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*An analysis of North Saami gradation**

Berit Anne Bals Baal
University of Tromsø

David Odden
Ohio State University

Curt Rice
University of Tromsø

This paper gives a moraic analysis of gemination and laryngeal alternations associated with consonant gradation in North Saami. Gradation gives rise to a surface three-way length distinction in consonants, which is essential to understanding length in vowels and diphthongs. It is explained by a system of prosodic rules applying to underlying representations containing only a two-way contrast between geminate and singleton consonants, plus a floating mora present in certain suffixes, which results in surface alternations between extra-long and long or between long and short consonants. An enlightening explanation of quantity alternations is available if one exploits the possibility implicit in moraic theory that the relationship between segments and moras can be surface-contrastive, and we show that recourse to trimoraic syllables is unnecessary, despite the surface three-way length difference. These prosodic alternations also result in shifts in the timing of preaspiration and preglottalisation, as well as loss of these laryngeal specifications.

1 Introduction

This paper analyses aspects of the phonology of North Saami, focusing on the alternations known as gradation. North Saami is one of ten Saami languages (a branch of Finno-Ugric spoken in Norway, Finland, Sweden and Russia) – see Sammallahti (1998) for details of the history and

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structure of the Saami languages. The Saami languages have very complex phonological grammars, and despite basic similarities, they vary from one another in linguistically significant ways. This paper focuses on one dialect, that of Guovdajohtolat, which is spoken in the Guovdageaidnu (Kautokeino) municipality, and is the dialect spoken by the first author (data in this paper come from the first author).[1] The North Saami language itself is spoken in numerous other municipalities of Norway, as well as Finland and Sweden.

The contributions of this paper are manifold. The major contribution is on the descriptive front. Put very simply, the language we are describing is virtually undescribed in terms of a full reporting of the relevant facts. While North Saami is a robust language with substantial written literature, obtaining sufficient data for a full phonological analysis would be impossible on the basis of written sources. North Saami is not phonologically monolithic, and data from speakers of one area is not always the same as that from speakers from another North Saami speaking area or generation, which is unsurprising since Guovdageaidnu itself is so large. Even phonetically transcribed data from sources such as Magga (1984) and Sammallahti (1998) are from slightly different dialects, and these differences are significant enough to materially affect the analysis.

The morphophonology of the language is extremely complex, which is why grammar books such as Nielsen (1926–29), Bergsland (1961) and Nickel (1994) cannot cover the volume of data necessary to demonstrate generalisations within the language. Since grammar books tend to represent pandialectal idealisations, important phonological facts are omitted. Written forms of North Saami cannot be translated into phonetic data without prior description of how to interpret the spelling in a given dialect, and not all relevant phonetic facts are represented in the orthography. The written language represents the most important linguistic distinctions, albeit through a spelling system that is initially hard to interpret phonetically, but the orthography also omits some important details. The lack of indication of vowel or diphthong length, and some types of consonant length, are orthographic defects that would plague an analysis of the type of data that we analyse here if it were based on written forms. Our primary goal is thus descriptive: we present and analyse a paradigmatic corpus of surface-phonologically transcribed data of what is, from this perspective, an underdescribed language. Certain theoretical results will be seen to flow from this description.

The fact of theoretical interest which North Saami is best known for is the existence of a three-way length distinction in consonants, exemplified by triples such as [rŭosssɑ] 'cross (NOM SG)', [ruossɑ] 'cross (ACC SG)' and [ruosɑ] 'Sweden (ACC SG)'. Our analysis yields data relevant to numerous issues, including the theory of length, details of how syllabification may

[1] Guovdageaidnu is a *kommune* in Norwegian, which is conventionally translated as 'municipality'. A Norwegian *kommune* covers on average 764 km^2; Guovdageaidnu is the largest in Norway, covering 9708 km^2.

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operate in moraic theory and the representation of the timing of pre-aspiration and preglottalisation. These issues arise in the course of answering the central analytic questions of North Saami phonology: how many degrees of phonological length are there on the surface and underlyingly, and how are they represented formally; is there a phonological unity to the gradation alternations; what are the underlying representations of stems?

We assume a moraic theory of geminates (Hayes 1989, Davis 1994, 2011, Topintzi 2008) – whether or not prosodic representation also requires skeletal positions along with moras (Hock 1986, Hume *et al.* 1997, Curtis 2003) is not important for our analysis, since North Saami provides no relevant evidence. A unified and enlightening analysis can be given for the rich prosodic and segmental alternations of the language, which reveals that the relationship between segments and moras within the syllable is not trivial, yet it is systematic. We show that there is a prosodic unity to gradation, and argue that the best account of the three-way surface length distinction exploits a possibility implicit in moraic theory but hardly exploited in the literature, i.e. that the alignment of segments to moras can be surface-contrastive, just as the alignment of consonants into syllables can be surface-contrastive (e.g. English *Nye trait vs. night rate*). Thus, despite an apparent three-way consonantal length system, we do not require recourse to syllables dominating three moras, or any unprecedented types of underlying or intermediate representations. The most constrained theory compatible with incontrovertible fact is that syllables contain at most two moras, and even in the context of an analysis that assumes (prematurely, we argue) that trimoraic syllables are necessary, Bye (2005) still maintains – drawing on data from North Saami – an observational universal limit that no segment may be trimoraic, indicating that the search for constrained theories of phonology should not be abandoned.

In our analysis, the only underlying prosodic information is lexically contrastive consonant gemination, where underlying geminates are associated to a mora, and at no point do we require recourse to syllables dominating three moras. This result is quite significant, since some scholars treat such as English *films* [fɪlmz] or Hungarian *váll* [vaall] 'shoulder' as trimoraic, where three degrees of length are not even relevant. Morén (1999) and Hall (2001), for example, posit such representations without attempting to analyse the data in a maximally bimoraic model and exploiting many-to-one associations between segment and mora, as we do. A theory positing only monomoraic and bimoraic syllables has a prior logical claim on our attention over a theory which additionally claims trimoraic syllables, on classical Occam's Razor grounds: see Russell (2000: 462–463) for general discussion. The burden of proof rests on the proponent of trimoraic syllables to show that there is no reasonable account of the language using maximally bimoraic syllables. The length facts of Saami are *prima facie* the same kind of surface-difference facts that have led people to misanalyse languages like Estonian and Kikamba as having three lengths, represented by one, two or three

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prosodic slots. Demonstrating that Saami, which superficially appears to require trimoraic syllables, actually does not should encourage deeper consideration of the morphophonology of other languages said to have trimoraic syllables.

We also demonstrate that prelaryngealised consonants exhibit dual behaviour, acting as single segments for parts of the phonology but as clusters for others. Our explanation for this dual behaviour is that they are underlyingly single segments, with the laryngeal feature being segmentalised in the course of the derivation, resulting in full segments, thus /tʰ/ → [ht] and /nˀ/ → [ʔn]. Segment-splitting in synchronic phonology is rare, and has not received adequate attention in the theoretical literature – this paper contributes a body of facts that must be handled by any theory of splitting.

The phonological complexity of the language is considerable, so this paper limits the domain of investigation to the basic patterns found in two of the case-number inflectional categories in regular bisyllabic vowel-final noun stems. Analysis of other parts of the phonology must await presentation in other venues. See Bals *et al*. (2007) for a more extensive descriptive paper, which provides additional examples, acoustic data including duration measurements and broader coverage of the phonology.

2 Surface and underlying inventory

The surface single consonants of this dialect of North Saami are given in (1). This inventory excludes length distinctions. As we shall see, [hp hhp ʔm ʔʔm mʔm] and their counterparts at other places of articulation are phonologically long versions of single segments.[2]

(1)	p b pʰ	t d tʰ	tˢ dᶻ	ʧ ʤ	k g kʰ
	m	n		ɲ	ŋ
	f v	ð	s	ʃ	
		r l ʎ		j	h

In this dialect, [ŋ] is non-contrastive, appearing only before velars. Surface postaspirated [pʰ tʰ kʰ] have a limited distribution, as discussed below.

Additionally, the language has the following series of surface preglottalised and preaspirated consonants.

(2)	hp	ht	htˢ	hʧ	hk
	hhp	hht	hhtˢ	hhʧ	hhk
	ʔm	ʔn		ʔɲ	
	ʔʔm	ʔʔn		ʔʔɲ	
	mʔm	nʔn		ɲʔɲ	

[2] A series of voiceless sonorants [r̥ l̥ j̥ m̥ n̥] may be part of the inventory, or they may be clusters of /h/ + sonorant. These are rare and there is no evidence unambiguously showing how they should be treated phonologically.

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We demonstrate that these are underlying single segments which are moraic, which undergo segment-splitting and derive underlyingly from the following segments (factoring out prosodic differences).

(3) p^h t^h t^{sh} $ʧ^h$ k^h
$m^ʔ$ $n^ʔ$ $ɲ^ʔ$

The vowels and diphthongs of this dialect, again excluding length, are given in (4).

(4) i u e o ɑ a ie uo ea oa

The vowels [ɑ] and [a] are qualitatively different, but are nearly in complementary distribution, the former usually being short and the latter usually being long. We cannot determine which low vowel is phonetically closer to the second element of the diphthongs which we transcribe as [ea] and [oa]. There is no contrast between [oɑ] and [oa], or between [eɑ] and [ea].

Vowels and consonants can be long or short, and there are extensive length alternations. All consonants except [h] can be long; [ʎ] is always long. Consonant-length differences are seen in (5a) for medial consonants, and vowel-length differences in the first syllable in (5b) (long segments in the first column, short ones in the second). In the case of short diphthongs, we indicate shortness on the first element of the diphthong, e.g. [ŭo], without implying anything about how much shorter the first and second elements of short diphthongs are in comparison to their duration in long diphthongs.

(5) a.	staallu	'troll (NOM SG)'	staalu	'troll (ACC SG)'
	viessu	'house (NOM SG)'	viesu	'house (ACC SG)'
	mearrɑ	'sea (NOM SG)'	mearɑ	'sea (ACC SG)'
	gaaffe	'coffee (NOM SG)'	gaafe	'coffee (ACC SG)'
	roaðði	'redness (NOM SG)'	roaði	'redness (ACC SG)'
	dievvaa	'mound (NOM SG)'	dievaa	'mound (ACC SG)'
b.	staalu	'troll (ACC SG)'	bɑlu	'fright (ACC SG)'
	goolli	'gold (ACC SG)'	dolaa	'fire (ACC SG)'
	stoobe	'can'	gobi	'depression (ACC SG)'
	duuʔmi	'bird-berry (ILL SG)'	duʔmui	'judgement (ILL SG)'
	luottɑ	'road (ACC SG)'	lŭoddɑ	'road (NOM SG)'
	ruoʔmɑ	'tracebearer (ACC SG)'	lŭoʔni	'dirt (NOM SG)'
	fuoððu	'wild animal (NOM SG)'	gŭoddu	'stump (NOM SG)'
	gɑɑskaa	'distance (ACC SG)'	gɑsskɑ	'distance (NOM SG)'

One theoretically interesting property of the North Saami inventory is the three-way length distinction in consonants illustrated in (6), where C_i,

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C_iC_i and $C_iC_iC_i$ represent respectively short, long and overlong consonants, traditionally referred to as Q1, Q2 and Q3 (see Lehiste 1965).

(6) a.	Q1	viesu	'house (ACC SG)'
		ŋuolɑ	'arrow (ACC SG)'
		ruosɑ	'Sweden (ACC SG)'
		dolaa	'fire (ACC SG)'
b.	Q2	viessu	'house (NOM SG)'
		ruollɑ	'rude person (ACC SG)'
		ruossɑ	'cross (ACC SG)'
		goolli	'gold (ACC SG)'
c.	Q3	gŭosssi	'guest (NOM SG)'
		rŭollla	'rude person (NOM SG)'
		rŭosssɑ	'cross (NOM SG)'
		gollli	'gold (NOM SG)'

Given that robust ternary length distinctions even in vowels are quite rare (see Odden 2011) and that their phonological nature is usually either unknown or epiphenomenal,[3] an understanding of the phonological nature of ternary length in North Saami will contribute substantially to our overall understanding of purported phonological ternarity.

An important relationship between consonant and vowel length should be noticed in (6), i.e. that an overlong consonant can only be preceded by a short vowel or diphthong. In addition, a plain long consonant can never be preceded by a short vowel. This is not merely a statistical fact about lexical distributions, but is relevant to morphophonemic alternations, as evidenced by forms such as [rŭollla] *vs.* [ruollɑ] in (6) and nouns of the type [dolllaa] ~ [dolaa] 'fire (NOM SG ~ ACC SG)', discussed in §3.3. A phonological account of North Saami must then explain the complex complementarity between vowel length and consonantal length.

The glottal stop, which arises from the segmentalisation of glottalisation on nasals, has two surface allophones, a short one which appears after a long nucleus, and a long one after a short nucleus, as shown in the nominative singular forms in (7).

(7) a.	baaʔni	'tooth'		loaʔnɑ	'loan'
	ruoʔmaa	'tracebearer'		lieʔmɑ	'broth'
	duoʔmɑ	'bird-berry'		deaʔnu	'large river'
b.	lɑʔʔŋaa	'room'		ʧiʔʔmaa	'bend, bowing'
	guʔʔnaa	'ash (tree)'		joʔʔŋaa	'lingonberry'
	gŭoʔʔmi	'roof of mouth'		jŭoʔʔmu	'sorrel'

[3] See for example Estonian ternarity, which reduces to binary length interacting with distinctive foot structure (Prince 1980), or Kikamba, where vowel length *per se* is strictly binary but heterosyllabic identical vowel sequences like [o.o] contrast with long vowels like [o:], and other cases discussed in Odden (2011).

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We show that this surface distinction follows automatically from our phonological analysis.

There is a significant degree of predictability to length, both in vowels and consonants. There are some exceptional unpredictable long vowels, for example in [geeso] 'cradle' and [stoobe] 'can', but such words are exceptional in more than one way, also falling outside the system of regular grade alternations. Vowel and diphthong length is generally predictable in the language, but it is not *surface*-predictable, and thus cannot be reduced to being a matter of phonetic implementation, as vowel nasalisation in English might be. Diphthongs generally surface as long, but under certain prosodic and segmental conditions they may be short. Monophthongs lengthen in a segmentally defined context (before certain coda consonants, discussed in §3.2), and in addition the vowel /a/ is usually long (except in one context), whereas /ɑ/ is usually short (but can be lengthened). Monophthongs can derive from diphthongs conditioned by sometimes abstract properties of the following syllable – a following mid vowel causes /ie uo ea oa/ to become [i u e a], as seen in [luuʔmot] 'your (SG) holiday' ~ [luoʔmu] 'holiday', or [biittʃot] 'your lair' ~ [biettʃu] 'lair'. Such vowels generally have the length of their diphthongal source. Despite the three-way surface consonant-length difference, we show that underlyingly there is only a two-way contrast, between plain (single) and moraic (geminate) consonants.

The main segmental complication of gradation pertains to laryngeal features, so attention must be paid to laryngeal distinctions in order to understand gradation. Surface forms present more laryngeal distinctions than can be motivated for underlying forms, meaning that some laryngeal differences can be derived. On the surface, there are both voiced and voiceless stops (geminate and singleton), but these distinctions are predictable. Geminate voiced stops (which present the only unambiguous evidence in North Saami for phonological voicing) arise predictably just in the strong grade of bimoraic geminate stops.[4] There is no question, given minimal pairs such as [oabbaa] ~ [oappaa] 'sister (NOM SG ~ ACC SG)', that voicing must be phonologically present in the language, and it is equally clear that geminate voicing is not a property of underlying representations, since voiced geminates only arise in strong grade categories.

There are phonetically voiced, postaspirated, voiceless unaspirated and preaspirated stops, but they do not all contrast fully. The postaspirated stops have the most restricted distribution: they always come before the main stressed vowel and only appear in loanwords (8a).[5] See Sammallahti

[4] The voicing aspect of gradation is an area of gradation not treated in this paper, but is described in Bals *et al.* (2007).

[5] Stress is on the penultimate syllable of the root, and every odd syllable after that. Native roots are disyllabic, so stress is usually on the first syllable: root-trisyllabicity is a hallmark of a loanword. That portion of the word preceding the stressed syllable has numerous phonological oddities, which are beyond the scope of this paper. Stress is phonetically abstract in this language, though it is well motivated in the phonology in terms of stem-size restrictions and numerous syllable-weight alternations computed in terms of odd *vs.* even count.

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(1998) for the history of Saami consonants and the development of aspiration. The preaspirated stops are always post-sonorant and post-stress (8b). The voiceless unaspirated stops appear post-stress after another (voiceless) obstruent or anywhere after a voiceless fricative (8c), and voiced stops appear between sonorants or word-initially (and are always followed by a sonorant) (8d).

(8)	a.	[k͡hapˈt͡heajʔna]	/kʰaptʰeajnʔa/	‘captain (NOM SG)’
		[ˈt͡haaŋhka]	/tʰaŋkʰa/	‘tank (NOM SG)’
		[ˈp͡hennna]	/pʰenna/	‘pen (NOM SG)’
		[fak͡hʉlˈt͡heehta]	/fakʰʉltʰeetʰa/	‘faculty’
	b.	[ˈkʰaalh͡ka]	/kʰalkʰa/	‘calcium (ACC SG)’
		[ˈgoah͡ti]	/koatʰi/	‘big tent (NOM SG)’
		[ˈpʰaanh͡ta]	/pʰantʰa/	‘(bottle) deposit (ACC SG)’
	c.	[ˈfraak͡ta]	/frawta/	‘freight (ACC SG)’
		[ˈbɑɑs͡te]	/pɑste/	‘spoon (ACC SG)’
		[ˈruʃʃ͡pi]	/ruʃpi/	‘carrot (NOM SG)’
		[ˈs͡taallu]	/stallu/	‘troll (NOM SG)’
	d.	[ˈg͡oahti]	/koatʰi/	‘big tent (NOM SG)’
		[ˈsto͡o͡be]	/stoope/	‘can’
		[ˈg͡aan͡da]	/kantɑ/	‘boy’

The surface choice between the two variants of aspirated stop (preaspirated and postaspirated) is predictable, based on their position relative to stress. The two surface variants of unaspirated stop, the voiced and voiceless, are predictable by reference to whether the stop is adjacent to another voiceless segment, in which case it is voiceless. Thus, at a more abstract level of analysis, preaspirated and postaspirated stops are simply aspirated, and unaspirated voiced and voiceless stops are just unaspirated. In the case of surface-predictable voicing, as in [goahti] from /koatʰi/ or [stoobe] from /stoope/, there are no phonological facts to tell us, one way or the other, whether the actual phonological outputs are [goahti] and [stoobe], with a phonologically [+voiced] segment arising by late rule, or [koahti] and [stoope], with vocal fold vibration arising from phonetic implementation. We remain agnostic as to whether (non-geminate) obstruent voicing is phonological, but assume for the sake of concreteness that there is a late voicing rule.

Nasal consonants also exhibit surface differences in laryngeal type, between plain, preglottalised and interrupted-glottalised.

(9)	deanu	‘large river (ACC SG)’	baani	‘tooth (ACC SG)’
	deaʔnu	‘large river (NOM SG)’	boaʔɲi	‘husband (ACC SG)’
	boaɲʔɲi	‘husband (NOM SG)’	gunʔni	‘honour (NOM SG)’

We show here how the distinction between [ʔN] and [NʔN] emerges from the phonology of gradation. The differences in (9) segmentally

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reduce to glottalised and non-glottalised, and the specifics of timing as preglottalised *vs*. interrupted-glottalised follow as a consequence of the analysis.

The underlying consonant inventory then reduces to (10).

(10)	p	t	ts	ʧ	k
	p^h	t^h	ts^h	$ʧ^h$	k^h
	m	m		ɲ	
	$m^ˀ$	$m^ˀ$		$ɲ^ˀ$	
	f	ð	s	ʃ	
	w	r l ʌ		j	h

The underlying prosodic inventory is, simply, that any consonant – excluding /h/ – can be bare or moraic (thus geminate). The underlying vocalic system is /i e a ɑ o u ie uo ea oa/, as well as in a few instances unpredictably long vowels /iː eː oː uː/.

3 The nature of gradation

Our main analytic concern is the phonology of gradation, which is a stem-internal consonantal modification, somewhat similar to the better-known alternations of Finnish (Harms 1964), associated with particular morphological categories. An illustration of gradation alternations is given in the case and number paradigm of the noun /koat^{h}i/ 'big tent'.[6]

(11)	*singular*	*plural*
nominative	[goahti]	[goaðit]
accusative	[goaði]	[gooðit]
illative	[goahtaaj]	[gooðije]
locative	[goaðis]	[gooðin]
comitative	[gooðin]	[gooðigon]
essive	[goahtin]	

The simplest illustration of gradation involves a comparison of the nominative singular, which exemplifies the strong grade, and the accusative singular, which exemplifies the weak grade, since these two cases present no other segmentally realised affixes. The general character of the gradation alternation is that the postvocalic consonant is longer in the strong grade and shorter in the weak grade. This paper focuses on the alternations in (12), which reflects the traditional view that only considers gradation from the perspective of changes to consonants.

[6] The forms given here are appropriate for the dialect – the written language has somewhat different endings, *viz*. *-guin* for the comitative plural and *-ide* for the illative plural. Monophthongisation affects many forms of this noun when root-final /i/ merges with suffix-initial /i/, as in /-in/, /-it/ and /-ije/.

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(12)		*strong grade* (NOM SG)	*weak grade* (ACC SG)	
	Q2 ~ Q1	ss	s	(§4.1)
		hp	b	(§4.4)
		ʔm	m	(§4.7)
	Q3 ~ Q2	sss	ss	(§4.2)
		hhp	hp	(§4.5)
		mʔm	ʔm	(§4.8)
	Q3 ~ Q1	sss	s	(§4.3)
		hhp	b	(§4.6)
		ʔʔm	m	(§4.7)

The entire system of alternations is extremely complex, and, given dependencies between consonant prosody and vocalic length, cannot be adequately represented in a table. To give the reader a flavour of the whole system, we list representatives of the other major patterns of alternations in (13); see Bals *et al*. (2007) for further information.

(13) *strong grade*	*weak grade*	*strong grade*	*weak grade*
hrr	hr	rVs	rss
ttʃ	j	rVb	rpp
bb	pp	rVhp	rhp
jjs	jss	kt	wht
llt	ltt	ks	wss
		sst	st

An analysis of gradation must answer numerous questions. How many quantity categories are present in underlying forms and in surface representations? What is the phonological representation of the distinction? How are differences in aspiration ([b hp hhp]) and glottalisation ([n ʔn nʔn]) connected to ordinary quantity differences? How does gradation influence vowel length? What unifies 'gradation'?

In our analysis, the unity of gradation is that, in those morphological contexts where the strong grade appears, a floating mora (represented as $\underline{\mu}$) is present in, and sometimes is the entire content of, the triggering affix (see Svenonius 2008 for a similar floating-prosody affix). We identify such a mora by underlining. This mora is subject to a mapping rule which specifically targets a floating mora, and otherwise the distinctions that characterise gradation are the result of strictly phonological rules. The surface distinction between Q2 and Q3 is a rule-governed consequence of how segments align to moras. Following standard analytic practice in moraic phonology, a (short) Q1 consonant, as in [ruosɑ], is non-moraic, and appears just in onset position in a single syllable (14a). An overlong Q3 consonant, as in [rŭosssɑ], is moraic, appears in the coda (as well as the onset of the following syllable) and exhausts its

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mora (14c). In comparison, a plain long Q2 consonant, as in [ruossɑ], is moraic and ambisyllabic, like Q3, but shares a mora with a preceding vowel (14b).

(14) a. Q1 C b. Q2 V C c. Q3 C



The aforementioned dependency between consonant and vowel quantity emerges from this theory of the representation of consonant quantity, as we elaborate below.

A significant portion of the segmental aspect of gradation results from the syllabification potential of coda moras and the fact that laryngeal features become coda consonants. This explains the structural analogies [ss : s :: hp/ʔm : b/m]. The quantitative analogies are clearer when considered at a more abstract level, below the surface, where preaspiration and preglottalisation or interrupted-glottalisation are represented as ordinary unordered laryngeal features on a single segment whose prosody varies, thus /s, ss, sss : p^h, p^hp^h, $p^hp^hp^h$: $m^ʔ$, $m^ʔm^ʔ$, $m^ʔm^ʔm^ʔ$/. The surface realisations [s, ss, sss : b, hp, hhp : m, ʔm, mʔm] result from segmentalisation of the laryngeal feature as an ordered segment, [h] or [ʔ], which interacts with other rules of syllabification.

4 The gradation alternations

This section analyses gradation patterns pertaining to gemination, preaspiration and glottalisation, providing the basics of the analysis of North Saami gradation. We document the pattern primarily by looking at the nominative singular *vs.* the accusative singular, because these two cases are distinguished in vowel-final stems only by the presence of the nominative singular case suffix $\underline{\mu}$ *vs.* the null accusative singular case suffix. The same pattern of prosodic and segmental alternations arise in connection with numerous word-formation processes, such as the illative singular or essive cases, the infinitive, 1st plural present, 1st singular preterite, and so on.

4.1 Simple gemination

The alternations in (15) are the simplest manifestation of strengthening, namely gemination of a consonant in the strong grade. The phonological class of nouns represented in (15) contains many nouns with a diphthong or /a/ followed by a fricative or sonorant consonant, and the consonant alternates between single in the weak grade and geminate in the strong grade.

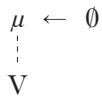
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(15)

strong grade (NOM SG)	*weak grade* (ACC SG)	
[guolli]	[guoli]	'fish'
[viessu]	[viesu]	'house'
[mearrɑ]	[mearɑ]	'sea'
[gaaffe]	[gaafe]	'coffee'

The derivation of the weak-grade form involves just basic prosodification, which we assume involves various simple and explicitly formalisable steps, such as morification of vowels, syllable projection and onset creation (see Kahn 1976 and Dell & Tangi 1992 for similar approaches, Clements & Hume 1995 for the related notion of single-operation rules and McCarthy 2007 for cognate concepts in OT-CC). The syllable nucleus in this class of words is bimoraic for segmental reasons: it either contains a diphthong or the vowel /a/, which is usually long. Given a sequence of vowel segments, i.e. a diphthong, the first vowel is morified by (16a), and that mora then projects a syllable by (16b).

(16) a. *Head Morification*

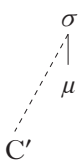


b. *Syllable Projection*



A further well-known process defining core syllabification assigns an unaffiliated consonant to the onset of a syllable (X′ denotes an X which is unassociated).

(17) *Onset Creation*

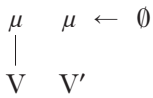


Moraic support for syllabically parsing the non-head elements of a diphthong may come by attachment to a consonantal mora in strong grade forms (e.g. [guolli]), but when there is no coda consonant (e.g. [guoli]) a mora is directly added at the end of the syllable and linked to the vowel. The following rule guarantees that both elements of a diphthong can be syllabified, by providing a mora that the second half of a diphthong can attach to – association to the mora and syllabic parsing of that mora come about by separate rules.[7]

[7] This does not mean that diphthongs are always bimoraic, as we show below.

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(18) *Diphthong Morification*



An unsyllabified mora is then parsed from the right into a syllable.

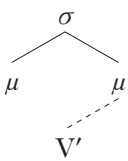
(19) *Mora Syllabification*



There are multiple sources for such a second mora, one being (18), others including lexically specified consonantal moras, as well as the nominative singular suffix $\underline{\mu}$. The context where there may be two unsyllabified moras will be discussed in sections concerned with the Q3 alternation.

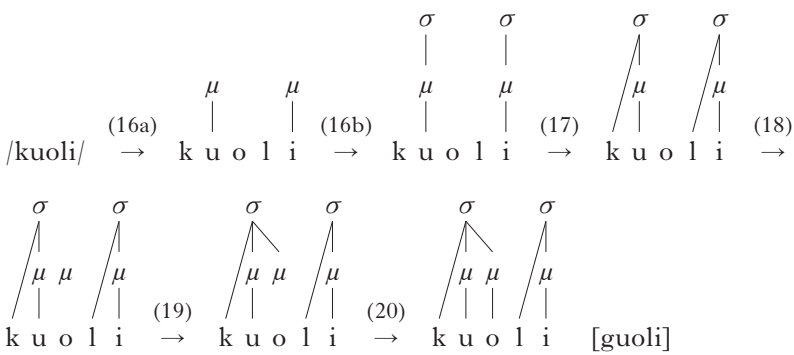
Finally, the second vowel of a diphthong associates to the second mora in the syllable by Attachment to Mora.

(20) *Attachment to Mora*



These rules apply to /kuoli/, which underlyingly contains only segments, giving the syllabified surface output in (21).[8]

(21)



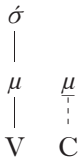
[8] Forms in / / and [ ] brackets have their standard interpretation as underlying or surface forms; unbracketed forms are intermediate forms.

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The phonetic interpretation of this output is straightforward: the diphthong is long, since it is bimoraic, and the consonant is short, because it is neither moraic nor ambisyllabic.

In the strong grade, $\underline{\mu}$ links to the consonant after the stress, which causes lengthening of that consonant. We posit the rule of $\underline{\mu}$-docking in (22) to associate $\underline{\mu}$ to a consonant.

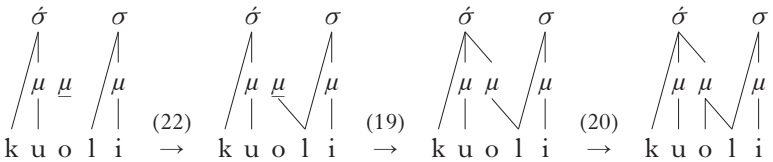
(22) *$\underline{\mu}$-docking*



Core syllables are erected by the application of (16) and (17), and binary left-headed feet are built on those syllables. In the strong grade, after the medial consonant is morified by (22), it syllabifies by Mora Syllabification (19), linking leftwards to the stressed syllable.[9]

The derivation of [guolli] is parallel to that of [guoli] with respect to creation of the core CV syllable via Head Morification (16a), Syllable Projection (16b) and Onset Creation (17), but diverges from that of [guoli], because application of $\underline{\mu}$-docking to $\underline{\mu}$ renders *l* moraic, which causes it to syllabify as a coda.[10] When that happens, the structural description of Diphthong Morification (18) is not satisfied, and that rule is not necessary to provide a position for syllabification of the vowel *o*. Instead, Attachment to Mora links *o* to the morphologically provided coda mora. The relevant differentiating steps in the derivation are those in (23), which starts after core syllabification.

(23)



[guolli]

The nuclear vowel may also be the monophthong /a/, which as we have noted is generally long (the exception is explained in §3.8). An example of such a noun is [gaaffe ~ gaafe] 'coffee'. In the morphological weak grade, where there is no consonantal mora which /a/ could link to, a second mora

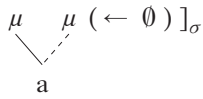
[9] For the majority of nouns that we consider here, the stress condition is not crucial. It becomes crucial in explaining the lack of gemination in the stem-final consonants of ['gɑhhpir-'in] 'cap (ESS)' as compared with ['mujhtɑ'luss-ɑn] 'story (ESS)'.

[10] Our rules do not depend on a particular order of $\underline{\mu}$-docking and Onset Creation. The former will target the first postvocalic consonant, regardless of other prosodic links, and the latter targets a prevocalic consonant.

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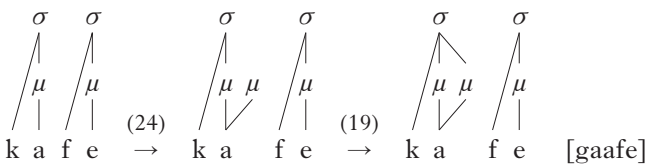
is assigned to /a/, which results in the lengthening of /a/. Similar to the case of Diphthong Morification (18), the low front vowel becomes long by (24), which links /a/ to a second mora, inserting it if necessary.

(24) *Low Front Vowel Lengthening*



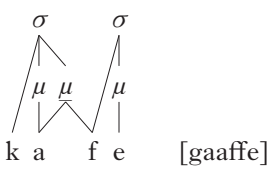
The formulation is to be interpreted as always linking a second mora to /a/, and inserting a second mora if there is not already a following mora that /a/ can link to. This rule completes the derivation of weak-grade [gaafe] (from /kafe/), starting in (25) after core syllabification.

(25)



The derivation of strong-grade [gaaffe] differs minimally from this, in that it is the nominative singular case suffix $\underline{\mu}$ which links to /f/ and causes gemination, providing the second mora for /a/, resulting in (26).

(26)



4.2 Overlong geminates

Some stems (with the same segmental type as in the previous section) have an underlying medial moraic (geminate) consonant. The geminate appears as such in the weak grade, and in the strong grade the nominative singular suffix $\underline{\mu}$ associates to this already moraic consonant. This additional mora indirectly results in overlength of the consonant; there is, additionally, a related vocalic length alternation associated with the nucleus.

(27) *strong grade* (NOM SG)	*weak grade* (ACC SG)	
[gollli]	[goolli]	'gold'
[mĭellli]	[mielli]	'high bank of river'
[binnnaa]	[biinnaa]	'bit of something'
[gŭosssi]	[guossi]	'guest'

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This phonological class of nouns also includes the diphthongs /ea oa/, discussed below.

Ordinary syllabification accounts for weak grade forms such as [guossi], which is analogous to the strong grade of [guolli] in §4.1, except that the consonant's mora is lexically present. The second vocoid of [guossi] syllabifies by linking to this lexically specified consonant mora, just as *o* of strong grade [guolli] syllabifies by linking to $\underline{\mu}$.

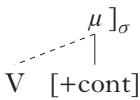
The weak grade of nouns such as [gollli ~ goolli], with a length-alternating monophthong, requires further comment. The type of noun discussed in §4.1 contains a diphthong plus the inherently long monophthong /a/, therefore the nucleus of such nouns is always long. The present class of nouns is entirely complementary with respect to the class of monophthongal nuclei, in that the nucleus is never /a/. The question arises as to the source of vowel lengthening in weak grade [goolli]. Core syllabification plus Mora Syllabification would result in the following representation.

(28)



The surface form [goolli] results from a rule which lengthens monophthongs before a syllable-final continuant, by spreading a syllable-final consonant's mora to the vowel. Pre-continuant Lengthening (29) does not spread $\underline{\mu}$, a point discussed in §4.3. The relevant continuant consonants in the language are [l r m n ɲ v ð f s ʃ h] (we consider [h] further below).

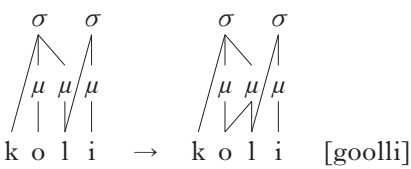
(29) *Pre-continuant Lengthening*



Monophthongs are not lengthened before moraic stops, which occur in nouns such as [loddi ~ lotti] 'bird (NOM SG ~ ACC SG)', discussed in Bals *et al*. (2007).

This lengthening rule applies as in (30) (continuing from (28)).

(30)



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Thus vowel length in weak grade [goolli] is the predictable result of spreading the mora of a coda continuant to the preceding vowel.

In the strong grade, $\underline{\mu}$ is inserted after the head mora of the stressed syllable. The last mora, which is lexically linked to the medial consonant, is parsed into the coda, resulting in (31).

(31)



[gollli]

Pre-continuant Lengthening cannot apply between *o* and syllable-final lexical μ, since that mora is not adjacent to the mora of the *o*, and also cannot apply between *o* and $\underline{\mu}$, because that mora is not syllable-final.

In order to be phonetically interpreted, material must be fully parsed into the representation, and in (31) $\underline{\mu}$ is not syllabified, since the syllable already dominates two moras. Whether or not this mora remains present in the derivation is an empirical question (addressed below). What is important at the moment is that we do not rely on a third mora to represent consonantal overlength in the output. If a satisfactory analysis of the facts is possible within the confines of a model where syllables dominate no more than two moras, then there would be no evidence to support the less constrained theory, which posits that syllables may also dominate three moras. We assume that Stray Erasure, proposed in McCarthy (1979) and subsequent literature (Steriade 1982, Itô 1989, Lin 1997, van Oostendorp 2008), operates at least by the end of the phonological derivation, so that floating moras are not available to the phonetic interpretation component. Rather than rely on surface floating moras or trimoraic syllables to represent overlength,[11] we rely on the distinction between a consonant which exhausts a mora (32a) and one which shares a mora (32b).

(32) a.



[gollli] (NOM SG)

b.



[goolli] (ACC SG)

A mora implies some period of time, and when a consonant exhausts a mora, as in (32a), it has all of the timing of the mora, and is therefore 'overlong', resulting in a triply long consonant. In (32b), the timing entailed by μ is shared between [o] and [l], but in (32a), all of the timing entailed by the mora is implemented on [l], making it longer.

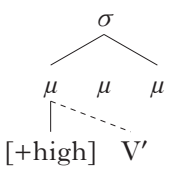
[11] A trimoraic syllable is one that dominates three moras.

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The derivation of the strong grade of nouns with a high vowel diphthong [ie uo] such as [gŭosssi] is similar to that of nouns with a monophthong: the nucleus is short in the strong grade. The mechanism for deriving this fact must be explained, since ordinarily one would expect a diphthong to have two moras in a language with a vowel-length distinction, especially given rules like (18) and (20). While the mid diphthongs [ea oa] are usually long (short [ĕa ŏa] are explained in §4.4), the morification of the high diphthongs [ie uo] is more variable in North Saami. The two vocoids of a diphthong are generally each parsed into a separate mora, but in certain contexts the more general V_2 morification process (20) is pre-empted by a rule parsing the mid vowel to the head mora in the syllable, which yields the distinction long (bimoraic) [ie uo] *vs*. short (monomoraic) [ĭe ŭo]. Full analysis of all contexts where short diphthongs are formed involves numerous segmental and prosodic facts, and is outside the scope of this paper. The basic generalisation in North Saami is that high vowel diphthongs ([ie uo]) are parsed as short in two contexts, depending on the nature of the following material, whereas mid vowel diphthongs are so parsed in a single, distinct context, before overlong [hh]. For the class of stems relevant to this section, high diphthongs are parsed as short in case the head mora is immediately followed by two non-head moras (thus [gŭosssi] 'guest (NOM SG)', [mĭehhki] 'sword (NOM SG)', [bĭemʔmɑt] 'to feed'), which correspond to traditional Q3. The other context for creating short high diphthongs before so-called Q2 clusters is discussed in §4.7.

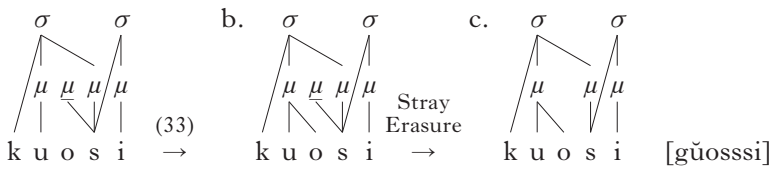
Given these conditions, the vowels [e] and [o] in [mĭellli] and [gŭosssi] respectively are linked to the head mora, pre-empting Diphthong Morification (18) and Attachment to Mora (20) as the means of syllabifying the second vocoid. The rule creating short diphthongs in this context, where only the moraic properties of the affected syllable are relevant, is formalised as follows.

(33) *Short Diphthong Formation 1*



Basic syllabification yields (34a). Rule (33) then links [o] to the head mora in (34b), forming a short diphthong. Unsyllabified $\underline{\mu}$ deletes via Stray Erasure, and the surface form is (34c).

(34)

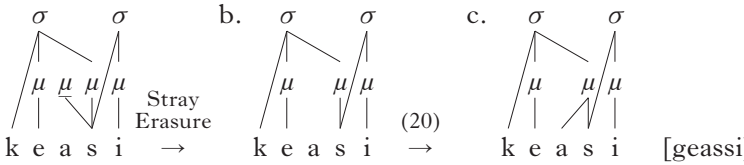


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Since [ŭo] is associated to one mora, it is short, and since the consonant is moraic, it is geminate, but because no other segment is linked to the coda mora, [s] is phonetically extra-long.

Since short high diphthongs are created by (33), the question arises as to how our rules would handle an underlying form like /keas$_{\mu}$i/ in the nominative singular, where the initial vocoid of the diphthong is not high, and so could not undergo (33). Core syllabification and $\underline{\mu}$-docking would result in (35a). The unparsed consonantal mora will be deleted by Stray Erasure applied to prosodic elements, giving (35b). Floating /a/ can then associate to the syllable-final mora by Attachment to Mora, resulting in (35c).

(35)



Since the vowel /a/ is not parsed to the preceding mora by (20), which only targets diphthongs with a [+high] first vocoid, it remains liable to later syllabification to the second mora. In lieu of a specific rule addressing mid-vowel diphthongs (as exists for high-vowel diphthongs), our analysis predicts that stems with lexically moraic surface-geminating consonants preceded by mid-vowel diphthongs will not exhibit a surface alternation in the nucleus or consonant, and the output would be [geassi] for both the strong and weak grades.

The problem is diagnosing such underlying representations. There is a phonologically defined class of nouns, such as [geassi] 'one who pulls', [neavvu] 'work tool', [hearraa] 'lord', [ʃeaffɑ] 'chef', which do not have a surface consonant alternation in the nominative singular *vs.* accusative singular, with mid diphthongs in their non-final syllables. If these stems are underlyingly /keas$_{\mu}$i, neav$_{\mu}$u, hear$_{\mu}$aa, ʃeaf$_{\mu}$ɑ/, they should not have a surface gradation alternation, since normal morification of diphthongs would link /a/ to the following consonant, eliminating the mora-exhausting association that is overlength. However, another way to look at such stems is that they are simply lexical exceptions to gradation. There are two facts which show that the invariant Q2 nature of some such nouns is not due to lexical exceptionality.

Non-alternating [geassi] is the agent nominalisation of /keasi/ 'pull', and agent nominalisations are actual exceptions to gradation – no agent nominalisation alternates between strong and weak grades in the nominal paradigm. It is an important grade-related generalisation about these nominalisations that the medial consonant is generally in the strongest grade, Q3, thus [tˢĭellli] from /tˢiellɑ+i/ 'yell', [vĭehhki] from /viehkɑ+i/ 'run', [stŏahhki] from /stoahkɑ+i/ 'play', each form being both nominative singular and accusative singular. Support for our prediction that a bimoraic parse of mid-vowel diphthongs overrides overlong gemination

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comes from the fact that roots with the diphthongs /oa ea/ before geminate consonants always have a surface (invariant) Q2 consonant rather than a Q3 consonant. Consider the distribution of surface vocoid and consonant lengths in the following set of agent nominalisations (which are both nominative singular and accusative singular).

(36)	[geassi]	/keasi+i/	'pull'
	[tˢĭellli]	/tˢielɑ+i/	'yell'
	[stŏahhki]	/stoakʰɑ+i/	'play'
	[bŭohhtˢi]	/puotˢʰi+i/	'be sick'
	[bĭemʔmi]	/piemʔɑ+i/	'feed'
	[deaffi]	/teafa+i/	'talk rude'
	[gĭesssi]	/kiesa+i/	'wind into a ball'
	[vĭehhki]	/viekʰɑ+i/	'run'
	[geanʔni]	/keanʔi+i/	'tie'

The only context where the medial consonant in an agent nominalisation is surface Q2 rather than Q3 is when the consonant is a geminate (not aspirated or glottalised) and preceded by [ea oa]. This is the context where the burden of realising the quantity distinction rests solely on duration. There is no need to complicate the account of agent-nominalisation morphology with a disjunctive description of quantity properties, when our analysis automatically predicts that Q3 is realised the same way as Q2 in this context.

Additional evidence shows that surface non-alternating nouns such as [neavvu] and [ʃeaffɑ] do in fact undergo gradation, whose effect is often (but not always) obscured by the regular bimoraic syllabification of mid-vowel diphthongs. Since the presumed Q3 quantity of the geminate is thwarted by parsing /a/ to the consonant's mora, and overlong geminates are representationally possible only if the consonant exhausts its mora, then the prediction of our analysis is that a process monophthongising /ea oa/ could eliminate the segment /a/ which deprives a Q3 geminate of its normal Q3 realisation. Monophthongisation is an active part of North Saami phonology, and occurs in the illative singular of stems ending in the back vowels /ɑ u/. The illative singular suffix is /i/, which causes short /ɑ/ to delete: illative singular is also a morphological category supplying the floating mora which triggers strong grade consonants (see (11)). When added to a stem ending in /ɑ u/, the illative singular causes monophthongisation of a preceding diphthong.

(37)	*nom sg*	*acc sg*	*ill sg*	
	healla	healɑ	heelli	'heel of shoe'
	viessu	viesu	viissui	'house'
	ʧiehkɑ	ʧiegɑ	ʧiihki	'corner'
	muohtu	muoðu	muuhtui	'cheek'
	loaʔnɑ	loanɑ	looʔni	'loan'
	lieʔmɑ	liemɑ	liiʔmi	'broth'

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We can now contrast stems such as /healɑ/, with a mid diphthong and a lexically non-moraic consonant which manifests a length alternation between nominative singular and illative singular *vs.* accusative singular, with stems such as /neav$_{\mu}$u/ and /ʃeaf$_{\mu}$ɑ/, which manifest a length alternation, but only in the illative singular, when the diphthong is eliminated.

(38)	*nom sg*	*acc sg*	*ill sg*	
	neavvu	neavvu	nevvvui	'work tool'
	ʃeaffɑ	ʃeaffɑ	ʃefffi	'chef'
	hot^{h}eallɑ	hot^{h}eallɑ	hot^{h}ellli	'hotel'

As we predict, superficial 'exceptions' like [neavvu] and [ʃeaffɑ] are not actually exceptions, but are complications, namely that the realisation of Q3 as overlength of a geminate is overridden in a well-defined phonological context, which follows from the fact that /a/ in a diphthong links to the syllabically parsed mora of a would-be overlong consonant by Attachment to Mora.

4.3 Q3 ~ Q1 gemination

While strong-grade Q3 geminates alternate with weak-grade Q2 geminates after certain nuclei, Q3 and Q1 alternate after some monophthongs, but not diphthongs or /a/. Such stems have an underlying non-moraic consonant (hence weak-grade Q1).[12]

(39)	*nom sg*	*acc sg*	
	[vivvvaa]	[vivaa]	'son-in-law'
	[dɑvvvi]	[dɑvi]	'north'
	[vɑʃʃʃi]	[vɑʃi]	'hatred'
	[gusssaa]	[gusaa]	'cow'
	[dolllaa]	[dolaa]	'fire'
	[bɑlllu]	[bɑlu]	'fright'

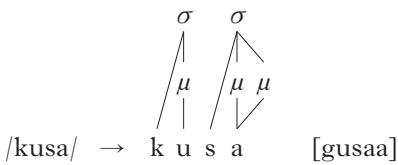
The class of such nouns is limited to stems with a monophthong nucleus which excludes /a/: that is, such nouns are the short monophthongal counterpart of the nouns in §4.1.

The appearance of Q3 in the strong grade rather than Q2 (the usual strong-grade quantity paired with Q1) is an automatic consequence of our analysis. In the weak grade, the surface form simply shows the direct prosodification of the underlyingly short consonants and vowels.

[12] Voiceless sonorants, whose analysis is uncertain, may also be analysed as falling in this class, e.g. [t^{s}ihrraa ~ t^{s}ihraa] 'squeaking of mice (NOM SG ~ ACC SG)'.

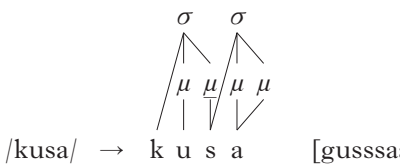
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(40)



The consequence of adding $\underline{\mu}$ to such a stem is that the medial consonant becomes moraic, thus geminate. This results in the syllabification in (41).

(41)



Pre-continuant Lengthening (29) does not apply here, since it is not triggered by $\underline{\mu}$. Its non-application can be guaranteed if lexically specified moraic consonants are syllabified in coda position before (29) applies, and syllabification of the output of $\underline{\mu}$-docking (22) takes place after (29), so that $\underline{\mu}$ is not syllable-final at the stage when lengthening might apply, and forms like [gusssaa] do not have a syllable-final moraic continuant when (29) applies.

Under an analysis where overlong geminates are bimoraic in a trimoraic syllable, it would be difficult to explain the source of the spontaneous third mora here – there is not even a requirement in the language that stressed syllables be bimoraic (e.g. the first syllable of [dolaa]). Thus not only does our analysis account for overlong consonants without requiring three moras, but positing a third mora for the sake of representing overlength would be an ad hoc complication in the grammar.

4.4 Ordinary preaspiration

Similar patterns arise when the medial consonant is an underlying aspirated stop, but there are segmental complications. As seen in (42), such stems (which, like the case of the simple gemination stems in §3.1, all have a bimoraic nucleus with the vowel /a/ or a diphthong) have a preaspirated consonant in the strong grade and a voiced consonant in the weak grade. We analyse this as an alternation between (moraic) aspirated stops (realised as preaspirated) and non-moraic deaspirated stops, as indicated in the intermediate forms, which abstract away from certain segmental changes.

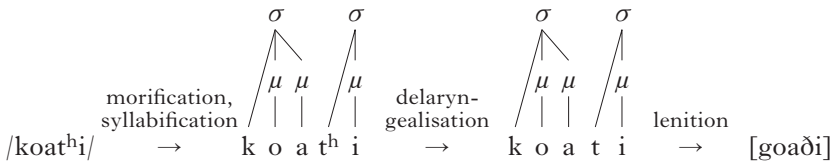
(42)

nom sg	*intermediate*	*acc sg*	*intermediate*	
[ʧiehkɑ]	ʧiekk^{h}ɑ	[ʧiegɑ]	ʧiekɑ	‘corner’
[muohtu]	muott^{h}u	[muoðu]	muotu	‘cheek’
[goahti]	goatt^{h}i	[goaði]	goati	‘big tent’
[aaht^{s}i]	aatt^{sh}i	[aad^{z}i]	aat^{s}i	‘hay-rack’
[neahpi]	neapp^{h}i	[neabi]	neapi	‘nephew/niece of man’

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While the underlying segmental properties of the consonant are best revealed in the strong grade (aspiration is preserved), the prosody is best revealed in the weak grade – the consonant is underlyingly non-moraic. In the weak grade, the consonant syllabifies as the onset of the second syllable. Being non-moraic, it loses aspiration, and between vowels it is phonetically voiced, or lenites to [ð] in the case of /t^{h}/.

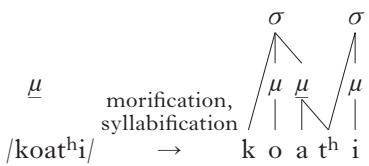
(43)



Informally stated, there is a requirement in North Saami that laryngeal features be licensed by a mora – we discuss this below. Because of this, when a consonant is non-moraic, its laryngeal features are deleted, resulting in the intermediate forms *koati*, *neapi*. Assuming that intervocalic voicing of unaspirated stops is a phonological rule, the mapping from *neapi* to [neabi] involves the application of a voicing rule. The realisation of *koati* as [goaði] involves a further general process in the language, which spirantises a single unaspirated alveolar stop *t* to [ð] between vowels.

In the strong grade, $\underline{\mu}$ links to the intervocalic consonant. The prosodic pattern of these stems is parallel to that of [guolli ~ guoli], discussed in §4.1.

(44)



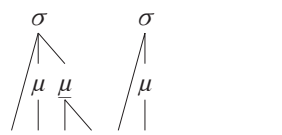
The phonological account could end here, saying that because the consonant is moraic, aspiration is licensed, and is phonetically timed as preaspiration. We pursue a phonological treatment of preaspiration and deaspiration, and show the advantages of treating preaspiration as a phonological matter.

In the strong grade, stems with underlyingly non-moraic aspirated stops behave parallel to stems with underlyingly single consonants which alternate between singletons and geminates. Strong grade [goahti] and [guolli] morify the first vowel of the diphthong by core syllabification, and $\underline{\mu}$ attaches to the post-tonic consonant, which syllabifies as the coda of the first syllable. The second element of the diphthong syllabifies by linking to the coda mora via Attachment to Mora (20). Strong grade [aaht^{s}i] and [gaaffe] lengthen their first-syllable vowel by Low Front Vowel Lengthening (24), linking $\underline{\mu}$ to the low vowel. Weak grade [aad^{z}i] and [gaafe] similarly undergo (24), which inserts a mora for /a/ to attach to.

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We posit that derivation (44) continues by splitting an aspirated stop into a sequence of *h* in the coda plus stop in the onset, resulting in (45).

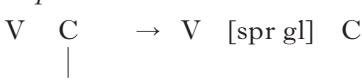
(45)



[goahti]

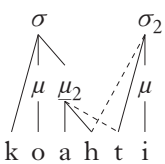
This requires a segmental sequencing process, where the feature [spread glottis] (which is an unordered part of an ambisyllabic consonant) becomes a separate segment, ordered with respect to the remains of the consonant. We propose that this be accomplished by (46).

(46) *Aspiration Linearisation*



By this rule, a single segment (a feature structure dominated by a root node) splits into two segments, the first having only the feature [spread glottis], i.e. [h]. Prosodic reorganisation of /t^{h}/ is phonologically necessary: were each of the segments resulting from segment-splitting to retain all of their original prosodic linkages, crossed lines would result, as in (47).

(47)

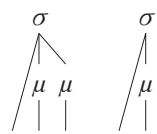


This is prevented by eliminating at least one of the crossing lines. Since *[ht] is not a word-initial onset in North Saami, we may assume that the association of [h] to σ_2 is eliminated. Since there are no word-final clusters at all, we may also assume that the association of [t] to μ_2 is eliminated. It is difficult to pin down the exact output of (46) by appeal to other phonological rules which refer to the precise derived prosodification of [h] or [t].

We now return to the nature of the laryngeal licensing requirement, in light of the proposal that aspiration is converted to a full coda segment [h]. In (45), [h] exists on the surface because it is prosodically licensed in the syllable via a coda mora. The linearisation rule does not require the aspirated segment to be moraic in order for the laryngeal feature to be segmentalised, so the question arises as to what would become of *h* when the stop is not moraic, that is, when (46) produces (48).

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(48)



[goaði]

In lieu of any other syllabification process rescuing the stranded consonant, floating [h] simply deletes by Stray Erasure.[13] Thus, under our linearisation approach to aspiration, the laryngeal moraic licensing requirement reduces to the fact that without a mora for coda syllabification, the segmentalised laryngeal feature has no place in the phonological representation, and is therefore subject to Stray Erasure.

4.5 Long preaspiration

Parallel to the overlong ~ long gemination pattern analysed in §4.2, there is an alternation between long and regular preaspiration, with alternations in nuclear length. The stems of (49) have an underlyingly moraic stop, so their aspiration is always licensed and realised.

(49)

nom sg	*acc sg*	
[gĕahhʧu]	[geahʧu]	'surveillance'
[mĭehhki]	[miehki]	'sword'
[sĕahhkɑ]	[seahkɑ]	'bag'
[ŏahhpɑ]	[oahpɑ]	'teaching'
[hehhke]	[heehke]	'hay-frame'
[mohhki]	[moohki]	'corner (natural)'
[lahhti][14]	[laahti]	'floor'

All diphthongs and monophthongs can occur in the first syllable nucleus of such stems.[15]

The weak grade (e.g. [geahʧu]) syllabifies in a manner analogous to the strong grade of simple aspirates (e.g. [goahti]), the difference from (44) being that here the mora on the aspirated consonant is lexically present. In either case, the second member of the diphthong links to that mora by Attachment to Mora, and is thus syllabifiable independent of the first vowel. In the case of monophthongs, as in [heehke], the underlying short monophthong is lengthened by Pre-continuant Lengthening, which

[13] Phonological deletion of *h* is necessary since derived *t* undergoes intervocalic lenition to [ð].

[14] Since there is no perceptible phonetic distinction between [a] and [ɑ] before overlong aspiration, we represent the vowel as front [a], since in other contexts it is clear that the vowel is underlyingly front /a/.

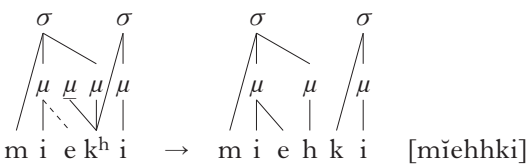
[15] We know of no such stems with /ɑ/.

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spreads the mora of the syllable-final continuant *h* to the preceding vowel. This provides further phonological evidence for the phonological treatment of preaspiration as a sequence of [h] + stop – aspiration behaves as a coda continuant with respect to the lengthening rule. We shall see in §4.7 that, in contrast, the segmentalised realisation of glottalised nasals as glottal stop + nasal yields a laryngeal segment that is, as expected, not treated as a continuant for purposes of vowel length.

The derivation of strong grade [mĭehhki] proceeds in a fashion analogous to that of [gŭosssi] in (34). Because of the presence of the lexical and inflectional moras, core syllabification and Short Diphthong Formation (33) create a short diphthong. The moraic stop syllabifies as the coda of the first syllable (as well as the onset of the following syllable), giving the first step in (50). Segmentalisation of aspiration realises the aspiration as the exclusive consonant of the coda, followed by Stray Erasure of the unparsed mora.

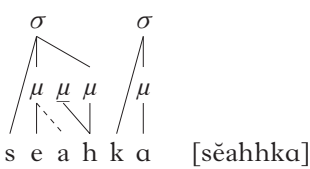
(50)



Note that when coda [h] exhausts the mora, preaspiration is long – the [h] receives all of the timing implied by the mora. When, as in weak-grade [miehki], the coda [h] shares a mora with the preceding vowel, [h] is phonetically shorter.

Since short diphthongs are formed only by a specific rule (like (33)) parsing the second element of a diphthong into the first mora of a syllable, we must now consider forms with an aspirated moraic stop and a mid diphthong, as found in examples such as [sĕahhkɑ] and [ŏahhpɑ]. It should be noticed that although [ea] and [oa] are generally long, there is one context in the language where they can be short, namely in the strong grade of lexically moraic aspirated stops. This indicates that at some point after segmentalisation of aspiration, something specific happens to the /a/ element of the diphthong, i.e. it associates with the mora to its left.

(51)



The rule of Leftward Capture (52) links an unsyllabified vowel to the mora to its left, just in case the free mora to its right associates with *h*.

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(52) *Leftward Capture*



If the following mora is not free but is syllabified (as in the case of strong grade [goahti] or weak grade [seahkɑ]), then /a/ does not join with a mid vowel under a single mora. As we will see in §4.8, if the following free mora is linked to a consonant other than *h* (as in [boaɲʔɲi]), /a/ does not form a short diphthong.

4.6 Q3 ~ Q1 aspiration

Parallel to the gemination alternation discussed in §4.3, there is an alternation between a strong-grade Q3 preaspirate and a weak-grade Q1 voiced stop after an underlying short monophthong.

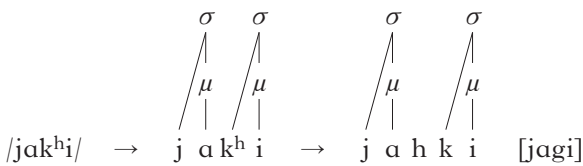
(53)

nom sg	*acc sg*		
[jɑhhki]	[jɑgi]	/jɑkʰi/	‘year’
[ʧɑhhtˢaa]	[ʧɑdᶻaa]	/ʧɑtˢʰa/	‘isthmus between two lakes’
[ruhhtaa]	[ruðaa]	/rutʰa/	‘money’
[bɑhhtaa]	[bɑðaa]	/pɑtʰa/	‘ass’
[ohhtˢu]	[odᶻu]	/otˢʰu/	‘search, register’

All such stems have a short monophthong, excluding /a/.

The weak-grade form involves just basic CV-syllable prosodification, and deaspiration of the moraically unlicensed aspiration (since there is no coda mora).

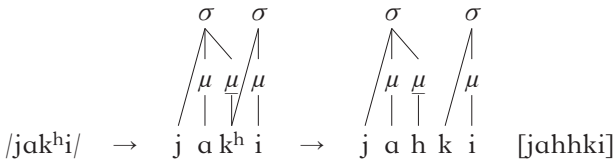
(54)



With the case suffix μ added in the nominative singular, this renders the medial consonant moraic, which gives a syllabic position for [h] resulting from aspiration. The monomoraic nucleus has only a single vowel, so Diphthong Morification (18) would not motivate adding a second mora. Segmentalisation of aspiration as a coda [h] in the strong grade does not trigger Pre-continuant Lengthening (29) of the nuclear vowel, since, as we noted above, μ is not syllabified until after (29) applies, so the conditions required for (29) are not satisfied at this stage. Consequently, the vowel remains short, and later syllabification of coda [h] exhausts the second mora.

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(55)



Because no other segment is associated with $\underline{\mu}$, all of its timing is realised on [h], making it phonetically overlong.

4.7 Preglottalised nasals: Q1 ~ Q2

The plain nasal ~ preglottalised nasal alternation is seen in (56) after a long nucleus.

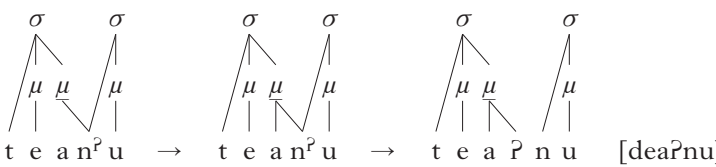
(56)

nom sg	*acc sg*	
[deaʔnu]	[deanu]	'large river'
[loaʔnɑ]	[loanɑ]	'loan'
[baaʔni]	[baani]	'tooth'
[laaʔnɑ]	[laanɑ]	'heap'

As mentioned above, the distribution of diphthong length is complex, and we begin with invariantly long nuclei – those which, for segmental reasons, always have long vowels. All mid-vowel diphthongs are long, as is /a/.

Parallel to the analysis of preaspirated stops, preglottalised nasals are treated as underlying nasals with a laryngeal feature, one that is mapped to a glottal stop segment, thus /mˀ/ → [ʔm]. We start with the strong grade, where the laryngeal feature can be realised. Since an additional mora, $\underline{\mu}$, is available and associates to the medial consonant, the nasal is also parsed as the coda of the first syllable. Core syllabification and coda syllabification result in the first step of (57). Attachment to Mora then results in the syllabification of /a/ in the second step. Segmentalisation of the laryngeal feature finally realises glottalisation as a coda glottal stop.

(57)

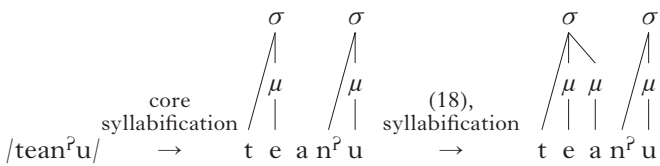


At this point, it looks as though a generalised version of Aspiration Linearisation (46) could handle this final step: but below, we give evidence that there is a separate rule, one which specifically assigns glottal stop to syllable-final position (rather than postvocalic position), as specified by (46).

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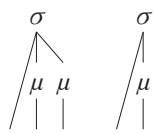
In the weak grade, when there is no mora for the consonant to associate with, it is exclusively in the onset.

(58)



When the laryngeal feature is sequenced as the segment [ʔ], since it cannot be syllabified due to the lack of a coda mora, it is deleted, and surface [deanu] results.

(59)



This analysis extends easily to nouns such as [laaʔnɑ ~ laanɑ], with the vowel /a/. In the weak grade, an additional mora must be assigned to the nuclear vowel /a/, and in the strong grade, μ provides the mora required by Low Front Vowel Lengthening (24). Thus there is significant parallelism between stems with medial glottalised nasal and those with preaspirated stops.

Differences also arise when the preceding nucleus is short. As seen in (60), monophthongs in this phonological class are invariantly short (except for /a/, covered above, which is long). We also indicate in our transcriptions that there is (surface-predictable) lengthening of the coda glottal stop, a fact whose explanation has significant implications for the phonological analysis.

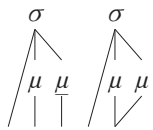
(60)

nom sg	*acc sg*	
[joʔʔɲaa]	[joɲaa]	'lingonberry'
[lɑʔʔɲaa]	[lɑɲaa]	'room'
[gɑʔʔmu]	[gɑmu]	'instinct'
[rɑʔʔni]	[rɑni]	'crumb, morsel'
[ʧiʔʔmaa]	[ʧimaa]	'bend, bowing'
[iʔʔmi]	[imi]	'uncle's wife'

The consonantal alternation here is exactly the same as that in (57) and (58). The nuclear vowel does not lengthen even when it is followed by a coda consonant, since stops do not trigger Pre-continuant Lengthening. Nothing causes a sharing of the coda mora with the preceding vowel, so the vowel remains short. Thus the surface representation of [joʔʔɲaa] is as in (61).

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(61)



[joʔʔɲaa]

The structural difference between [deaʔnu] (57) and [joʔʔɲaa] (61) makes the prediction that there should be a difference in the duration of glottal stops after long vowels and diphthongs *vs*. those after short vowels. This is indeed the case, though it is a non-contrastive phonetic detail that a glottal stop is longer after a short nucleus, and this length is perceptually somewhat less salient than the degree of overlength associated with exhausting the mora in the case of overlong [h] or other fricatives. In a set of 71 words of the structure (C)V(V)ʔNV with long and short nuclei, glottal stop had a mean duration of 318 ms after a short nucleus and 235 ms after a long nucleus. Total nucleus + [ʔ] duration is indistinguishable for words like [laaʔnɑ] and [lɑʔʔɲaa], being on average 417 ms.

Nouns of this phonological type (medial glottal stop + nasal), with a high-vowel diphthong, have an invariant long nucleus in some contexts and an alternating-length nucleus in others. The nucleus is always long when the vowel of the second syllable is /ɑ/.

(62)

nom sg	*acc sg*	
[lieʔmɑ]	[liemɑ]	‘broth’
[ruoʔmɑ]	[ruomɑ]	‘tracebearer’

This is as expected: it is parallel to the data in (56).

High diphthongs are short in the strong grade when the vowel of the second syllable is either /i/ or /u/.[16]

(63)

nom sg	*acc sg*	
[gŭoʔʔmi]	[guomi]	‘roof of mouth’
[fŭoʔʔni]	[fuoni]	‘bad’
[dŭoʔʔmu]	[duomu]	‘judgement’

The data of (63) illustrate the second context where high diphthongs can be short, namely before a consonant cluster when the vowel of the following syllable is not /ɑ/.

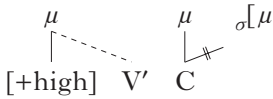
It is unclear what the best way is to capture the fact that /ɑ/ does not trigger this short diphthong formation rule. In other areas of the phonology, there is evidence for associating /ɑ/ with prosodic weakness, for example, the epenthetic vowel in the essive case is [i] in

[16] An accidental gap in the data make it impossible to test what would happen before /a/ which otherwise patterns with /i u/; before /e o/, all diphthongs independently monophthongise, as noted in §2.

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odd-numbered (stressed) syllables ([ʧaalim-i-n] 'writing', [vuogɑs-i-n] 'suitable', [ɑhhkið-i-n] 'boring') but [ɑ] in even-numbered (unstressed) syllables ([beaivɑðɑhhk-ɑ-n] 'sunshine', [nuorɑmuss-ɑ-n] 'youngest', [monemuʤʤ-ɑ-n] 'kidney'). Rather than refer directly to the presence of two consonant segments, we refer to this fact indirectly via the requirement that the consonant following the unparsed diphthong element must be exclusively associated to one syllable – that is, it is not geminate (the notation in (64) indicates that there is no association between C and any item to the right of μ).

(64) *Short Diphthong Formation 2*



This rule pre-empts Attachment to Mora, which would otherwise parse the diphthong of *guoʔmi* as long, by associating [o] to the mora of [ʔ].

There are other contexts where Short Diphthong Formation 2 applies, especially in all stems with obvious medial consonant clusters and the requisite following vowel context, illustrated below and documented more extensively in Bals *et al*. (2007).

(65)	[gŭowwlu]	'area (NOM SG)'	[gŭowllu]	'area (ACC SG)'
	[rŭowwdi]	'iron (NOM SG)'	[rŭowtti]	'iron (ACC SG)'
	[bĭerkku]	'meat (ACC SG)'	[vŭowssaa]	'bull (ACC SG)'
	[gĭelldu]	'prohibition (NOM SG)'	[gĭelttu]	'prohibition (ACC SG)'

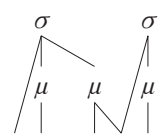
The rule does not parse a diphthong as short before /i u a/, even though a consonant cluster appears to follow before geminate consonants ([guolli], [guossi]) and preaspirated stops ([muohtu], [miehki]). What distinguishes the stems which are subject to (64) from those such as [guolli, muohtu], which are not, is that at this point in the derivation, stems which shorten the diphthong have consonant clusters, but stems like [guolli, muohtu] have single consonants shared between syllables.

(66) a.



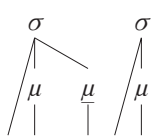
[guolli]

b.



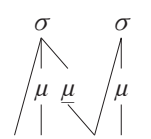
[gŭowllu]

c.



[gŭoʔʔmi]

d.



[muohtu]

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This correlation is obvious in the case of [guolli] *vs.* [gŭowllu], following standard assumptions regarding the monosegmentality of geminates. The difference between [gŭoʔʔmi] and [muohtu] follows from the fact that segmentalisation of glottalisation applies before and feeds (64), whereas segmentalisation of aspiration follows (64); thus a preaspirated consonant is a single consonant when (64) applies. This provides one piece of evidence that segmentalisation of aspiration and segmentalisation of glottalisation are separate processes, the latter being formalised in (70) below. We consider below additional data showing a difference in surface realisation in Q3 preaspiration *vs.* preglottalisation.

4.8 Interrupted nasals: Q2 ~ Q3

Parallel to the Q2 ~ Q3 alternations with geminates and preaspirated stops, there is an alternation between interrupted nasals and glottalised nasals. In the strong grade a glottal stop is flanked by identical nasals, and in the weak grade we find a glottal stop followed by a nasal.

(67)

nom sg	*acc sg*	
[boaɲʔɲi]	[boaʔɲi]	'husband'
[gunʔni]	[guʔʔni]	'honour'
[bonʔni]	[boʔʔni]	'bottom'
[bĭemʔmu]	[bĭeʔʔmu]	'food'

We also include the verbal forms [bĭemʔmɑt] 'to feed' (strong grade) and [bieʔmɑt] 'feed (2SG PRES)', which are morphologically related to the noun [bĭemʔmu], to further illustrate the connection between diphthong length and the vowel of the following syllable.

We derive the [NʔN ~ ʔN] alternation from one underlying segment, a glottalised nasal – parallel to our derivation of [hC] sequences from monosegmental /C^h/ – via segmentalisation of glottalisation. The prosody of this alternation is parallel to the [hhC ~ hC] preaspiration alternation, in that [NʔN] behaves like the overlong version of a glottalised nasal, but the rule segmentalising the glottal feature as a glottal stop is not the same as the one segmentalising aspiration. Whereas aspiration is sequenced to appear after the vowel, and thus entirely before the stop, glottalisation is sequenced to appear at the end of the syllable, which causes splitting of the nasal.

The weak grade of nouns having this alternation is identical to the strong grade of the Q1 ~ Q2 nouns such as [deaʔnu ~ deanu] discussed in the preceding section, being distinguished only by the fact that the mora resulting in surface [ʔN] is lexically present. The more interesting and phonologically distinct case is the strong grade, where both lexical and inflectional moras are present. In the case of [gunʔni], initial morification and syllabification yield (68).

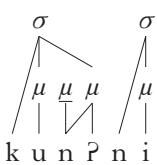
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(68)



The nasal is associated to three positions: $\underline{\mu}$, the following lexical mora and σ_2. The rule segmentalising [constricted glottis] does not directly eliminate these associations, and just positions the glottal stop at the end of σ_1, not after the vowel, as is the case with preaspiration. The emerging glottal stop associates to the syllable-final mora, so that it is followed by no other segmental material in the syllable. Because existing associations to prosodic tiers are preserved, this causes a splitting of the nasal. This is a process very similar in effect to the mitosis of a single multiply linked /b/ into two *b* segments in Tiberian Hebrew [sibbeːβ] 'he surrounded' from /sb/, discussed under the rubric of Tier Conflation (see McCarthy 1986). Splitting of *n* into two segmental instances is the result in North Saami, with the first nasal being postvocalic in the first syllable and the second nasal linking to the onset of the second syllable.

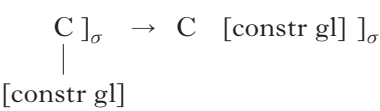
(69)



Stray Erasure eliminates the unassociated $\underline{\mu}$, which plays no further role in the grammar. Closer scrutiny of the details of diphthong length below provides evidence that the unsyllabified mora is actively deleted in the phonology, supporting the application of Stray Erasure.

Glottal stop creation can be derived by (70), which separates [constricted glottis] from the segment bearing it, linearising it into syllable-final position.

(70) *Glottalisation Linearisation*

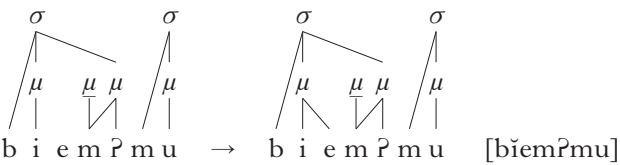


This rule differs from Aspiration Linearisation (46) both in terms of ordering ((70) precedes Short Diphthong Formation 2 (64), but (46) follows (64)), and the position to which the laryngeal feature is moved – postvocalically in the case of aspiration, but syllable-finally in the case of glottalisation.

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The derivation of [bĭemʔmu] is similar, except that the nucleus contains a diphthong with a high vowel. Because of the prosodic structure following the diphthong – the two non-head moras required for Short Diphthong Formation 1 and the coda stop + full vowel condition for Short Diphthong Formation 2 – either rule is applicable, and we expect the diphthong /ie/ to be short.

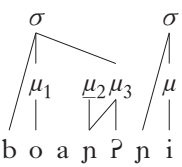
(71)



[bĭemʔmu]

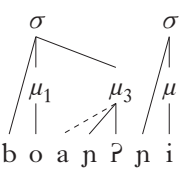
When the diphthong has a mid-vowel first element, as in [boaɲʔɲi], /a/ would not join with the head mora in a short diphthong, because only a high vocoid conditions general parsing of V_2 to the head mora, and /a/ in a mid diphthong links to the head mora only before long preaspiration. After basic prosodification and glottal stop linearisation, structure (72) results.

(72)



Stray Erasure eliminates floating μ_2, and subsequently Attachment to Mora applies, giving the surface output in (73).

(73)



[boaɲʔɲi]

We observe that three segments are associated to the final mora: the theory has no direct limit on the number of segments that can be under a mora, only indirect limits derived from the nature of the rules parsing segments to moras.[17]

[17] A reviewer notes that our account predicts that there should be a duration contrast between the [Nʔ] of [bĭemʔmu] and [boaɲʔɲi], since the second mora in the former dominates just [mʔ] but in the latter it dominates [aɲʔ]. We have not studied this matter extensively from a phonetic perspective but our data indicate that [Nʔ] is around 50 % longer in words like [bĭemʔmu], when it exhausts the mora, than when it shares the mora with the second part of a diphthong, as in [boaɲʔɲi].

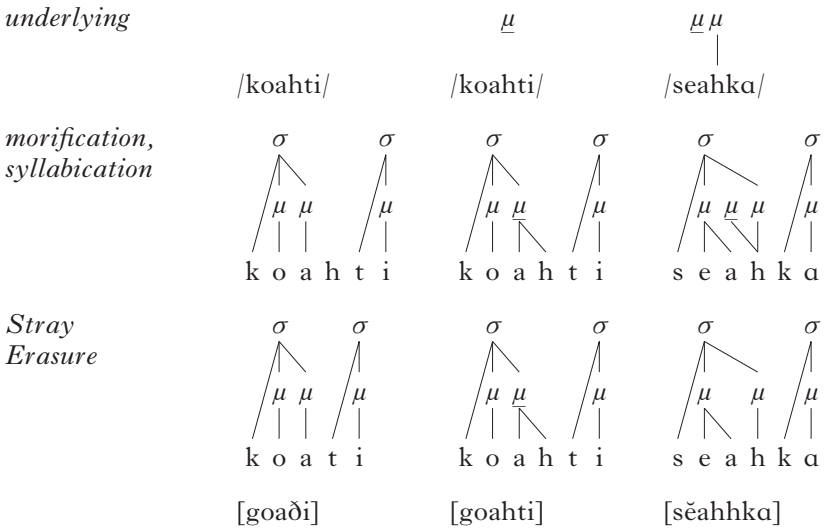
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4.9 The underlying representation of laryngealised consonants

In light of the fact that deaspiration and deglottalisation are explained by assuming a sequential representation of such consonants, interacting with Stray Erasure, a natural move to consider is that even underlyingly, preaspirated and preglottalised consonants are sequences of segments. There are a number of arguments against such a move.

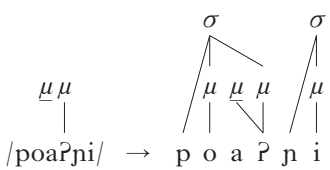
The most straightforward way to implement this would be to assume that, segmentally, stems have their Q2 form, e.g. /koahti/, /seah$_{\mu}$kɑ/, /lɑʔɲaa/, /pieʔ$_{\mu}$mu/. If a coda mora is available, it will map to the laryngeal, preventing its deletion. For stems such as /seah$_{\mu}$kɑ/, which have an underlyingly moraic consonant, we may presume that the mora is lexically attached to the laryngeal. One crucial aspect of morification under this account would be that a consonant cannot be parsed to the coda by association to a vowel's mora: the coda laryngeal is morified either lexically (for stems like /seah$_{\mu}$kɑ/ and /pieʔ$_{\mu}$mu/) or by association of $\underline{\mu}$ (in the strong grades of /koahti/ and /lɑʔɲaa/). Representative examples of preaspiration are given in (74).

(74)



The first challenge which an underlying sequence account faces is the problem of relating Q2 and Q3 preglottalisation, i.e. the alternation between [boaŋʔɲi] and [boaʔɲi]. Given the underlying stem /poaʔɲi/, the problem is explaining the copying of a nasal to get [boaŋʔɲi]. The input–output relation involved through core syllabification, $\underline{\mu}$-docking (22) and Mora Syllabification (19) is given in (75).

(75)



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It is crucial that the required nasal insertion rule precede Stray Erasure – it is specifically triggered by a bimoraic glottal stop, but Stray Erasure will eliminate one of the moras. The formalisability of such a rule depends on certain theoretical assumptions. The process could be stated as a direct consonant copying rule such as (76).

(76) $$\emptyset \rightarrow \begin{bmatrix} +\text{nas} \\ \alpha\,\text{cor} \\ \beta\,\text{lab} \\ \gamma\,\text{ant} \end{bmatrix} / \text{—} \quad \overset{\text{ʔ}}{\underset{\mu \quad \mu}{\wedge}} \quad \begin{bmatrix} +\text{nas} \\ \alpha\,\text{cor} \\ \beta\,\text{lab} \\ \gamma\,\text{ant} \end{bmatrix}$$

Subsequently, the inserted nasal must link to a syllabified mora, after Stray Erasure. This of course runs counter to research within autosegmental phonology which has sought to limit the power of rules, so that apparent insertion of an identical segment is the result of a spreading rule (see Clements 1985, Hayes 1986, McCarthy 1988, Clements & Hume 1995).

Construing this process as a spreading rule faces a major difficulty, which is that such a rule would involve crossed association lines, involving the relationship between the target mora and the root node of the glottal stop.

(77)



Thus it would be necessary to construe the hypothesised nasal spreading as being the result of multiple rules spreading lower-level segment constituents, such as nasality spread (since intervening glottal stop would have no specification for nasality) and place spreading (assuming that glottal stop is placeless).

A quite significant problem with treating preaspirated and preglottalised consonants as underlying consonant clusters is that actual underlying clusters behave rather differently from preaspirated and preglottalised consonants. While a full analysis of gradation in stems with consonant clusters is beyond the scope of this paper, the gradation pattern of such stems can be considered briefly. As seen in (78), whenever the stem has a medial cluster, in the strong grade the first consonant is somewhat longer (it is the only consonant linked to $\underline{\mu}$) and the second consonant is a singleton, whereas in the weak grade the first consonant is shorter and C_2 is geminated, i.e. both consonants of the cluster are linked to a coda mora, and the second consonant is also in the onset of the following syllable.[18]

[18] This non-contrastive phonetic fact follows from our theory of the relationship between moraic structure and timing, but could be expressed as a simple generalisation that a syllable-final consonant is longer than a consonant followed by something within the syllable.

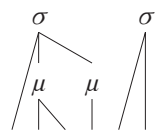
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(78)

nom sg	*acc sg*	
[mojjvi]	[mojvvi]	'chaos'
[doajjvu]	[doajvvu]	'belief'
[gŭowwlu]	[gŭowllu]	'area'
[leawwgɑ]	[leawkkɑ]	'flag'
[aajjgi]	[aajkki]	'time'
[daawwdɑ]	[daawttɑ]	'sickness'
[dĭewwdu]	[dĭewttu]	'man'
[doaŋŋgi]	[doaŋkki]	'clumsy person'
[gĭelldɑ]	[gieltɑ]	'community'

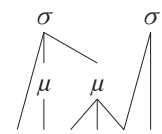
A typical representation of this distinction is that in (79).

(79) a.



[gĭelldɑ]

b.



[gieltɑ]

In other words, when the stem contains a consonant cluster, an extra mora is always mapped to the syllable, and in the weak grade it is assigned to the rightmost consonant, so that the cluster is always syllabifiable, and is thus phonetically realised. This is manifestly not the pattern followed by preaspirated and preglottalised consonants: if no lexical or suffixally determined mora is available for parsing derived *ʔ* or *h*, then that segment is deleted, e.g. weak grade /muot^{h}u/ → [muoðu] and /tuom^{ʔ}u/ → [duomu]. If stems of the type /muot^{h}u/ and /duom^{ʔ}u/ had underlying clusters, we would expect both consonants to always be parsed, as is the case with any other stem with a consonant cluster, and the gradation alternation should involve gemination of the final consonant in the weak grade, again as is the case with any other stem with a consonant cluster. Thus, if preglottalised and preaspirated consonants were underlying consonant clusters, we would incorrectly predict the following.

(80)

	nom sg	*acc sg*	
Q1 ~ Q2 preaspiration	(*)ʧiehhkɑ	*ʧiehkkɑ	'corner'
Q2 ~ Q3 preaspiration	sĕahhkɑ	*seahkkɑ	'sack'
Q1 ~ Q2 preglottalisation	*deaʔʔnu	*deaʔnnu	'large river'

5 Theoretical consequences

In this section, we discuss the consequences of North Saami phonology for two theoretical issues, first, the nature of laryngeal representations, and second, questions of syllable structure and length in moraic phonology.

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5.1 Laryngeal properties

Our analysis of preaspirated consonants in North Saami is they are underlyingly aspirated stops which split into [hC] clusters, with [h] being syllabified in coda position just in case there is a prosodic position (mora) for it. The treatment of preaspirated consonants has received a fair degree of attention in the literature (Garnes 1976, Thráinsson 1978, Clements & Keyser 1983, Hermans 1985, Hayes 1990, Buckley 1994, Keer 1999, Morén 1999, Ringen 1999, Helgason 2002, Hansson 2003, Silverman 2003, Kehrein & Golston 2004), but there is no consensus as to their proper representation or origin. Discussions have been significantly influenced by the facts of Icelandic, the best-studied example of preaspiration. It is generally agreed that in Icelandic, the difference between preaspiration and postaspiration is predictable and can be subsumed under one phoneme type, namely aspirated stop, which alternates prosodically in how aspiration is realised (e.g. [jœːtʰʏn] 'giant (NOM SG)', [jœhtnɪ] 'giant (DAT SG)'). Transcriptions of forms disagree in a manner that indicates a lack of clarity as to what the phonological output is. One can find transcriptions of the type [jœhtnɪ] (Thráinsson 1978), which implies full-segment status, [jœʰtnɪ], which implies 'property of the stop' status (Einarsson 1945), or even [jœ̥tnɪ] (Hansson 2003). Hansson (2003: 64) proposes that languages can differ in their treatment of preaspiration: 'Faroese preaspiration appears to be a genuinely sub-segmental property (like postaspiration), whereas in Icelandic it is clearly a full-fledged moraic segment [h]'.

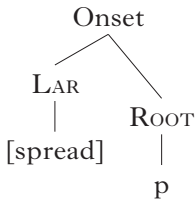
A theory of prelaryngealisation (subsuming preaspiration and preglottalisation under one theory) must address two aspects of the problem: what are the representations, and how is one type of representation mapped to another? This presupposes, of course, that two types of representation are possible. One line of theorising on laryngeal properties of consonants, seen in Golston & Kehrein (1998) and Kehrein & Golston (2004, ms), is that laryngeal features are not properties of specific segments, but are unordered properties within a prosodic constituent, and distinctions such as [pha] *vs.* [pʰa] are purely orthographic.[19] In contrast, standard representational theories since before *SPE* allowed for the possibility of a contrast between bisegmental [ph] and monosegmental [pʰ]. See Kehrein & Golston (2004) for restrictiveness arguments in support of an unordered properties model, based on the lack of contrast between [ʰp] and [pʰ], or [ph] and [pʰ], within a particular prosodic position. Golston & Kehrein (1998: 335) state that 'there is no contrast between pre- and postglottalization or between pre- and postaspiration, just as there is no contrast between pre- and postnasalization'. Ladefoged & Maddieson (1996: 73) observe: 'we do not know of any language in which it is necessary to regard preaspiration as a feature required for distinguishing underlying forms'.

[19] A similar view is expressed in the Converter-Distributor Model (Fujimura 2000).

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Kehrein & Golston (ms: 2) 'assume that laryngealized sounds (t^h, t') are phonologically and phonetically indistinct from laryngeal clusters (th, tʔ) within an onset or coda'. The equivalence of [ph hp p^h ^{h}p] is reduced in Kehrein & Golston (2004) to the representational assumption that laryngeal features are unordered with respect to supralaryngeal properties of segments.[20]

(81)



The claim in Kehrein & Golston (ms: 1) is that the cross-linguistic differences in pre- and post- realisation of aspiration and glottalisation 'result from three prosodic considerations: sonority sequencing, syllable-final fortition, and the avoidance of syllable-final glottalization'. Thus the postaspiration realisation in Icelandic [phaːr] 'pair' follows the standard increasing-sonority requirements of onsets, and preaspiration in [jøht.nɪ] reflects decreasing-sonority requirements of codas.

One of the most significant challenges for restrictive theories of laryngeal representation such as those of Kehrein & Golston is posed by Kashaya (Buckley 1994), which possesses, on the evidence of behavioural patterns, preaspirated/preglottalised and postaspirated/postglottalised consonants, as well as combined pre- and postlaryngealisation, and [hC/ ʔC] clusters.

(82)

ca-	'sit (SG)'
^{h}ca	'fly'
c^{h}a	'grasp'
^{h}c^{h}a	'knock over'
muhtu	'great horned owl'

Golston & Kehrein (1998) addresses this language, and their response to the facts is instructive of how the theory relies on a particular notion of 'contrast'. It is correctly noted that Kashaya does not present equivalently rich phonetic outputs within a syllable position. Preaspirated stops are realised as [h.C] clusters, thus preaspirated stops neutralise with /hC/ clusters. Preaspiration is also phonetically absent in utterance-initial position, exactly where /h/ could not be syllabified in the coda of a preceding syllable. Furthermore, /hC/ clusters are underlyingly in complementary

[20] We take the liberty of representing the Laryngeal and Root nodes on separate lines: Kehrein & Golston are explicit that no ordering between these nodes is to be assumed.

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distribution with preaspirated consonants – both are present in Buckley's analysis, but do not underlyingly contrast. The distinction between hC and preaspiration is thus a fact about deeper phonology, not surface phonetics. Kashaya phonetic forms can indeed be entirely described in terms of a contrast [h.t] *vs.* [.th].

Golston & Kehrein's analysis of Kashaya underscores an important difference in the goals of the present paper, compared to the former theory. Their theory concentrates on 'contrast' as a property of phonetic outputs. As Kehrein & Golston (2004: 325) put it, quoting Ladefoged & Maddieson (1996: 2), 'our study focuses on the elements 'that are known to distinguish lexical items within a language', i.e. on laryngeal contrasts involving voicing, aspiration and glottalisation that account for minimal pairs'. Our concern, on the other hand, is the proper representation of the phonological units at all levels of the phonology. We would also be concerned with accounting for the morphophonemic patterning of Kashaya roots beginning with preaspirated consonants, even though they are always mapped to plain stops or hC sequences.

As we have shown above, the representational nature of preaspiration in North Saami changes in the course of the derivation, and thus the presumption of behavioural uniformity throughout a language is falsified. In this respect, our analysis of preaspiration in North Saami is parallel to typical generative phonological analyses of Icelandic preaspiration, involving the mapping from a more abstract single segment /C^h/ with a laryngeal feature to a surface cluster [hC]. It is difficult to see how the theory of Golston & Kehrein could reconcile surface patterns of aspiration realisation which favour a sequence analysis of preaspiration with the failure of preaspirated and preglottalised consonants to behave like true clusters such as /lt jt wt nt/ in terms of C_2 gemination, and with the failure of preaspirated consonants (but *not* preglottalised nasals) to behave like clusters under Short Diphthong Formation 2 (64). That is, preaspirated stops in North Saami act both like single segments and like clusters, whereas the Golston & Kehrein theory of prosodic laryngeal representations does not countenance such dual behaviour.

North Saami also poses a problem for the claim of Kehrein & Golston (ms: 19) that 'aspiration and glottalisation never uncouple from sonorants, but always surface in whatever syllable the sonorant surfaces in', and (ms: 15):

> aspiration and glottalisation seem always to be tautosyllabic, so we never find e.g., preaspiration of [n] on the preceding vowel or preglottalisation of [n] on the preceding vowel: *[a^h.na], *[a^ʔ.na]. Generally, laryngeals stay bound to the sonorants they are associated with.

Their theory predicts uniform onset and intervocalic postlaryngealisation, thus [n^{ʔ}a.n^{ʔ}a] and [n^{h}a.n^{h}a], never *[^{ʔ}na.^{ʔ}na] or *[^{h}na.^{h}na]. It is unclear how such irrevocable coupling of laryngeal feature and sonorant is to be accomplished. However such a tautosyllabicity requirement might

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be enforced, this forbidden pattern is exactly what happens in North Saami.[21]

We have shown that a crucial factor governing the appearance of preglottalisation in nasals is whether the consonant is moraic, which clearly indicates that the glottal stop would have to be in the coda. Given the claim that the laryngeal feature is always in the same syllable as the sonorant, it follows that the nasal would also have to be in the coda, hence under Golston & Kehrein's restrictions, [lɑʔŋaa] must be parsed as [lɑʔŋ.aa]. This is a highly improbable conclusion, since the language does not allow any onsetless syllables except at the beginning of the word. It is also unclear how to reconcile the statement that laryngeal features 'always surface in whatever syllable the sonorant surfaces in' with forms like [bĭemʔmu], since the correspondents of the nasal appear in two different syllables.

We conclude that the unordered cluster theory of laryngeal properties is not tenable at all levels of the grammar, but we leave open the possibility that the theory may be correct in its claims about phonetics.

5.2 Length and syllable structure

A central argument of this paper is that, despite surface ternary durational differences in consonants, it is unnecessary to posit trimoraic syllables, and that limiting syllables to two moras is enlightening especially when it comes to understanding surface length trade-off relations between vowels and coda consonants.

Non-linear theories of length generally treat length as association to two prosodic positions (see Davis 2011, Odden 2011). Moraic theory somewhat complicates that relation for intervocalic geminates, in that linkage to a mora in one syllable and onset position in the other represent intervocalic geminates. The representation of strictly coda geminates has been most problematic: see Odden (1996) for discussion.[22] The fundamental question of interest to us is how a moraic coda consonant can be integrated into a syllable that already contains a long vowel, since such syllables have impelled others to posit trimoraic syllables.

Morén (1999) proposes a representation for weight-bearing coda *vs.* weightless coda, which as he points out, are 'sometimes referred to as final geminates' (1999: 22), e.g. in Hungarian, where final geminates (moraic, weighted consonants) are dominated by a mora, whereas a non-geminate consonant directly links to the syllable.

[21] It is also attested in Yurok, as shown by Blevins (2003).

[22] We only consider versions of moraic theory which allow segments to directly associate to the syllable like Hayes (1989), excluding the versions of Hyman (1985), Zec (1988) and Itô (1989), where all segments are dominated by a mora. We also set aside theories which combine moras and skeletal positions, such as Vago (1989).

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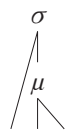
(83) a. 

[ʃɔk]

b. 

[ʃɔkk]

This contrasts with the type of representation assumed in Hayes (1989), where a weightless coda C is represented as in (84a) and a weight-bearing coda C is as in (84b).[23]

(84) a. 

[ʃɔk]

b. 

[ʃɔkk]

We take as our point of theoretical departure the principle that a maximally bimoraic syllable suffices universally, though we do not address every proposal for trimoraic syllables, e.g. the proposal of Hayes (1989) for trimoraic syllables in Estonian. Certain kinds of syllable structure pose a challenge for a moraic analysis which limits syllables to two moras, namely syllables which have long vowels plus a geminate consonant coda, i.e. [XV:C:] syllables. An example of such a language is Hungarian, which has words like *áll* [a:ll] 'stand' *vs.* *ál* [a:l] 'false'. Morén's (1999) moraic account of Hungarian relies on trimoraic syllables.

(85) 

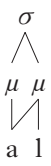
[a:ll]

A similar analysis is given to Finnish in Sherer (1994) and Kiparsky (2011). The question is whether facts such as the existence of [a:ll] in Hungarian are also consistent with restricting syllables to two moras.

The assumption that a coda geminate consonant is dominated by a mora does not automatically lead to the conclusion that the consonant is dominated by its own mora. Following the analysis which we have motivated for North Saami, a coda geminate after a long vowel can share a mora with the preceding vowel, thus [a:ll] can be represented as (86).

[23] Hayes does not imply that there is a connection between being geminate and representation (84b).

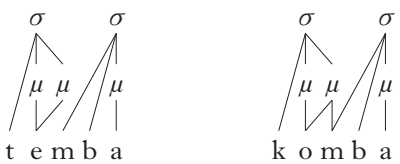
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(86) 

[a:ll]

Mora-sharing where the onset and first vowel are dominated by one mora has been proposed in a number of moraic subtheories, such as Hyman (1985), Zec (1988) and Buckley (1994), but is surprisingly rare in the literature with respect to vowels and following tautosyllabic consonants. Such mora-sharing representations have been employed in work by Maddieson (1993), Hubbard (1995) and Broselow *et al*. (1997), but only to handle differences in how languages can differ in vowel and consonant duration patterns.[24] Hubbard (1995) argues that Luganda and Runyambo differ in their phonetic realisation of long vowels before NCV sequences, proposing that in Luganda the nasal is (in surface representations) exclusively in the onset of the following syllable, as in (87a), whereas in Runyambo the nasal is also in the onset but shares a mora with the preceding long vowel, as in (87b).

(87) a. *Luganda* b. *Runyambo*



The motivation for this distinction is a phonetic difference, i.e. that in Runyambo long vowels before NC are proportionally not lengthened as much as they are in Luganda. This follows from the representation, so that in Runyambo, but not in Luganda, part of the timing of the second mora is assigned to the consonant. Broselow *et al*. (1997) give a similar analysis for the phonetic difference between Hindi and Malayalam.

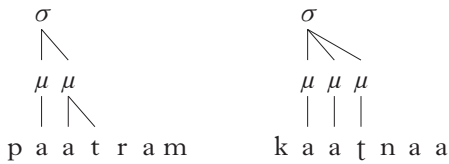
In Malayalam (88a), a long vowel before a coda consonant is shorter than a long vowel with no coda consonant, whereas in Hindi (88b), long vowel duration is not affected by a coda consonant. This fact is attributed to different representations of coda consonants in Hindi *vs*. Malayalam:

[24] Zec (1988) and Hayes (1989) also employ mora-sharing structures to distinguish coda consonants which contribute to syllable weight from those which do not, but they treat moraic consonants as exhausting their own mora, whereas non-moraic consonants share a mora with the preceding vowel, and they do not consider a so-called appendix representation such as that employed in Sherer (1994), Morén (1999) and Zec (2007) for a non-moraic non-geminate, where a coda consonant directly associates to the syllable. In addition, Zec (1988) assumes as a theoretical postulate that all segments link to the mora, never linking directly to the syllable.

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Malayalam coda consonants share a mora with a preceding vowel, whereas Hindi coda consonants have an independent mora.[25] The possibility that coda consonants in Malayalam are non-moraic is not considered by Broselow *et al*. (1997).

(88) a. *Malayalam* b. *Hindi*



Ham (1998) similarly investigates the phonetic connection between length and duration given the possibility of mora-sharing.

The above authors have identified and exploited a representational power of moraic theory: a mora may dominate one segment, as in the second mora of (88b), or it may dominate two segments, as in the second mora of (88a). The phenomena which have motivated these representational differences are details of phonetic implementation, and are differences between languages, not within a language. In principle, if the representational theory allows a mora to dominate either one segment or two, then it follows that such a difference could exist within a single grammar, and could be available to categorial phonology as well as phonetic implementation. North Saami is such a language, where representations similar to (88b) in having a consonant that exhausts the mora result in Q3 consonants, and ones similar to (88a) in having a consonant which shares a mora with a preceding vowel result in Q2 consonants.

By allowing both one-to-one and one-to-many mappings between mora and segment, the theory sanctions more possibilities than would be the case if only one-to-one mappings between mora and segment are allowed.[26] Then the question arises why such contrasts are not common – why are more languages not like North Saami? We believe that the answer lies in how such representations would come about. The surface contrasts arise through interaction between rules of morification and

[25] The difference between the languages in moraic treatment of coda consonants is also justified phonologically by the fact that stress is sensitive to coda consonants in Hindi, but not in Malayalam. Hindi is claimed to present stress evidence for a ternary weight distinction, thus by implication evidence for ternary moraic contrasts within a syllable. However, Crowhurst & Michael (2005) show using evidence from Nanti that 'weight' as judged from stress systems is much more complex than can reasonably be captured by an enumeration of moras in a syllable, thus it is not a foregone conclusion that an *n*-way prominence hierarchy for stress entails 1 to *n* moras in a syllable.

[26] We take it to be self-evident from the literature that many-to-one mappings between mora and segment are also allowed.

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syllabification plus a floating mora present in various affixes. Very simply, if a language lacks a source for prosodic opacity (a surface-unpredictable distinction between one-to-one and one-to-many mappings), then it will not have such contrasts on the surface.

It is an empirical question whether languages like Hungarian and Finnish, which are claimed to have trimoraic syllables based on surface forms such as Hungarian [a:ll] and Finnish [aluun] 'beginning (GEN SG)', actually require such syllables, a question which can only be answered by a detailed investigation of the phonology of such languages. That investigation must take into consideration the possibility that coda consonants may be moraic and yet share a mora with the preceding vowel. We have demonstrated in the preceding sections that this is not only conceivable, but enlightening for North Saami.

6 Summary

The focus of the preceding sections is the consonant gradation system of North Saami as spoken in Guovdageaidnu (Kautokeino). Our goal has been to present a description of the phenomenon in a way that makes the facts available to phonologists who are not specialists in Saami or Finno-Ugric. Because of the complexity of the language, we have narrowed our focus to the patterns of regular bisyllabic vowel-final stems. We have proposed a characterisation of the maximally relevant slice of the grammar, identifying the syllabification algorithm, the prosodic entity responsible for the particular manifestation of gradation, and the phonological interaction between them. Two issues of particular theoretical relevance have commanded our attention. We have proposed a representation of laryngeal features and the grammar of their realisation, and have also demonstrated and embraced a restrictive moraic theory of syllable structure, emphasising the possibility of representing the complex length facts of North Saami within the confines of a theory in which syllables dominate a maximum of two moras.

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