows that in Crow, vowels are shortened to avoid post-vocalic long vowels, a marked structure in this language. This alternation makes sense, as consecutive long vowels are marked in Crow and, as we have already seen, moraic quality is a feature of vowels that is frequently changed in Crow. This constraint ranking explains the cases in which the plural morpheme surfaces as *–u* when attached to either of the long non-high vowels *aa*, *ee* or *oo*. When plural morpheme attaches to the long high vowels *ii* or *uu*, a similar process of shortening takes place, but in these cases an additional phenomenon is also observed.

In the cases where the word stem ends in *ii* or *uu*, the plural morpheme is still shortened, but the output form is *–o* rather than *–u*. Because the *–o* allomorph is only observed following high vowels, I analyze it as the result of a process of vowel height dissimilation. This analysis is supported by an absence of instances of consecutive high vowels in the data. This means that in order to avoid a sequence of two consecutive high vowels, Crow vowels will lower in height. This can be analyzed within the framework of OT by ranking a markedness constraint preventing

consecutive high vowels over the faithfulness constraint IDENT(height). This markedness constraint is NOCONSECHIGH.

- NOCONSECHIGH: No two consecutive vowels can both be high. Assign one violation mark for each domain of two adjacent vowels in which each vowel contains the feature [+high].

To put it more simply, the constraint NOCONSECHIGH causes height dissimilation by preventing adjacent high vowels. This constraint interacts with the faithfulness constraint IDENT(height).

(15) NOCONSECHIGH >> IDENT(height)

kuluu-o 'pile'

	/kuluu-uu/	NOCONSECHIGH	IDENT(height)
→	[kuluuo]		*
	[kuluuu]	*!	

This tableau shows that Crow vowels will lower in height to avoid instances of adjacent high vowels, a marked structure in Crow. This constraint is natural, as it prevents a sequence of three *u*'s. In most languages, it would be impossible to distinguish a three-*u* sequence from a bimoraic *uu*, since very few languages have three degrees of vowel length. This height dissimilation could also be motivated by more functional considerations. Lowering the plural marker to *–o* creates a contrast that allows the plural marker to be more easily distinguished from the preceding stem. In words ending with long vowels, the plural morpheme is shortened and in some cases the vowel is lowered.

Cases in which the plural marker attaches to a word ending in a short vowel are much more straightforward. In words ending with a short vowel, the short vowel is deleted and the plural morpheme surfaces faithfully as *–uu*. This deletion is motivated by *VV:. For example, a faithful output of the plural form *aaiwciuu*, meaning 'climbers' would violate *VV:. This means that some process must alter this word to prevent this violation. The fact that the stem-final short vowel is deleted and the plural morpheme is unchanged indicates that in Crow, it is better to delete a vowel than to change the length of a vowel. This is represented by the ranking of IDENT(μ) over MAX.

(16) IDENT(μ) >> MAX

aaciw-uu 'climber'

	/aaciwi-uu/ | | μ μ	*VV:	IDENT(μ)	MAX
→	[aaciwuu] | | μ μ			*
	[aaciwiu] | μ		*!	
	[aaciwiuu] | | μ μ	*!		

This tableau shows that in order to avoid violating *VV: Crow deletes the stem-final short vowel rather than shortening the long vowel of the plural marker. If we go back and apply this ranking to stems which end in long vowels, problems appear to emerge. In words like /biilaa-uu/ in (17), candidates emerge which challenge the ranking in (16):

(17) IDENT(μ) >> MAX ??

bilii-o 'door'

	/bilii-uu/ | | μ μ	*VV:	IDENT(μ)	MAX
	[biliio] | μ		*!	*
!!	[biluu] | | μ μ			**

This tableau would suggest that MAX outranks IDENT(μ), challenging the ranking IDENT(μ) >> MAX established in (16). Because of candidates like this this, it seems that a more specific parameterized version of MAX that is at work here. A way to solve this problem is by creating a more specific version of MAX which militates against deletion of long vowels. This constraint is MAX(V:).

- MAX(V:): Bimoraic vowels are not deleted. Assign one violation mark for every bimoraic input vowel with no corresponding output segment.

(18) MAX(V:) >> IDENT(μ) >> MAX.

bilii-o 'door'

	/bilii-uu/ | | μ μ	MAX(V:)	IDENT(μ)	MAX
	[biluu] | | μ μ	*!		(*)*
→	[biliio] | μ		*	*

This tableau shows that in Crow, while it is better to delete a vowel than change the height of a vowel, this generalization does not extend to the deletion of long vowels. This confirms that the initial ranking IDENT(μ) >> MAX is accurate, but the constraint MAX(V:) outranks IDENT(μ). MAX(V:) is undominated in this data.

These rankings thus far have shown that when stems end in a long or short vowel (i.e. non-diphthong) the main motivation for alternations is avoiding instances of post-vocalic long vowels. This avoidance causes shortening in cases with a stem-final long vowel and deletion in cases with a stem-final short vowel. Additionally, sequences of consecutive high vowels are avoided through height dissimilation. The plural formation constraint hierarchy up to this point is as follows:

(19) Plural formation constraint hierarchy

*VV:, NOCONSECHIGH

||

IDENT(μ) , IDENT(height)

||

MAX

*VV: and NOCONSECHIGH are undominated while IDENT(μ) and IDENT(height) are not ranked with respect to one another. In some cases of pluralization, deletion of the plural marker altogether would produce the most optimal form given the analysis thus far. The constraint Realize(morpheme) prevents these cases from surfacing without the plural marker.

- Realize(morpheme) : some segmental material must surface for each morpheme. Assign one violation mark for every input morpheme which is not represented by some segmental output material (Kurisu 2001).

This constraint outranks the faithfulness constraint IDENT(μ).

(20) Realize(morpheme) >> IDENT(μ)

kulaau 'pile'

	/kulaa-uu/	*VV:	Realize(morpheme)	IDENT(μ)
→	.ku.laa.uu.	*!		
	.ku.laa.u.			*
	.ku.laa.		*!	

This ranking shows that in order to the marked structure VV:, Crow shortens the marked long vowel rather than deleting the entire morpheme. This is very intuitive as outright deletion of the plural marker would result in a plural form which is identical to the singular (Kurisu 2001).

Cases in which diphthongs are word-final in the singular also require special attention. Diphthongs found in Crow are *iiə* and *uuə*, which are comprised of bimoraic high vowels followed by a schwa off-glide. When words ending in these diphthongs are pluralized, the resulting forms end in [–iio] and [–uuo] respectively. These alternations mirror those that are found in singular words ending in *–ii* and *–uu*. The only difference is the schwa off-glide, which is deleted between the input and output (e.g. /duuə-uu/ →[duuo]). This leads to the conclusion that the constraint MAX is outranked by some markedness constraint which prohibits vowels after diphthongs or schwa-off glides. I will represent this markedness constraint *VəV.

- *VəV : schwas do not appear between vowels. Assign one violation mark for every intervocalic schwa.

(21) *VəV >> MAX

axuuo ‘bodies’

	/axuuə-uu/	*VəV	MAX
	[axuuəu]	*!	
→	[axuuo]		*

In this ranking tableau, I have assumed the other constraints already presented. This ranking shows that deletion occurs to avoid intervocalic diphthong endings.

These rankings produce the following overall ranking, which sufficiently account for the alternations observed in this data:

(22) Crow pluralization summary tableau

biliio ‘door’

	/biliiə-uu/	*VV:	NOCONSEC HIGH	Realize	*VəV	MAX(V:)	ID(μ)	ID(height)	MAX
	[biliiəuu]	*!			*				
	[biliiəu]				*!		*		
	[biliiuu]	*!	*						*
	[biliiu]		*!				*		*
→	[biliio]						*	*	*
	[biliiə]			*!		*			(*)
	[biluu]					*!			(*)

Considering these constraints and this ranking, we are left with the following hierarchy:

(23) Constraint hierarchy for vowel sequence restrictions

*VV:, NoConsecHigh, Realize(morpheme), *VəV, Max(V:)

||

Ident(μ), Ident(height)

||

Max

V. Phrase-final vowel sequences

As we have seen in (III), only particular single vowel structures are allowed in Crow phrase-finally. After examining Crow vowel sequence restrictions through an analysis of plural formation, it is clear that there are more complex vowel sequences present in Crow than just the single vowel phrase endings which were initially analyzed. When the plural marker is found phrase-finally, the lengthening, neutralization and diphthongization constraints described in (III) come into conflict with the plural formation constraints discussed in (IV).

(24) Phrase-final vs. phrase internal plural forms

(24a) No change

phrase-internal	phrase-final	
duuxaau	*duuxaau*	'spread out'
iio	*iio*	'mouths'
iio	*iio*	'wear'
duuo	*duuo*	'lift up'
chiio	*chiio*	'packs'
kuluuo	*kuluuo*	'piled up'
biilaau	*biilaau*	'geese'
akbinnawoou	*akbinnawoou*	'scientists'
axuuo	*axuuo*	'body'
biliio	*biliio*	'door'

(24b) Diphthongization

phrase-internal	*phrase-final*	
baluu	*baluuə*	'woods'
baaluu	*baaluuə*	'beads'
aaciwuu	*aaciwuuə*	'climb'
apusuu	*apusuuə*	'cut through'
alaxuu	*alaxuuə*	'fried'
aliisuu	*aliisuuə*	'hungry'

These data shows that when vowel sequences are in phrase-final position, they appear to be largely unaffected by the rules in (III). The endings remain the same, with the exception of phrase-final high long vowels, on which diphthongization is still observed. For the remaining vowel endings, interaction between phrase-final constraints and vowel sequence constraints are observed. For example in words ending with the *–o* or *–u* plural morphemes, vowel lengthening fails to take place. An example can be seen in the word for geese *'biilaau'* which is observed as such in the output both phrase-internally and phrase-finally. Under the analysis of phrase-final single vowel endings, the phrase final *–u* in this word would be lengthened. This phrase-final lengthening does not take place. Instead, the vowel is observed as monomoraic in the output, indicating that the phonotactic restriction preventing post-vocalic long vowels in Crow takes precedence over the restriction requiring final vowels to be bimoraic. No new constraints are needed to account for this observation. The existence of this monomoraic vowel phrase-finally in the output indicates that FINALLENGTHV, undominated for single vowel endings, is crucially outranked by *VV:, which prohibits consecutive long vowels. This generalization is represented by the constraint ranking seen below.

(25) *VV: >> FINALLENGTHV

biilaau 'geese'

	/biilaa-uu/	*VV:	FINALLENGTHV
	[biilaauu]$_{phrase}$		*
→	[biilaau]$_{phrase}$	*!	

This tableau shows that when a monomoraic final vowel is preceded by another vowel, final lengthening is blocked by the undominated phonotactic constraint *VV:.

The existence of peripheral vowels phrase-finally also poses a problem for the phrase-final constraints proposed in (III). The data in (24a) show that there are multiple cases in which high vowels appear phrase-finally in the output. This observation contradicts the ranking of NOFINALPERIPH over IDENT(height) seen in (7).

(26) NOFINALPERIPH >> IDENT(height)

biilaau 'geese'

	/biilaa-uu/	NOFINALPERIPH	IDENT(height)
	[biilaau]$_{phrase}$	*!	
!!	[biilaao]$_{phrase}$		*

This tableau shows that the ranking of NOFINALPERIPH over IDENT(height) fails to account for the phrase-final peripheral vowels seen in the output for two vowel phrase-final sequences.

These final vowels suggest a more specific constraint which only prohibits phrase-final peripheral vowels which are also bimoraic, NOFINALPERIPH(μμ):

- NOFINALPERIPH(μμ): Bimoraic peripheral vowels are not found phrase-finally. Assign one violation mark for each bimoraic phrase-final vowel with a positive value for [hi] or [low]

(27) NOFINALPERIPH(μμ) >> IDENT(height)

biilaau 'geese'

	/biilaa-uu/	NOFINALPERIPH(μμ)	IDENT(height)
→	[biilaau]$_{phrase}$		
	[biilaao]$_{phrase}$		*!

This tableau shows that phrase-final monomoraic vowels are not targeted by NoFinalPeriph(μμ) and thus do not undergo the process of neutralization. This reformulation does not interfere with the single sequence phrase-final restrictions discussed in (III), as the only vowels which were targeted by the original NOFINALPERIPH were bimoraic due to simultaneously occurring final lengthening. This explains why the monomoraic final vowels, which exist in the output due to *VV: >> FINALLENGTHV, avoid neutralization. This is a counter-feeding relationship, as the restriction on postvocalic long vowels prevents NOFINALPERIPH from being able to target the phrase-final plural allomorph. This hypothesis is supported by the *–uu* plural allomorph. Using the word for 'wood' as an example, we can clearly this:

sg. phrase-internal	sg. phrase-final	pl. phrase-internal	pl. phrase-final
bala	*balee*	*baluu*	*baluuə*

Vowel sequence restrictions cause the deletion of the stem final *–a* in the plural form, resulting in a single vowel *–uu* sequence. When phrase-final, this ending undergoes diphthongization, as expected according to the phrase-final single vowel restrictions seen in (III).

Aside from the reformulation of NOFINALPERIPH, no new constraints are needed to account for the interaction between phrase-final single vowel restrictions and vowel sequence restrictions. The conflict arises from the contrasting nature of each set of restrictions. Phrase-final restrictions cause vowels to lengthen and vowel height to neutralize, while vowel sequence restrictions cause vowels to shorten and undergo vowel height dissimilation. When vowel sequences occur phrase-finally, it is not surprising that there is interaction between these two distinct sets of restrictions and processes. It is clear from the data in (24) that the sequence restrictions take precedence over the phrase-final restrictions. Phrase-final lengthening fails occur as it would cause a marked vowel sequence. Bimoraic height neutralization, which is fed in single vowel endings by lengthening, is counter-fed due to the fact that the necessary lengthening does not occur.

VI. Conclusions

When analyzed separately, Crow phrase-ending and vowel sequence restrictions appear to be straightforward if slightly complex problems for OT. When vowel sequences are phrase-final, the value of OT as a theoretical framework for phonological analysis is made clear. As seen in (III), Crow has particular restrictions for which vowels can appear phrase-finally. These restrictions cause final lengthening, which then feeds the process of neutralization which only targets bimoraic vowels. Additionally, diphthongization is observed as an alternate means of avoiding marked structures phrase-finally. This means that monomoraic vowels are not

observed phrase-finally when phrases end in a single vowel sequence. This picture of phrase-final endings is complicated when multiple vowel sequences, caused by attachment of the plural morpheme, are found phrase-finally. In these cases diphthongization is still observed, but restrictions on vowel sequences which outrank phrase-final restrictions cause a monomoraic vowel to appear phrase-finally in the output. The restriction against post-vocalic long vowels causes monomeric vowels to appear phrase-finally which are immune to the lengthening and neutralization observed in single vowel phrase-final endings. These interactions provide insight into the phonotactics of the Crow language. Final lengthening and neutralization, processes observed in many languages, are generally seen in Crow. The cases in which these processes fail to occur are those in which the result would be structures which are phonotactically prohibited in all circumstances.

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