Quality-sensitive stress

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In this paper we examine several languages in which stress is attracted to the most prominent vowel in a disyllabic or unbounded domain where prominence is determined by the quality of the syllabic nucleus. Two factors are distinguished: lower vowels are more prominent than higher vowels and peripheral vowels are more prominent than central vowels. Our analysis is couched in terms of Optimality Theory as this model perspicuously expresses resolution of the competing forces that determine stress location in the systems studied here.*

1. Introduction

Quantity-sensitivity is a well-known parameter in the typology of stress. In a [–QS] system, stress is typically determined by the odd/even location of a syllable with respect to the left or right edge of the word. In [+QS] languages, the weight of the syllable must also be considered, with heavy syllables typically attracting stress over and above their odd/even position. We can distinguish two subtypes: in bounded systems stress is confined to a two or three syllable window while in unbounded systems stress is attracted to a heavy syllable regardless of its distance from the edge of the word. In both the [+QS] and [–QS] systems, the quality of the syllabic nucleus does not typically play a role: it is simply the presence or absence of a nucleus and the presence or absence of a second mora that is the determining factor (though which consonants count as moraic may depend on feature structure – see Zec (1995) for recent discussion). Distinctions in vowel quality are more commonly known to figure into prosody in determining where the syllabic nucleus falls in a sequence of vowels. For example, in his recent discussion of Tahitian Bickmore (1995) demonstrates that two successive vowels form a tautosyllabic diphthong provided that the first is lower than the second.

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(1)

	$V_1 > V_2$			$V_1 < V_2$	
	a > i,u	pa.ráu	'speak'	ti.á.re	'flower'
		ʔa.ʔái	'story'	fe.pu.á.re	'February'
		tà:.táu.ro	'cross'	me.tú.a	'parent'
	a > e,o	ma.háe	'torn'	te.á.ta	'theater'
		máo.ro	'long'	mo.á.na	'ocean'
	e,o > i,u	ho.rói	'wash'	ʔi.ó.re	'rat'
		fà:.re.réi	'meet'	hu.é.ro	'egg'
				ma.tí.e	'green'

As Bickmore shows, this syllabification is crucial to the location of stress (which falls within a two-syllable window at the right edge of the word on the rightmost heavy syllable and otherwise on the penult).

Our primary goal in this paper is to document cases in which vowel quality plays a comparable role in determining the location of stress. Specifically, we show that in several diverse languages stress seeks out the most optimal vowel as determined by the hierarchies in (2).

(2) a. a, ä > e, o > i, u
b. a, ä, e, o, i, u > ə

That is, lower vowels are more optimal stress-bearing units than higher vowels (2a) and peripheral vowels are more optimal than central vowels (2b). Secondly, we argue that with its key idea of ranked and violable constraints, Optimality Theory (Prince & Smolensky 1993) provides a particularly perspicuous way to express this preference hierarchy.

In order to extend the OT model to the systems we consider here, several proposals are made. First, the Peak-Prominence constraint Prince & Smolensky (1993) develop for quantitative distinctions in Hindi stress is extended to the vocalic distinctions in (2). Second, comparable to the Prince & Smolensky (1993) analysis of Berber syllabification, the Peak-Prominence constraint is broken down into a set of micro constraints for each level in the hierarchy. It is demonstrated how these constraints can be interleaved with constraints that orient prominence with respect to the edges of the word. We also show that evaluation in terms of the prominence hierarchy must proceed in a "worst-to-best" fashion rather than "best-to-worst". Finally, in order to express the two opposing edge orientations in languages such as Mari (Cheremis), it is suggested that the scale in (2b) also optimizes the trough (nonpeak) portions of metrical constituents.

This application of the scale parallels the margin constraints in the Prince & Smolensky (1993) analysis of Berber syllabification.

The rest of this paper is organized as follows. First, we review the basic features of the OT model that will be relevant to our discussion. We then examine three bounded stress systems in which the peak of the prosodic word lands on the most prominent vowel inside a disyllabic window at the right (Kobon, Chukchee) or the left (Aljutor) edge of the word. In the next section, the analysis is extended to unbounded systems found in Mordwin and Mari (Cheremis). The paper concludes with some speculations as to the phonetic basis of the prominence hierarchies in (2).

2. *Preliminaries*

We begin by briefly reviewing the basics of the OT model (Prince & Smolensky 1993) and the metrical parsing constraints that form the background of our discussion. In OT, input is matched with output via two functions. For any input, a function GEN(erate) constructs a large pool of candidate structures – large enough to encompass the output in any possible language. The correct output is found by a function EVAL(uate) which imposes a language-particular ordering on a fixed set of UG constraints. The constraints sift through the pool of candidates eliminating all but one, which is defined as the output for the given input. Many of the constraints represent conflicting forces that pull the input in divergent directions expressing the intuition that phonological systems possess an inherent dynamism. Individual grammars resolve this tension in their own characteristic ways, modeled as differing prioritizations of the fixed set of constraints. A major objective of the OT program is to express typological distinctions as different constraint rankings. Through its key notion of constraint conflict, the OT model can impose crosslinguistically different outputs for essentially equivalent inputs and thus more readily come to terms with the undeniable variability found in phonology that has stymied previous constraint-based models. On the other hand, to the extent that the variability can be expressed in terms of a fixed set of constraints, OT offers a more restricted view of phonological structure than (unparametrized) rule-based systems which allow greater latitude in mapping from input to output.

In all of the languages we look at here, there is just a single stress per word. We will assume that even in these cases stress is metrical in nature – i.e. it reflects the head of a prosodic constituent – the metrical foot (Liberman 1975). Let us first consider bounded systems. The constraints in (3) (from McCarthy & Prince 1993) are relevant in optimizing bounded systems.

(3) Foot-Binarity (Ft-Bin): A foot is binary at the syllabic or moraic level.
Align (Ft, L, PW, L): The left edge of every foot coincides with the left edge of the prosodic word.
Align (Ft, R, PW, R): The right edge of every foot coincides with the right edge of the prosodic word.
Parse-s: Syllables are parsed into feet.

These constraints conflict with one another. This point can be seen by examining the table in (4) showing how they evaluate potential metrical parses of a generic five-syllable word.[1]

(4)

/sssss/	Ft-Bin	Align-Ft-R	Align-Ft-L	Parse-s
a. sss(ss)			#sss	***
b. (ss)sss		sss#		***
c. (sssss)	***			
d. (ss)s(ss)		sss#	#sss	*

The first candidate sss(ss) satisfies binarity and rightward alignment but violates leftward alignment (indicated by the number of syllables that intervene between the left edge of the word and the left edge of the foot). It also has three unparsed syllables and hence violates Parse-s three times. The symmetric (ss)sss shows a comparable violation of rightward alignment. The unbounded foot (sssss) satisfies both alignment constraints; but because it groups five syllables in a single foot it violates binarity three times. Finally, (ss)s(ss) satisfies binarity and has fewer Parse-s violations; but because it has more than one foot, it necessarily incurs greater alignment violations. The table (4) illustrates the basic premise of OT that no output is perfect: since the constraints conflict it is impossible to satisfy all of them simultaneously. Rather, the output is determined by finding the most optimal candidate. Optimality is determined by prioritizing the constraints so that they will eliminate competing candidates in such a way that the last one remaining is defined as the output. For example, in a language with a bounded foot at the right edge the (sssss) candidate can be eliminated by evaluating for binarity before evaluating for Parse-s (Ft-Bin >> Parse-s). The remaining (ss)sss and (ss)s(ss) candidates will be eliminated if evaluation for right-edge alignment takes precedence over left-edge alignment (Align-FT-R >> Align-Ft-L). The crucial constraint rankings for this grammar are listed in (5).

(5) Ft-Bin >> Parse-s
Align-Ft-R >> Align-Ft-L

The tableau in (6) shows how this constraint ranking maps the /sssss/ input to the sss(ss) output. The $ designates the winning (most optimal) candidate – the output. The exclamation point '!' indicates when a candidate is eliminated from the competition. A vertical line denotes a crucial ranking. These tableaux function like truth tables in propositional logic and are the OT equivalent of a derivation showing how the grammar maps a given input into the correct output.

(6)

/sssss/	Ft-Bin	Align-Ft-R	Align-Ft-L	Parse-s
a. $sss(ss)			#sss	***
b. (ss)sss		s!ss#		***
c. (sssss)	*!**			
c. (ss)s(ss)		s!ss#	#sss	*

It should be easy to see that a language with a single binary foot at the left edge of the word arises from changing the ranking between Align-Ft-R and Align-Ft-L to Align-Ft-L >> Align-Ft-R.

Finally, unbounded stress systems arise when Foot-Binarity is subordinated to Parse-s and one of the alignment constraints anchoring the foot at the edge of the word; the foot will expand in unbounded fashion taking in more syllables in order that its head fall on a vowel with inherent prominence.

In the more familiar languages studied in the metrical literature, the head of the metrical constituent is consistently found at its left or right edge in virtue of the constraints in (7).

(7) Head-Right: Align (Ft,R,'s,R): The right edge of the foot coincides with a stressed syllable
Head-Left: Align (Ft,L,'s,L): The left edge of the foot coincides with a stressed syllable.

In the languages we study here, stress seeks out the most prominent vowel in terms of the prominence hierarchies lower > higher and peripheral > central. Consequently, a constraint orienting stress in terms of this hierarchy (dubbed Peak-Prominence after Prince & Smolensky 1993) must dominate Head-R/L. We claim that the prominence hierarchy formally parallels the more familiar sonority hierarchy in syllabification. Just as more sonorous phonemes make better syllable peaks (nuclei) and less sonorous phonemes make better syllable margins (i.e. onsets and codas) so lower/peripheral vowels make better peaks in the stress wave while higher/centralized vowels make better troughs. Prince & Smolensky (1993:127-67) formalize this phenomenon as the "alignment" of two separate UG prominence scales: in the case of syllables, the Sonority Scale for phonemes a > e, o > i, u > ə > .... > p,t,k and the Peak > Margin (a.k.a. Nucleus > Onset, Coda) for syllables. A one-to-one alignment of the two scales generates the harmonic relations of (8) that grade phonemes for their suitability as syllable peaks and margins.

(8) PEAK$_{\text{SYLL}}$ a > e, o > i, u > ..... > p, t, k
MARGIN$_{\text{SYLL}}$ p, t, k > ..... > i, u > e, o > a

Prince & Smolensky derive the scales in (8) by deploying the alignment as the series of micro constraints in (9) that evaluate candidate syllable peaks and margins from "worst to best". Under worst-to-best evaluation, candidates that are least optimal are eliminated before more optimal ones are assessed.

(9) PEAK PROMINENCE
*P/p, t, k >> ..... >> *P/i, u >> *P/e, o >> *P/a

MARGIN PROMINENCE
*M/a >> *M/e, o >> *M/i, u >> .... >> *M/p, t, k

Casting the role of sonority in this way has two effects: first, each step in the scale is a separate constraint that can be evaluated in a binary yes/no fashion. More importantly, other constraints can be interleaved inside the sonority hierarchy.

In this paper, we demonstrate the existence of languages whose metrical stress is defined through the alignment of the prominence scales lower > higher and peripheral > central of (2) with the Peak > Trough scale for metrical feet. The result is the grading of vocalic nuclei as optimal peaks and troughs of the stress "wave" (10a). These hierarchies are derived from the constraint rankings in (10b) whose order is fixed by UG and cannot be reversed by individual grammars.

(10) a. PEAK$_{\text{FOOT}}$ a, ä > e, o > i, u
a, ä, e, o, i, u > ə
TROUGH$_{\text{FOOT}}$ i, u > e, o > a, ä
ə > i, u, e, o, a, ä

b. *P/i, u >> *P/e, o >> *P/a, ä

*P/ə >> *P/i, u, e, o, a, ä
*T/a, ä >> *T/e, o >> *T/i, u
*T/a, ä, e, o, i, u >> *T/ə

3. *Bounded Quality-Sensitive systems*

In this section, we examine languages in which the word stress is located on the most prominent vowel in a disyllabic window at the right or the left edge of the prosodic word. These systems thus have the Ft-Bin >> Align-FT-L/R >> Parse-s ranking schema from (4) that confines the peak of the prosodic word to this narrow window. The Peak-Prominence hierarchy rises above Head-R/L in the constraint hierarchy to situate the stress over the most prominent vowel inside the window. In the case of syllables with equivalent prominence, lower-ranked Head-R or Head-L then resolves the ties.

3.1. Kobon

The Kobon language of Papua New Guinea (Davies 1981) discriminates among its vowels in a particularly granulated way for purposes of stress placement.[2] The phonemic inventory of Kobon is composed of the familiar vowel triangle distinguishing low, mid, and high vowels supplemented with a pair of unrounded central vowels. Also, the low vowel [a] combines with a following high vowel [i] or [u] to form diphthongs.

(11)	i		ɨ		u
		e	ə	o	
			a		

Unaffixed word's stress is restricted to one of the final two syllables, seeking out the most prominent nucleus in this disyllabic window. The data in (12) illustrate this point. We depart from Davies' transcriptions by utilizing schwa for the mid central unrounded vowel.

(12)	a > e	hagápe	'blood' [226]
		gáłe#gáłe	'to cry, of pig' [225]
	a > o	alágo	'snake species' [226]
		kɨdolmáɴ	'arrow type' [226]
	a > i	ki.á	'tree species' [220]
	a > i	háu.i	'vine species' [221]
	a > u	ái.ud	'story' [221]

a > ɨ	áñɨm#áñɨm	'to lightening' [225]
a > ə	wái.əN	'cassowary' [221]
	ái.ən	'witch' [221]
o > u	mó.u	'thus' [220]
o > i	si.óg	'bird species' [221]
o > ɨ	gɨró#gɨró	'to "talk" - of mother pig to piglet' [225]
i > ə	gaɫínəN	'bird species' [226]
	wí.ər	'mango tree' [221]
u > ə	ɫú.əɫ	'horizontal house timbers' [221]
u > ɨ	mú.ɨs	'edible fungus species' [221]
ə > ɨ	gɨsə́#gɨsə́	'to tap' [225].

When both vowels in the foot have equivalent prominence (13), stress lands on the penult, suggesting that Head-Left dominates Head-Right[3].

(13) u ≈ u dúbu#dúbu 'to make noise by footsteps' [225]
i ≈ u jínup#jínup 'to make squeaking noise, bird, rat' [225]
ɨ ≈ ɨ kɨjɨ́gɨl 'tattoo' [226].

While Davies' statement of the stress generalizations is tentative, it seems clear that for the data we do have, the postulated prominence hierarchy in (14a) is playing a decisive role.[4] This suggests that the Kobon vowel system is first sorted in terms of peripheral vs. central (14b) and then in terms of height (14c). We consider a vowel "central" if it is bounded on either side of the vowel triangle by another vowel: thus, schwa is bounded by [e] and [o], and [ɨ] is bounded by [i] and [u].

(14) a. *P/ɨ >> *P/ə >> *P/i, u >> *P/e, o >> *P/a >> Head-L >> Head-R
b. a, e, o, i, u > ə, ɨ
c. a > e, o > i, u > ə > ɨ

In Kobon, the entire Peak-Prominence constraint rises above the constraint that orients stress laterally in the foot as a left-headed trochee. Let us examine a few tableaux to show how the analysis works. A form such as *gaɫínəN* shows that the search for a more prominent vowel is confined to a disyllabic window at the right edge of the word. This follows if Ft-Bin and Align-Ft-Right right dominate the Peak-Prominence package of constraints.

(15)

/gaɬinəN/	Ft-Bin	Al-Ft	*P/ɨ	*P/ə	*P/i,u	*P/e,o	*P/a	Head-L
a. ('ss)s		s#!					*	
b. ('sss)	*!						*	
c. $s('ss)					*			
d. s(s's)				*!				*

In (16), the first two cases show where Peak Prominence seeks out the most prominent vowel before Head-L gets a chance to stress the penult. Thus in *si.óg* the *P/i,u constraint eliminates the ('ss) candidate before *P/e,o assesses its violation against (s's). The latter is the only candidate left and so is declared the output even though it violates the lower-ranking Head-Left constraint. The latter comes into play when the various Peak-Prominence constraints fail to make a decision, as in such forms as *jínup* where the vowels have equivalent inherent prominence. Here each candidate is assessed a violation by *P/i,u and so the decision is passed on to Head-Left which resolves the tie in favor of penultimate stress.

(16)

/mo.u/	*P/ɨ	*P/ə	*P/i, u	*P/e, o	*P/a	Head-L
a. $('ss)				*		
b. (s's)			*!			*

/si.og/	*P/ɨ	*P/ə	*P/i, u	*P/e, o	*P/a	Head-L
a. ('ss)			*!			
b. $(s's)				*		*

/jinup/	*P/ɨ	*P/ə	*P/i, u	*P/e, o	*P/a	Head-L
a. $('ss)			*			
b. (s's)			*			*!

3.2. Chukchee

Like Kobon, the Paleo-Siberian language Chukchee exhibits a quality-based gradation among its vowels in their willingness to bear stress. The Chukchee hierarchy distinguishes nonhigh vowels from high vowels and schwa from the rest and thus discriminates its vowels in terms of both peripherality and height. Our data come from the chapter on stress in Skorik's grammar (1961:67-71) and from Krause (1979).

We first survey the generalizations governing stress as set out by Skorik, putting schwa to the side. A basic limitation is that stress is bound to the base – it never appears on an inflectional suffix (17).

(17) a. *pójg-a* 'spear' erg. [67], *wə́kw-a* 'stone' erg. [67], *íw-ək* 'to say' [68] *winrét-ək* 'help' Infin, *winrét-ərkən* 3sg., *winrét-ərkənitək* 2pl. [68]

b. *jará-ɴə* 'house' [68], *weló-lgən* 'ear' [68], *ekwét-ək* 'to send' [68], *wiríɴ-ək* 'to defend' [68], *reqoká-lgən* 'sand' [68], *migcirét-ək* 'to work' [68].

The location of stress within the base is governed by the following factors. When the final syllable of the base is not the final syllable of the word (i.e. when one or more syllabic suffixes follow), then stress is located on the final syllable of the base. However, when there is no suffix (e.g. one of the allomorphs of the absolutive sg.) or the suffix lacks a vowel, then stress is retracted from the final syllable of the base (18).

(18)

abs.sg.		*abs.pl.*
tití-ɴə	'needle'	títi-t [69]
qorá-ɴə	'reindeer'	qóra-t
melotá-lgən	'rabbit'	milúte-t[5]
rícit	'belt'	ricít-ti
wárat	'people'	warát-te
játjol	'fox'	jatjól-te
jéjwel	'orphan'	jejwél-ti

The plural suffix /-ti/ apocopates its vowel unless the base ends in a coronal to produce an apparent shift of stress from left to right (e.g. *rícit, ricít-ti*) or from right to left (e.g. *qorá-ɴə, qóra-t*) in singular-plural pairs.

The data introduced so far indicate that certain constraints are active in Chukchee. First, there is an undominated alignment constraint optimizing candidates in which the right edge of the base coincides with the right edge of a binary foot: Align-Base-Rt, Ft-Bin >> Parse-s. This constituent is right-headed (iambic) but an overriding constraint of Nonfinality (Hung 1994) blocks candidates with stress on the word-final syllable to choose outputs with a retracted (trochaic) stress: Nonfinality >> Head-R.

(19)

/milute+t/	Align-Base-Rt	Nonfin	Head-R
a. $ s('ss)			*
b. s(s's)		*!	
c. ('ss)s	*!		*

/ricit+ti/	Align-Base-Rt	Nonfin	Head-R
a. s('ss)	*!		*
b. ('ss)s			*!
c. $(s's)s			

Evidence for a prominence distinction among the vowels comes from cases (20a) in which the stress unexpectedly retracts from the final syllable of the base. They contrast with the examples in (20b) and indicate that stress will seek out a more prominent nonhigh vowel in the penultimate syllable of the base. In the nouns of (20), the absolutive sg. is marked by a reduplicative suffix that many disyllabic CVCV nouns take to protect themselves from apocope (Krause 1979).

(20)	a.	wéni-wen	'bell'	[68]
		céri-cer	'dirt'	
		kéli-kel	'paper'	
	b.	nuté-nut	'land'	
		piɴé-piɴ	'snowfall'	
		jilʔé-jil	'squirrel'	

These data indicate that the *P/i, u portion of the Peak-Prominence constraint dominates Head-R. Due to the regular rule of vowel harmony whereby [i] and [u] become [e] and [o] in words with [o] and [a] (Kenstowicz 1979), the stress prominence of the nonhigh vowels [o] and [a] with respect to the high vowels [i] and [u] unfortunately cannot be assessed. The tableaux in (21) show the role of Peak Prominence in forcing violations of Head-Right.

(21)

/keli+kel/	*P/i, u	Head-R
a. $('ss)s		*
b. (s's)s	*!	

/nute+nut/	*P/i,u	Head-R
a. ('ss)s	*!	*
b. $(s's)s		

However, attraction of stress to the more prominent mid vowel is always over-ridden by Nonfinality, as seen in the plurals *núte-t* and *píɴe-t* (Krause 1979:122). These forms indicate that Nonfinality dominates *P/i, u.

(22)

/nute+t/	Nonfinality	*P/i, u
a. $('ss)		*
b. (s's)	*!	

In (23), we summarize the constraint rankings of interest that have been introduced so far.

(23) Nonfinality >> *P/i,u >> Head-R >> Head-L

Let us now turn to the behavior of schwa. According to Skorik (1961:70), if the final syllable of the base has a schwa nucleus then stress is retracted to the preceding vowel (24a) unless the preceding vowel is also schwa, in which case stress remains on the final syllable of the base (24b).

(24) a.

pátgərg-ən	'hole'	[70]
pipíqəlg-ən	'mouse'	
tátləɴ-ək	'to answer'	
rócgəp-ək	'to enervate'	

b.

məcə́kw-ən	'shirt'
təlwə́lq-ən	'fire site'
rəkgə́t-ək	'to get stuck'
rəmə́t-ək	'to wash up'.

This behavior follows if the peripheral > central wing of the Peak-Prominence constraint (2b) splits off the schwa from the remaining vowels to make it the weakest in the hierarchy: *P/ə >> *P/i, u, e, o, a. Stress will retract from the final syllable of the base to a preceding stronger vowel (25a); but when the preceding syllable is also schwa (25b), then the two candidates tie on Peak-Prominence and the lower-ranked Head-R constraint decides in favor of stress on the final syllable of the base.

(25) a.

/pipigəlg+ən/	*P/ə	*P/i,u	Head-R
$s('ss)s		*	*
s(s's)s	*!		

b.

/rəmət+ək/	*P/ə	*P/i,u	Head-R
('ss)s	*		*!
$(s's)s	*		

There is, however, one respect in which the Chukchee schwa behaves differently from the other vowels in the prominence hierarchy. As shown by the forms in (26), when the penult is a schwa, the final syllable is stressed provided it is a stronger vowel. But when both the final and the penult are schwa, then the stress lands on the penult--as predicted by Nonfinality >> Head-R.

(26) a. ətlá 'mother' [K. 123]
lələ́-t 'eyes'
ʔəló 'day'
ənré 'a little, somewhat'
ʔənín 'your' [D. 43]
ʔənún 'middle'

b. ə́tləq 'tundra' [K. 124]
kə́tʔət 'sable'
ə́ttəm 'bone'
cə́mŋə 'old bull'.

Thus, in a form such as *lələ́-t* 'eyes' Peak-Prominence wins out over Nonfinality while in *núte-t* 'land pl.' Nonfinality wins out over Peak-Prominence. This contrast motivates breaking the Peak-Prominence constraint into the subhierarchies of (2a) and (2b). Nonfinality splits the hierarchy between *P/ə and *P/i, u

(27) *P/ə, >> Nonfinality >> *P/i, u.

The tableaux in (28) show the effect of ranking Nonfinality below *P/ə. In *ətlá* (28a), *P/ə, rejects the candidate with stress on the schwa, allowing the one with final stress to win. In *ə́tləq* (28b) the initially and finally stressed candidates tie at *P/ə, allowing the lower ranked Nonfinality to decide in favor of retracted stress. Finally, in *núte+t* (28c) both candidates tie on *P/ə, in virtue of lacking a schwa. Once again, lower ranked Nonfinality eliminates final stress in favor of retracted stress.

(28) a.

/ətla/	*P/ə,	Nonfin
('ss)	*!	
$(s's)	*	

b.

/ətləq/	*P/ə	Nonfin
$('ss)	*	
(s's)	*	*!

c.

/nute+t/	*P/ə	Nonfin
$('ss)		
(s's)		*!

The Chukchee data furnish an empirical argument that the Peak Prominence constraint must be evaluated from "worst to best". Consider the problems a "best-to-worst" scenario of (29) encounters.

(29) P/a >> P/e,o >> P/i,u >> P/ə

We assume that these constraints also evaluate stress over a vowel in a binary up or down fashion: i.e. P/a assesses a penality if stress does not fall on a low vowel. As shown by the schematic example in (30), the "best-to-worst" mode of evaluation also succeeds in isolating the most prominent vowel of the domain. Each of the three candidates fails the P/a constraint for lack of low vowel. P/e, o then passes the CiCéCəC candidate and fails any other that does not stress a mid vowel. It should be clear that "best-to-worst" evaluation homes in on the most prominent vowel in the domain.

(30)

/CiCeCəC/	P/a	P/e,o	P/i,u	P/ə
'sss	*	*!		*
$s'ss	*		*	*
ss's	*	*!	*	

Consider now the ranking of the Head-Right and Nonfinality constraints. To derive *pipíqəlg-ən*, Head-Right must be ranked below P/i, u. Any higher ranking would eliminate *pipíqəlg-ən* in favor of *pipiqə́lg-ən*. Similarly, in order to derive *Pənín* Nonfinality must rank below P/i,u. Any higher ranking would eliminate final stress and incorrectly generate a stress on the schwa.

(31)

/Pənín/	P/i, u	Nonfin	P/ə
('ss)	*!		
$(s's)		*	*

But if Nonfinality ranks below P/i,u then we cannot account for the retraction in *núte-t*.

(32)

/nute+t/	P/e, o	P/i, u	Nonfin
('ss)	*!		
*(s's)		*	*

Reranking Nonfinality ahead of P/e, o (Nonfinality >> P/e, o) derives *núte-t* correctly. But this constraint ordering then fails to generate *Pənín*.

(33)

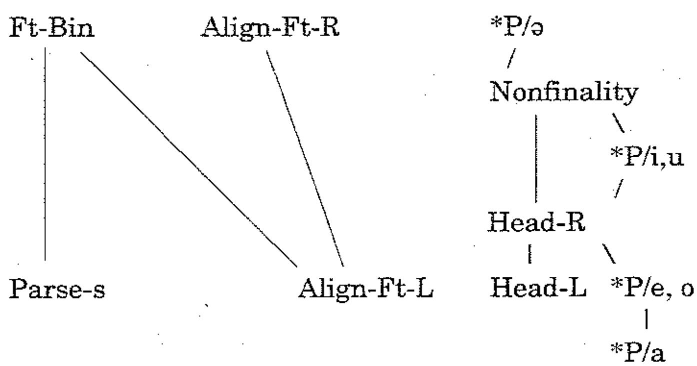
/nute+t/	Nonfin	P/e, o	P/i, u
$('ss)		*	
(s's)	*!		*

/Pənin/	Nonfin	P/e, o	P/i, u
*('ss)		*	*
(s's)	*!	*	

We thus have empirical evidence in favor of the "worst-to-best" evaluation scheme in Chukchee.

The diagram in (34) reviews the crucial rankings in our analysis; Head-Right >> *P/e,o is motivated by *jatjól-te* (18).

(34)



Let us summarize the crucial points of the discussion. First, Chukchee stress draws a three-way distinction in prominence among its vowels in their capacity to bear stress. This is captured by ranking the *P/i,u and *P/ə links of the Peak-Prominence constraint above Head-R. Second, the schwa behaves differently from the other vowels with respect to Nonfinality. This is explained by ranking *P/ə above Nonfinality. Thus, both the vowel height (2a) and the peripheral > central (2b) wings of the Peak Prominence constraint are active in Chukchee. Finally, Chukchee offers crucial empirical evidence for evaluating Peak Prominence from "worst to best" instead of "best to worst".

3.3. Aljutor

The stress system of Chukchee's sister language Aljutor differs in subtle ways that are perspicuously expressed in OT. Our data come from Kodzasov & Muravjova (1980).[6] In Aljutor, stress is rigidly restricted to the first two syllables of the word. It is phonetically realized as vowel lengthening in an open syllable and lengthening of the coda in a syllable closed by a consonant. We take the latter feature to indicate that stress aligns with the rightmost mora of the syllable in Aljutor. Like Chukchee, Aljutor stress tries to sidestep schwa; the language scrupulously avoids prominence on a light *Cə* syllable.

We set the stage by first considering nonschwa syllables. Here the generalizations are straightforward. In words of three or more syllables, the second syllable is stressed. Disyllabic words stress the initial syllable. Monosyllabic nonfunction words are not found.

(35)	quráNa	'reindeer'	[122]
	ʔaláʔal	'summer'	[105]
	ʔall'óʔəpaNa	'sweet soup'	[105]
	vitátək	'to work'	[122]
	navítatən	'he would work'	[122]
	ʔarNínati	'it rained'	[105]
	nutágitanaN	'binoculars'	[119]
	tátul	'fox'	[122]
	qápar	'wolverene'	[120]
	jánut	'today'	[121]
	ʔáNar	'star'	[122]
	ʔə́kul	'bedding, litter'	[122]
	wála	'knife'	[122].

These data indicate that Aljutor words contain a single binary foot that is preferably right-headed but may take the guise of a trochee in order to avoid final stress: in other words, Nonfinality >> Head-Right, just as in Chukchee. Aljutor differs from Chukchee in aligning its foot with the left edge of the word/base instead of the right: Align-Ft-Left >> Align-Ft-Right.

Let us now turn to the Aljutor schwa. Closed syllables with a schwa nucleus behave like ordinary syllables in every respect. They are regularly stressed when they form the second syllable of a trisyllabic or longer word: *vagə́lNən* 'nail' [122]; they accept initial stress in disyllables: *ʔə́ngam* 'worm' [104]; and they trigger retraction when final in disyllables: *ʔákək* 'son' [122]. (As indicated earlier, we take the phonetic lengthening of coda consonants to indicate that stress lands on the rightmost mora and so 'nail' and 'worm' are more accurately transcribed as [vagə̀lNən] and [ʔəńgam], respectively.[7]) Schwa stands out in Aljutor in that it never realizes prominence when it forms the nucleus of an open syllable. However, unlike in Indonesian (Cohn 1989), Aljutor's schwa is not simply invisible to metrical calculations. When occupying the second syllable of a trisyllabic or longer word, stress is regularly retracted to the initial syllable: *jíləjil* 'tongue' [122]; *tə́rgətər* 'meat' [122]; *táwəjatək* 'to feed' [112]. If schwa were simply invisible to metrical constraints we would expect stress on the third syllable of *táwəjatək* (i.e. **tawəjátək* instead of the correctly stressed *táwəjatək*). Similarly, when the initial syllable is *Cə* stress stops on the second syllable: *təgétatək* 'to tell' [113] not **təgetátək*. *Cə* syllables thus count like other syllables in defining the disyllabic window within which stress must be located. The avoidance of stressing a schwa rather reflects the *P/ə >> Head-Right constraint ranking. The tableau in (36) shows how the proposed analysis works.

(36)

/tawəjatək/	Ft-Bin	Align-Ft-L	*P/ə	Head-R
$('ss)ss				*
(s's)ss			*!	
(ss's)	*!			
s(s's)s		# s!		

We recall that when faced with /CəCV(C)/ words (V ≠ schwa), Chukchee avoids stressing the schwa and incurs a Nonfinality violation in the process: *ətlá* 'mother'. As shown by the data in (37), when Aljutor is faced with comparable structures it manages to satisfy both constraints by inserting a dummy CV syllable at the end of the word. This dummy is minimally specified by gemination of the preceding consonant to fill the onset and a schwa to fill the nucleus.

(37)	/pəHun/ →	pəHúnnə	'mushroom'	[122]
	/tənup/	tənúppə	'sopka'	
	/səgaj/	səgájjə	'sand'.	

Thus, Nonfinality is an undominated constraint in Aljutor. It is normally satisfied by retraction; but when this is not possible (due to top-ranking *P/ə), a final syllable is added at the price of a "Fill" violation (Prince & Smolensky 1993) that prohibits epenthesis. The tableau in (38) shows the effect of ranking Nonfinality above Fill. Reversing the ranking to Fill >> Nonfinality gives the CəCV́C Chukchee output.

(38)

/pəHun/	*P/ə	Nonfin	Fill
$(pəHún)nə			*
(pə́Hun)	*!		
(pəHún)		*!	

Since stress retraction is normally employed instead of augmentation, Fill must dominate Head-R. Otherwise, /tatul/ would be realized as *tatúllə* instead of *tátul* as shown in (39).

(39)

/tatul/	Nonfin	Fill	Head-R
$(tátul)			*
(talúl)lə		*!	

If augmentation is pressed into service only when retraction is blocked, there is just one additional case where we expect to find it – when the base is a monosyllable. Significantly, underlying monosyllables regularly augment as well.

(40)	/Naj/	→	Nájjə	'hill'	[122]
	/Nal/		Nállə	'herd'	
	/ʔal/		ʔállə	'no'	

As the tableau in (41) demonstrates, high ranking Nonfinality eliminates the monosyllable at the cost of a left-headed augmented structure with Fill violations.

(41)

/Nal/	Nonfin	Fill	Head-R
$(Nállə)		*	*
(Nál)	*!		

Finally, words beginning with two successive open *Cə* syllables have no stress according to Kodzasov & Muravjova (1980:124), who cite the examples in (42).

(42) nəkəkaqin 'hot' (cf. tətánəkəkavNən 'I will make it hot')
nəgətiNqin 'beautiful'
jərəNatək 'to stick'
gəməkəN 'to me' (cf. gə́mmə 'me' abs.)

We recall that when Chukchee was faced with a comparable situation (e.g. 26b), it stressed the schwa. Aljutor's high ranking *P/ə blocks prominence from surfacing inside the foot. Furthermore, *táwəjatək* 'to feed' [112] shows that foot binarity and strict alignment do not allow the foot to drift to the right to seek out a more suitable host for the prominence: Ft-Bin, Align-Ft-Left >> Head-Right. The tableau in (43) passes /nəkəkaqin/ through the constraint ranking we have established; the optimal candidate is the one which stresses neither of the initial two syllables.

(43)

/nəkəkaqin/	Ft-Bin	Align-Ft	*P/ə	Head-R
$(ss)ss				*
(s's)ss			*!	
('ss)ss			*!	*
(ss's)s	*!			
s(s's)s		#s!		

The constraint rankings in (44) summarize our analysis.

(44)
Ft-Bin Align-Ft-L *P/ə Nonfinality
Fill
Head-R
Parse-s Align-Ft-R Head-L *P/i,u
*P/e,o
*P/a

Aljutor is an interesting counterpoint to Chukchee showing the twists and turns that languages may take in order to avoid stressing a schwa – a phenomenon that the output-oriented OT model is well-suited to express.

4. Unbounded Peak-Prominence systems

In this section, we examine languages in which stress seeks out the most prominent vowel in the word regardless of how far it lies from the edge; we take our examples from two Finno-Ugric languages of the Volga region of Russia. In Mari (Cheremis), stress falls on the rightmost strong (peripheral) vowel of the word; in words composed of all weak (central) vowels, stress falls on the initial syllable. In Mordwin, the stress is oriented in the same direction in both cases: it lodges on the leftmost strong vowel and on the initial syllable in words with all weak vowels.

4.1. Mari

Mari distinguishes between a set of “strong” peripheral and “weak” centralized vowels with respect to their capacity to bear stress. The strong vowels include [a, ä, o, e, ö, u, i, ü] while the weak set is comprised of schwa and in certain dialects front and back round and unround variants of schwa transcribed here as [ᴜ, ᴜ̈, ɪ, ɨ]. In general, stress appears as far to the right as possible. But in words with all weak vowels, stress falls on the initial syllable. An overriding constraint of Nonfinality blocks final stress.

In Literary Mari (Gruzov 1960), the weak vowels are limited to schwa. According to Gruzov, a final open syllable is never stressed (see, however, below). Final closed syllables take the stress (unless their vowel is schwa). In words with only schwa vowels in nonfinal syllables, stress appears on the initial syllable.

(45)	ə́rəše	‘rotten’	[G.138]
	ə́ləžtəše	‘incendiary’	
	kə́čkərləše	‘tattler’	
	ə́štəktəšəže	‘find doing’.	
	áɴəšər	‘narrow’	[G.137]
	aɴəšəremáš	‘to narrow’	
	aɴəremdáš	‘narrows’	
	aɴəšəremdəmáš	‘narrowing’	

pə́ləš	'ear'	[G. 138]
pələšánəšte	'large-eared'	
pələšémən	'of my ear'	
kalasáš	'to say'	[G. 138]
kalásəšəm	'said'	
kalásəktəšəm	'find saying'	

To account for the absence of final stress, an undominated constraint of Nonfinality discards candidates that stress a vowel that is flush against the right edge of the word. The Peak-Prominence constraint *P/ə can be called upon to eliminate candidates that stress a schwa instead of a peripheral vowel. The problem is that words containing one or more peripheral vowels stress the rightmost one (*kalasáš*) while words composed entirely of (nonfinal) central vowels stress the leftmost one: *ə́ləžtəše*. The right or left-edge alignment constraints should then treat these cases identically predicting uniform leftward (ə*Á...; ə́ə*) or rightward (...Áə*; ə*ə́) stress orientation for words of both classes.

Our suggestion to deal with this problem is to take another lead from the Prince & Smolensky (1993) analysis of Berber. They show that not only is sonority relevant for the peak of the syllable; it also plays a role in optimizing syllable margins: the less sonorous the margin of the syllable the better. Accordingly, a family of margin constraints ordered from worst to best (46) is postulated (see Prince & Smolensky 1993 for details).

(46) *M/a >> *M/e,o >> *M/i,u >> *M/ə >> ... >> *M/p,t,k

Our proposal is that when the peripheral > central prominence scale for vowel quality is aligned with $\text{Peak}_{\text{foot}}$ > $\text{Trough}_{\text{foot}}$ it defines the constraints of (47) that optimize unstressed syllables of the foot in terms of their relative lack of prominence.

(47) *T/a, ä, e, o, i, u >> *T/ə

It is these Trough constraints (rather than Peak-Prominence) that are active in Mari and more generally in systems where stress appears to default to the opposite edge in weak-vowel words.[8] The intuitive idea is that a left-headed unbounded metrical constituent is anchored at the right edge of the word by Align-Ft-Rt. Align-Ft-Left will extend the foot towards the initial syllable but this will be inhibited if a peripheral vowel were to fall in the trough.[9]

The diagram in (48) shows the constraint rankings in the proposed analysis for the literary dialect.

(48)

Head-L	Align-Ft-R	Nonfinality	
Head-R		*T/A	(A = a, ä, e, o, i, u)
	Align-Ft-L		
	Ft-Binarity	*T/ə	

We get a sense for how the analysis works by considering words composed of more than a single peripheral vowel (49). The crucial ranking is *T/A >> Align-Ft-Left blocking the candidate that stresses a peripheral vowel that is not also the rightmost one (and hence includes another one in the trough).

(49)

/əAəAəə/	*T/A	Align-Ft-L
$əAə(Áəə)		#sss
ə(ÁəAəə)	*!	#s

But in words composed of just nonfinal schwa nuclei the foot is free to encompass the entire word and will do so to satisfy Align-Ft-Left (50).

(50)

/əəəəə/	*T/A	Align-Ft-L
$(ə́əəəə)		
ə(ə́əəə)		#s!

The Northwest Mari dialect described by Ivanov and Tužarov (1970) distinguishes front vs. back and round vs. nonround variants of the central (schwa-like) vowels (transcribed here as Ü vs. U and I vs. Ɨ). A second difference from the literary dialect is that Nonfinality is calculated at the syllable level so that both open and closed final syllables reject the stress (in contrast to the literary dialect where nonfinality is calculated at the segmental level). The upshot is that for this dialect stress falls on the penult (51a) unless the penult contains a central vowel in which case stress recedes to the closest peripheral vowel if one is available (51b) and otherwise stays on the penult (51c).

(51)	a.	jalúnto	'heel'	[89]
		šoráɴaš	'to get dirty'	
		roséta	'sprouts'	
		äšɨntäräš	'to remember'	
	b.	tɪgén'ɪkɪ	'such a'[89]	
		unálɨkeš	'as a guest'	
		šátsɨktaš	'to give birth'	
		kídɪštɪžɪ	'in his hand'	[90]
		pőrtɪštɪžɪ	'in his house'	[90]
	c.	íräš	'to heat up'	[38]
		kíškäš	'to throw'	[39]
		kúnam 'when'	[41]	
		mʊ́ro	'song'	
		küver	'bridge'	[43]
		vʏ̈tšer	'key'	

More interesting are words with more than a single central vowel in the nonfinal domain (52).

(52)	udʊ́rʊštaš	'to row	[90]
	ʏšʏ́kʏštö	'in shade'	
	šɪ́žɪšɪ ≈ šížɪšɪ	'autumnal'	[90]
	tɨ́lɨzɨ ≈ tɨlɨ́zɨ	'month'	
	tsɪtíräš ≈ tsítɪräš	'to shake' refl.	
	tʏtʊ́rä	'mist'	[90]
	tʊvʊ́rgaš	'to curdle'	
	mʊrʊ́ktʊlaš	'to thunder'	
	tʏ́dɨ	'he'	[88]
	šʏ́ldɨ	'cheaper'	
	*ú*rɨ	'handful'	
	kʊ́rʊk	'mountain'	[87]
	šʏ́dʏr	'axle'	

Here stress shifts to the second syllable (apparently obligatorily if rounded ʊ or ʏ and optionally if nonround ɪ or ɨ --a detail we overlook here) but not further: *udʊ́rʊštaš*. These data indicate that leftmost stress in the central vowel words is modulated by a Noninitial factor:

Noninitial >> Align-Ft-Left. But we must prevent Noninitial from affecting /Áə*/words such as *pö́rtɪštɪžɪ*. This is reminiscent of the phenomenon operating in Chukchee: stress moves away from the edge but fails to do so if the effect is to stress a weak central vowel instead of a strong peripheral one. We may achieve this effect for Mari if *P/ə dominates Noninitial (which in turn dominates Align-Ft-Left). The tableaux in (53) demonstrate how proper placement of the Noninitial constraint accounts for the shift of stress away from the left edge in this Mari dialect.

(53)

/pörtɪštɪžɪ/	*P/ə	Noninit	Align-Ft-L
$('ssss)		*	
s('sss)	*!		#s

/mʊrʊktʊlaš/	*P/ə	Noninit	Align-Ft-L
('ssss)	*	*!	
$s('sss)	*		#s
ss('ss)	*		#ss!

For inputs with an initial peripheral vowel such as *pö́rtɪštɪžɪ*, *P/ə eliminates candidates that stress a later syllable, leaving left-edge stress as the only survivor. In words with just nonfinal central vowels such as *mʊrʊ́ktʊlaš*, all candidates tie on *P/ə allowing the lower ranked Noninitial to eliminate initial stress. The Align-Ft-Left constraint then zeroes in on the candidate with peninitial stress.

The diagram in (54) summarizes the analysis for the Northwest dialect.

```
(54)  Head-L      Align-Ft-R      Nonfinality
        |                           /  \
      Head-R         *P/ə         *T/A (= *T/a, ä >>*T/e, o >>*T/i, u)
                      |
                  Noninitial
                      |
                  Align-Ft-L  \
                      |        \
                  Ft-Binarity   \
                                 *T/ə
```

This example shows that the Peak and Trough constraints can overlap and interact (i.e. *P/ə >> *T/ə)--another effect similar to the Prince & Smolensky (1993) analysis of Berber.

Our interpretation of the default to opposite edge phenomenon is based on the constraint *T/A barring peripheral vowels from the trough of the stress wave, and thus entails that metrical feet are unbounded in Mari. Some researchers (e.g. Hayes 1979, 1985) have viewed the Mari vowel harmony process affecting word-final vowels as defined in terms of the unbounded foot and hence as independent support for this metrical structure. Certain Mari dialects bar underlying schwas from absolute word-final position. The strengthened final schwa assimilates its place features from the preceding peripheral vowel which may lie a certain distance away: e.g. *tüɴəštö* 'at the bottom', *surt-əštə-žo* 'in his house', *kot-šə-žəm* 'the rest of it' (Hayes 1979:2). Since the rightmost nonfinal peripheral vowel is the seat of stress in Mari, it appears that the domain of harmony coincides with the metrical foot. However, C. Kisseberth (personal communication) points to certain Eastern dialects described by Beke (1961) in which the final harmonized vowel takes the word stress since on the surface it is the rightmost peripheral vowel. Evidently, these dialects downgrade the Nonfinality constraint. More importantly, they undercut the motivation for regarding the unbounded foot as the domain for harmony because the final vowel is stressed and hence presumably initiates a foot. It thus seems more accurate to say that the strengthened final vowel assimilates its place features from the closest available source--the rightmost preceding peripheral vowel--regardless of whether or not they lie in the same metrical constituent.

4.2. Mordwin

Mari's sister language Mordwin (Tsygankin & Debaev 1975) illustrates an unbounded system in which the stress of words with all weak vowels is oriented in the same direction as words composed of strong vowels or a mixture of strong and weak. In the Mokshan dialect, we find the vowel system of (55). Tsygankin & Debaev transcribe the Mordwin central vowel with a Russian yer; they describe this vowel as similar to the post-tonic vowel in such Russian words as *mólot* 'hammer' and *gólod* 'hunger' which are realized with a reduced vowel in Standard Russian. It is unclear whether this vowel should be treated as [+high] and thus transcribed as [ɨ] or as [–high] and thus as [ə]; for concreteness, we choose the former option.

(55)

i	ɨ	u
e		o
ä		a

According to Tsygankin & Debaev (1975:32-22), stress in the Mokshan dialect falls on the first (i.e. leftmost) "broad" vowel [e, ä, o, a]; if the word lacks such a vowel then stress is initial. In (56a) we show words composed of all "narrow" vowels [i, ɨ, u], while (56b) has words composed entirely of "broad" vowels. Each has initial stress. (56c) shows words that draw vowels from both sets. The stress falls on the leftmost [ä, a, e, o]. (56d) exemplifies alternations in the inflectional paradigm. Note that C' indicates a palatalized consonant.

(56) a. *púvɨndɨms* 'to press', *kíz'ɨfn'ɨms* 'to ask', *pɨ́s't'ɨrdɨms* 'to roll with the feet', *kúlit'i* 'in that ash'
b. *sǎr'äd'an* 'I ache', *rǎmasak* 'you buy it', kélas'kä 'fox', nóldasak 'you release it'
c. *sásɨndat* 'you arrive', *tɨrgádat* 'you fight', *tušɨndát* 'you go away', *tuc'ǎn'ä* 'cloud', *k'él'ɨpt'ɨms* 'to widen'
d. *pútɨms* 'to set down', *putát* 'you set down'; *m'íšɨn'd'ɨms* 'to sell', *m'išɨn'd'án* 'I sell'

Given the analysis developed for Mari, the Mordwin data can be characterized by saying that the Peak Prominence constraint is broken at the *P/i, ɨ, u >> *P/e, o link with *P/i, ɨ, u ranked above Align-Ft-Left. With this ranking, the head of the unbounded foot (i.e. the stressed syllable) moves away from the left edge of the word in order to avoid stressing a "narrow" vowel. The tableaux in (57) illustrate this analysis.

(57)

/tušɨndat/	*P/i, ɨ ,u	Align-Ft-L
('sss)	*!	
s('ss)	*!	#s
$ ss('s)		#ss

/puvɨndɨms/	*P/i,ɨ,u	Align-Ft-L
$('sss)	*	
s('ss)	*	#s!
ss('s)	*	#s!s

While Tsygankin & Debaev cite all-narrow words with a peripheral high vowel preceding the central vowel, their discussion includes no examples of the form CɨCi... or CɨCu... where a central vowel precedes a peripheral high vowel. They state (p. 16) that the central vowel seldom appears in the initial syllable. If *P/ɨ dominates *P/i,u then the candidate with initial stress will be eliminated first, forcing stress to move away from the edge.

(58)

/CɨCi.../	*P/ɨ	*P/i, u	Align-Ft-L
('ss...	*!		
s('s...		*	*

Assuming that Tsygankin & Debaev's statement that all-narrow words have initial stress holds in these cases as well, we would have to block this incorrect derivation. The simplest assumption would then be to treat the central vowel as [+high] (as perhaps implied by Tsygankin & Debaev's characterization of [i, ɨ, u] as "narrow" vowels). We have anticipated this point by transcribing the central vowel as [+high] [ɨ] rather than as [–high] [ə]. If this decision turns out to be correct and [ɨ] really is [+high] and still has a prominence level equivalent to the peripheral high vowels [i] and [u], then it would imply that languages can differ in terms of whether they divide the vowel space first in terms of height and then peripherality or first in terms of peripherality and then height.

One final point. According to Tsygankin & Debaev in the Erzyan dialect of Mordwin speakers either fail to distinguish any stress contours or assign uniform initial stress. For the latter, the difference with Mokshan is a simple reranking of Align-Ft-L above the entire Peak-Prominence family: in effect, aligning the left edge of the foot with the left edge of the word is more important than stressing a weak vowel.

5. Summary and conclusion

In this study, we have seen that stress may seek out the most prominent vowel in a domain. Two separate factors determine the prominence scales: height and peripherality. Depending on how these factors are prioritized with one another as well as with the alignment constraints that force stress to an edge, we derive different rankings. Let us briefly recapitulate how the prominence constraints partition the vowel inventories of the five languages examined in this paper.

Kobon shows the greatest resolution of the vowel space with a prominence constraint for every vowel ranked above edgeward orientation of stress. Recall that Kobon first partitions its vowels as peripheral {a, e, o, i, u} vs. central {ə, ɨ} and then for height: a > e, o > i, u > ə > ɨ.

(59) *P/ɨ >> *P/ə >> *P/i, u >> *P/e, o >> *P/a >> Head-Left

Chukchee also partitions for peripheral vs. central before grading its vowels for height. But unlike Kobon, it draws no prominence distinction between low and mid vowels. Also, Nonfinality slips between *P/ə and *P/i,u, breaking the Peak-Prominence chain at two points.

(60) *P/ə >> Nonfinality >> *P/i, u >> Head-Right, *P/e, o >> *P/a

Aljutor simply distinguishes schwa from the remaining vowels; its sorts for peripheral versus central but does not distinguish its vowels in terms of height in their capacity to bear stress.

(61) *P/ə >> Head-Right >> *P/i, u >> *P/e, o >> *P/a

Like Aljutor, Mari (Cheremis) also draws a minimal distinction between peripheral vs. central vowels but does not distinguish them in terms of height. However, the distinction is relevant for the trough of the stress wave rather than the peak.

(62) *T/a, ä >> *T/e, o >> *T/i, u >> Align-Ft-Left >> *T/ə

Finally, if we are correct in our speculation that the Mordwin central vowel is [+high], then this language must sort its vowels for height before sorting for peripherality. This allows the central vowel to join the ranks of [i] and [u] in forming the class of narrow vowels that allow the left edge of the foot to be drawn towards a more prominent "broad" ([–high]) vowel.

(63) *P/i, ɨ, u >> Align-Ft-Left >> *P/e, o >> *P/ä, a

Sorting by peripherality before height also predicts the existence of cases in which the mid central vowel schwa will outrank the high peripheral vowels in prominence. This would, in fact, explain the aberrant stress in Kobon *ru.ə́* but is inconsistent with other forms such as *gaɬínəŊ*, *wí.ər*, and *ɬú.əɬ*. Thus, we need to find better examples to determine whether this possibility is empirically attested.

Finally, we can ask why lower/peripheral vowels are more optimal stress-brearing units. It is a well-known phonetic universal that vowel duration is correlated with height. Lehiste (1970) mentions English, German, Danish, Swedish, Thai, Lappish, and Spanish as languages which support this finding. Indeed, in their citations of durations in Mokshan Mordwin, Tsygankin & Debaev (1975:32) report that one of their subjects had an average duration of 176 ms. for stressed [a] while stressed [u] was 152 ms. Ivanov & Tužarov (1970:36) mention that the central vowels of the Northwest dialect of Mari have a "weak articulation" and are "very short" though they provide no measurements of duration. Duration is one of the primary cues for stress. Thus, in the languages studied here stress exhibits a preference for vowels which more optimally express one of its primary perceptual correlates. There are other cases reported in the literature where duration is sensitive to height. For example, in the Borgo San Sepolcro dialect of Italian (Merlo 1929), consonants degeminate and lengthen preceding nonhigh vowels (see Repetti 1992 for recent discussion). This can be regarded as reassignment of the mora to the most optimal (duration-wise) vowels. Also, Baroni (1994) notes that in the Romagnolo dialect of Italian low vowels [a,ɛ,ɔ] lengthen in open syllables while high vowels do not. Furthermore, a subsequent lengthening of intervocalic consonants after stressed short vowels fails to apply after the lengthened low vowels showing that their increased duration is phonological in nature and not merely phonetic. Thus, we conclude that optimization of stress in terms of vowel height is not particularly surprising after all, and joins a growing list of cases in which a phoneme's inherent feature structure influences the distribution of prosodic categories.

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Notes

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[1] The table in (4) is not a tableau demonstrating a particular input-output map-

ping; rather it shows how the constraints of (3) evaluate various output structures in order to make the point that no candidate satisfies all the constraints since they are inherently conflicting.

[2] Thanks to Stuart Davis for bringing these data to our attention.

[3] We have found two exceptions in the cited data: *ru.ə́* 'day after tomorrow' [221] has stress on a weaker centralized vowel instead of the peripheral [u] while *kau.'ái* 'tree species' [221] has final stress instead of the expected penultimate stress.

[4] Davies (1981:226) remarks "the rules for positioning stress in two syllable words have yet to be determined. Relative vowel strength is almost certainly a conditioning factor since stress is almost always placed on the syllable which is strongest according to the following hierarchy: a/au/ai>o/e/ɯ/i>ö/ɨ".

[5] This form is stressed as *mílute-t*; we assume this is a printing error since it occurs in the list of examples Skorik uses to illustrate the generalization that when the suffix lacks a vowel then stress appears on the penult instead of the final syllable of the base.

[6] Thanks to Andrew Spencer for bringing this paper to our attention; see also Muravjova 1986 for a reconstruction of the protolanguage from which Aljutor, Chukchee and Korjak descend.

[7] A reviewer points out that this analysis is at odds with Kager's (1993) claim that monosyllabic iambs, unlike their disyllabic counterparts, have trochaic prominence due to a postulated syllable-internal prominence in which the first mora is stronger than the second.

[8] See, however, Hewitt & Crowhurst (1995) and Zoll (1995) for a different view.

[9] According to Hayes (1994:298), this is essentially the analysis of Prince (1976).

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