Quality-conditioned stress as length: glide epenthesis in Moksha

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In Strict CV, stress is assumed to be computed above the skeleton and therefore to be independent of melody (Scheer 2004), so the existence of genuinely quality-conditioned stress is not expected. It can, however, be reanalyzed with virtual length (Lowenstamm 1991; Ségéral & Scheer 2016; Ben Si Saïd 2011). This paper presents a reanalysis of quality-conditioned stress in Moksha, which helps model the interaction between stress and glide epenthesis, where /i/ and /u/ can spread to form a glide before vowel-initial suffixes. Vowel spreading can happen after polysyllabic nouns but not after the monosyllabic ones. This rule is linked to the representation of stress as underlying length.

Keywords: Stress, Glide epenthesis, Vowel-glide alternations, Virtual length, Strict CV, Moksha

Introduction

Strict CV is a lateral autosegmental approach to phonology (Lowenstamm 1996; Scheer 2004, 2012), an offshoot of Government Phonology (Kaye *et al.* 1990). Phonological representations have two tiers: a syllabic tier that consists of a sequence of CV units and a melodic tier, where segments are situated. The two tiers are linked with association lines.

In Strict CV, there is a special exponent for stress — the syllabic unit, or an empty CV (Larsen 1998; Szigetvári & Scheer 2005). The idea behind this representation is that it is a non-diacritical phonological object that can handle the effects that occur in vicinity of stress.[1]

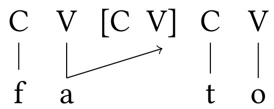
An important property of syllabic space as an exponent of stress is that it is purely skeletal. Strict CV presupposes the existence of two tiers, one syllabic and one melodic, which play different roles in the phonological computation. The processes that take place on the melodic level are strictly local. The melodic tier is not directly accessible to morphosyntax and such above-the-skeleton processes as stress and tone placement, infixation or phonologically-conditioned allomorphy (Scheer 2019b). Changes in the skeleton can cause melodic alternations, since melody is linked to skeletal slots with association lines, but melody cannot affect the skeleton. Stress is among the suprasegmental phenomena, so it belongs to the syllabic tier and can have effects on the melody, mediated by association lines.

For instance, a CV unit inserted by the stress algorithm can lengthen vowels or consonants. A classic example of an analysis featuring the empty syllabic unit as stress is Larsen's (1998) discussion of the interaction that tonic lengthening and *raddoppiamento sintattico* (lengthening of word-initial consonants) have with stress. Larsen (1998) suggests an explanation that rests on the representation of stress as an empty CV inserted after the stressed syllable. Tonic lengthening applies to stressed vowels, making them bipositional and therefore long (1). *Raddoppiamento*, on the other hand, causes the consonant to lengthen (2). Word-finally, long vowels are prohibited, that is why the syllabic

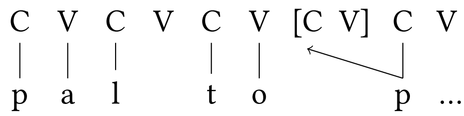
1. These effects are constrained: not every process can be triggered by stress. See Giavazzi (2010) for the discussion of stress-induced effects and Szigetvári & Scheer (2005) on the explanation of some of them in Strict CV.

space provided by final stress is taken up by the consonant.

(1) *fàto* [fa:to] ‘destiny’
(Italian; (Larsen 1998:90))



(2) *paltò pulito* [paltoppulito] ‘clean coat’
(Italian; (Larsen 1998:92))



So, stress can be exponed by syllabic space, and thus contribute to length. Length, in turn, can determine stress placement: in languages with contrastive length and a weight-dependent stress algorithm, syllables with long vowels are often heavy. Long vowels are considered bimoraic in the standard metrical theory of stress (Hayes 1995), and this is replicated in Strict CV, where long vowels take up two skeletal slots. Strict CV Metrics (Ulfsbjorninn 2014; Faust & Ulfsbjorninn 2018; Ulfsbjorninn 2022b; Faust 2023a), a metrical theory that makes use of the Strict CV skeleton and a mechanism of prominence projection and incorporation, provides a mechanism of stress assignment where bipositional long vowels can project higher than the short ones. This is achieved be means of empty nuclei, which are metrically relevant: if a vowel is associated to a second position, this additional slot can be incorporated to lend more prominence to the vowel.[2]

In Wolof, which is a weight-sensitive language, syllables with long vowels are heavy. By default, stress falls on the leftmost syllable, however, if the initial syllable is light and the second one is heavy, the stress shifts to the heavier one (Ka 1988; Ulfsbjorninn 2022c). For instance, in *kalá:me* ‘to accuse’, the second syllable has a long vowel, which receives stress because it projects to the highest level, having incorporated its second V-slot (see Figure 1).[3]

2. Projection of prominence is a classical feature of metrical theory; see Hayes (1983; 1995), Halle & Vergnaud (1987) on grid theories of stress.
3. In Figure 1, the grid mark indexed with α is incorporated.

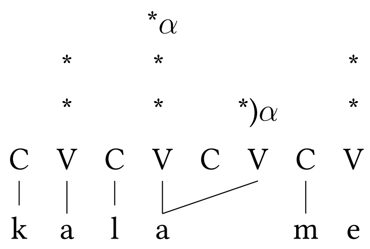


Figure 1: Incorporation in *kalá:me* ‘to accuse’

By parametrisation of empty nuclei, their projection and incorporation, Strict CV Metrics allows us to model weight-dependent stress assignment. It is still only the skeleton and the autosegmental levels of projection that participate in it; no melody is involved.

So, both the exponent and the assignment process of stress are predicted by the theory to go on above the skeleton, independently of the melodic tier. But what if stress is quality-dependent, that is, stress assignment tracks vowel quality rather than quantity? Consider the example of sonority-driven stress from Gujarati (3), reported by de Lacy (2002) and discussed by Shih (2016).

(3) Gujarati stress in brief (data from (de Lacy 2002:72), cited by (Shih 2016:1))

a. Default stress on penult
[sáɖa] ‘plus 1/2’
[dʒája] ‘let’s go’

b. Stress falls on final [a] if the penultimate vowel is a not [a]
[ʃikáɾ] ‘recently’
[hɛɾán] ‘distressed’

c. Stress falls on penultimate [a] if the final vowel is a not [a]
[sáme] ‘in front’
[sáɖu] ‘plain’

Vowel quality is relevant to the Gujarati stress rule: the vowel [a] is different from the others. By default, stress falls on the penultimate syllable, however, if [a] is in the final syllable but not in the penult, the stress shifts to the ultimate [a]. In other words, syllables with [a] in the nucleus are heavy and other syllables are light. If stress is computed above the skeleton, how can it be conditioned by vowel quality, which belongs to the melodic tier? Such a stress rule would be an example of melody affecting a suprasegmental process, which is not predicted to exist.

One way to model quality-conditioned stress is via virtual length (see Lowenstamm (1991, 2011); Ben Si Saïd (2011); Enguehard (2018); Ulfsbjorninn (2021) on virtual length in vowels and Ségéral & Scheer (2016) on virtual geminates). Virtual length refers to phonological length that manifests phonetically in ways other than duration, for example, as vowel quality. Since this is an apparent mismatch between phonetics and phonology, the existence of rules referring to virtual length can be used to argue for the absence of phonetic substance in the phonological computation, which is the thesis of Substance-Free Phonology (Hale & Reiss 2008; Scheer 2019a; Chabot 2021).

For instance, it is often the case that the full range of vowel quality contrasts available in a language only exists in stressed vowels, whereas the unstressed ones are reduced. One such case is Russian vowel reduction. If stress is assumed to be represented by underlying vowel length in Russian, then there is a direct correlation between length and the number of privative features that make up the vowel (Enguehard 2018). A long vowel is assumed to be able to hold more featural material, which is why we observe more contrastive segments in stressed lengthened vowels than in the unstressed shorter ones. Table 1 shows the vowel inventory in stressed syllables, which contains 5 phonemes; Table 2, on the other hand, illustrates the reduced range of three segments that exist in the unstressed syllables.[4]

4. The precise nature of Russian vowel reduction depends on the context. With palatalized and non-palatalized consonants, as well as in the pretonic and non-pretonic syllables, the phonetic realisation of the reduced consonants is different. Nevertheless, at least some quality contrast is erased in every context,

/i/	/u/
/e/	/o/
/a/	

Table 1: Full vowel inventory of Russian

[ɨ̞]	[ʊ̞]
[ɐ]	

Table 2: Reduced vowels in pretonic syllables (non-palatalized context)

Recasting vowel quality as length solves the problem of making stress related to quality, since stress is already known to interact with quantity. Two kinds of phenomena reduced to one is a favorable change of perspective. For Strict CV, it is particularly beneficial, since it presupposes that stress cannot depend on melody directly. Some proposals have come out that go against the existence of quality-driven stress as such (Shih 2016; Rasin 2018; Shih & de Lacy 2019; McCollum 2019).

This paper presents a virtual length analysis of stress in the Moksha language, which is well-known for its sonority-driven stress pattern (Kenstowicz 1997; Rasin 2018; Shih & de Lacy 2019). The vowel inventory is divided into "heavy" and "light" vowels: the heavy group includes the non-high vowels /a, ɛ, e, o/, while /i, u, ə/ count as light. Stress falls on the leftmost syllable with a heavy vowel and on the initial syllable in the absence of heavy vowels in the word. I propose to view heavy vowels as long and light vowels as short; stress will therefore track vowel length instead of segmental features.

I corroborate my proposal by considering vowel hiatus resolution rules, which rely on natural classes delineated by phonological length. I show that vowel deletion occurs after vowels that are either underlyingly long or lengthened by stress (4).

(4) Schwa deletion

a. Final heavy vowel

ava + *ən'* ⟶ *ava-n'* 'woman-GEN'

pe + *ən'* ⟶ *pe-n'* 'end-GEN'

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so just one of them is enough for demonstrational purposes.

b. Final stressed light vowel

mu + əms ⟶ mu-ms ‘find-INF’

ši + ən’ ⟶ ši-n’ ‘day-GEN’

Also, homorganic glide formation, which I argue to come from vowel spreading, is possible with short vowels only (5), since long vowels cannot spread due to a restriction on triple association.[5]

(5) Homorganic glide epenthesis

a. /u+ə/ ⟶ /uvə/

jožu + əl’ ⟶ jožuv-əl’ ‘smart-IMPF’

jožu + an ⟶ jožuv-an ‘smart-1SG’

b. /i+ə/ ⟶ /ujə/

tɛči + ən’ ⟶ tɛčij-ən’ ‘today-GEN’

vidi + an ⟶ vidij-an ‘sower-1SG’

I proceed to discuss the data in more detail and to describe my analysis. The remainder of the paper is laid out as follows: Section 1 introduces the data and summarises the patterns of behaviour of suffixes that start with schwa and /a/, as well as the stress rule of Moksha. Section 2 contains the proposed analysis of stress and hiatus resolution. Section 3 concludes the paper.

1 Data

Moksha is a Mordvinic language that belongs to the Uralic language family and is spoken in the Republic of Mordovia, which is located in the European part of Russia, as well as in some neighbouring regions. The primary sources of data for the present study

5. The imperfective suffix *-l’* ‘IMPF’ can be attached to nominal predicates to indicate past tense.

are the Moksha corpus, Kukhto's (2018) chapter on Moksha phonology and Kozlov & Kozlov's (2018) chapter on morphophonology in the book by Toldova & Kholodilova (2018). If not stated otherwise, examples come from the corpus. A practical transcription adopted from Toldova & Kholodilova (2018) is used throughout the paper; the IPA correspondence table is provided in the appendix. In the following section, I will give a brief introduction into Moksha phonology and morphophonology.

1.1 Moksha

As described by Kukhto (2018), the vowel inventory of Moksha comprises 7 phonemes (see Figure 2 below).

i		(ɨ)		u
e	(ɘ)		ə	o
ɛ		a		

Figure 2: Vowel inventory of Moksha

[ɨ] is an allophone of /i/ that occurs after non-palatalised consonants (6) and [ɘ] is an allophone of schwa that comes after palatalised consonants (7).[6]

(6) *ksti* [ɨ] 'berry' — *kšt'i* [i] 'dance.CN'

(7) *mol'əms* [ɘ] 'to go'

The consonant inventory, which is characterised by contrastive palatalisation and voicing, can be found in Figure 3 below. The phoneme /x/ only occurs in loanwords.

6. /l'/ corresponds to a palatalized /l/ (see the IPA correspondence table in the Appendix).

m		n n’				
p b		t d t’ d’				k g
	f v	s z s’ z’		š ž šč	j̊	(x)
		c c’		č		
					j	
			r̥ r r̥’ r’			
		l̥ l	l̥’ l’			

Figure 3: Consonant inventory of Moksha

Default stress is on the leftmost syllable, however, vowel quality affects stress placement (Kukhto 2018). Syllables can be divided into *heavy* (with /a, ɛ, e, o/) and *light* (with /u, i, ə/). The stress is borne by the leftmost heavy syllable, or, in words without heavy syllables, by the initial one (8).[7]

(8) Moksha stress pattern (Kukhto 2018:34)

a. Initial heavy

ˈt’ɛ.d’ɛ	‘mother’	ˈsa.ta.də	‘go.3PL’
ˈz’e.pə	‘pocket’	ˈjal.ga	‘friend’
ˈkoč.kas’	‘gather.PST[3SG]’	ˈmo.l’ə.ma	‘go.NZR’

b. Shift to the leftmost heavy (2nd)

ku.ˈva.ka	‘long’	ər’.ˈvɛ	‘wife’
u.ˈfaj	‘blow.3SG’	i.ˈl’ɛt’	‘evening’

7. I will continue to refer to the vowels that constitute the nuclei of heavy and light syllables as heavy and light vowels respectively.

c. Shift to the leftmost heavy (3rd/4th)

kucəmá	‘ladder’	t’ijəmá	‘do.NZR’
putəmá	‘lay.NZR’	udəftəmá	‘sleep.CAUS.NZR’

d. Default initial

ˈki.jə	‘who’	ˈtər.nə.s’əms	‘tremble.FREQ.INF’
ˈku.du	‘house.LAT’		

The stress rule is synchronically non-productive: consider late Russian loanwords in example (9), which defy the rule of stressing the leftmost heavy syllable.

(9) Loanwords as exceptions to the stress rule (Kukhto 2018:34)
ˈkruš.ka ‘cup’
ˈkni.ga ‘book’

In both *ˈkruška* ‘cup’ and *ˈkniga* ‘book’, the initial light syllable is stressed, despite the following syllable being heavy, because the original Russian stress is preserved.[8]

Stressed vowels are longer than the unstressed ones; unstressed vowels are centralised but not neutralised (Aasmäe *et al.* 2013; Kukhto 2018).

This paper will focus on vowel hiatus resolution, therefore, it is important to describe some positional restrictions on the occurrence of vowels in native Moksha words, i.e. which vowels can create the hiatus on the boundary between the base and the suffix.

8. The examples in (9) cited by Kukhto (2018) may not be completely valid, since unstressed /a/ in non-pretonic positions is reduced to [ə] in Russian. Hence, it is possible that Moksha speakers actually interpret those words as *kruškə* and *knigə*; in this case, initial stress would not be exceptional. An example that unequivocally demonstrates the exceptional status of Russian loanwords is *s’el’išči* — a part of the toponym *vad s’el’išči* (i).

(i) *s’el’išči* [sʲɪˈlʲiɕːɪ] ‘settlement’ (Rus.) — s’i.ˈl’i.šči (Moksha) [source]

This example only contains light vowels and violates the Moksha stress rule: stress falls on the second light syllable instead of the first one.

When it comes to bases, /e/ can only be found in stressed initial syllables (Kukhto 2018:30), it can occupy the word-final position in monosyllabic words like *pe* 'end'. Ivanova (2006:77), as well as the search of the dictionary by Serebrennikov *et al.* (1998) and the Moksha corpus, reveal a lack of non-borrowed words that end in /o/. Although Kukhto (2018) provides an example of an /o/-final word — *oc'o* — a dialectal variant of the word *oc'u* 'big', I will assume that /o/-final bases are extremely rare to nonexistent in Moksha.

In monosyllables, we can find base-final /a, ɛ, e, i, u/, as exemplified in Table 3 below.

Final vowel	Word	Translation
/a/	*šna*	processed leather
/ɛ/	*pr'ɛ*	head
/e/	*pe*	end
/i/	*ši*	day
/u/	*mu-*	to find

Table 3: Examples of vowel-final monosyllables.

In polysyllabic bases, the final position can contain /a, ɛ, i, u, ə/ (see Table 4), since the mid vowels /e, o/ are restricted to the initial syllable, except the dialectal lowered /u/.

Final vowel	Word	Translation
/a/	*ava*	woman
/ɛ/	*s'ijɛ*	silver
/i/	*cil'əd'i*	cricket
/u/	*kelu*	birch
/ə/	*kizə*	year

Table 4: Examples of vowel-final polysyllabic bases.

The vast majority of affixes in the Moksha language are suffixes, with a very small minority of prefixes (Kholodilova & Korjakov 2018). There are no suffixes that start with /o/, /e/ or /ɛ/; examples of suffixes that start with other vowels — /a, ə, u, i/ — are provided in Table 5.[9]

9. The absense of suffixes starting with /o, e/ is expected, since these vowels are restricted to the initial

Initial vowel	Suffix	Gloss	With C# base	Translation
/a/	*-an*	1SG	*az-an*	say-1SG
/ə/	*-ən'*	GEN	*ruz-ən'*	Russian-GEN
/u/	*-u/v/i*	LAT	*kud-u*	home-LAT
/i/	*-i/j*	3SG	*ul'-i*	be-3SG

Table 5: Examples of vowel-initial suffixes

Base-final schwa alternates with zero in some words (10). Whether the alternation happens or not is not predictable from the phonological appearance of the base, although the alternation-prone bases do tend to end in /p, k, g, x, c, c', č/ (Kozlov & Kozlov 2018:48).

(10) Base-final schwa-zero alternations (Kozlov & Kozlov 2018:48)

Disappearing schwa		Stable schwa	
z'epə	'pocket'	*stolbə*	'pillar'
z'ep-t	'pocket-PL'	*stolbə-t*	'pillar-PL'
z'epə-ška	'pocket-EQU'	*stolbə-ška*	'pillar'

As shown in example (10), the alternating schwa remains word-finally as well as before the equative suffix *-škə* 'EQU' but disappears in other cases, e.g. before consonant-initial suffixes.

Suffix-initial and base-final schwa is lost in some vowel hiatus contexts, for example, with the vowel /a/ (11).

(11) Schwa-zero alternations in suffixes (Kozlov & Kozlov 2018:40)

Suffix-initial schwa		Suffix-final schwa	
mastər-ən'	'land-GEN'	*vir'-sə*	'forest-IN'
ava-n'	'woman-GEN'	*vir'-s-an*	'forest-IN-1SG'

syllable, and consonant-only bases are lacking in Moksha.

I will now describe in more detail the behaviour of schwa-initial suffixes, which is superficially determined by syllable count and vowel quality but can instead be successfully linked to the stress pattern.

1.2 Schwa-initial suffixes

Moksha has a range of schwa-initial suffixes, some of which are shown in example (12).

(12) Examples of /ə/-initial suffixes

-ən' 'gen/pst.1sg'	*-əms* 'inf'
-ən'd'i 'dat'	*-əl'* 'ipf'

Suffix-initial schwa invariably appears after base-final consonants (13).

(13) /ə/-initial suffixes after C#

mastər-ən' 'land-gen'
ruz-ən' 'Russian-gen'
štraf-ən'd'i 'fine-dat'

In hiatus with schwa or with non-high peripheral vowels (/a o e ɛ/), the suffixal schwa is deleted (14). In a /ə+ə/ hiatus, only one schwa survives; it does not matter on a descriptive level, whether it belongs to the base or to the suffix.

(14) Schwa deletion

pe + ən' ⟶ *pe-n'* 'end-gen'
at'ɛ + ən' ⟶ *at'ɛ-n'* 'end-gen'
ava + əl' ⟶ *ava-l'* 'woman-ipf'
kizə + ən' ⟶ *kizə-n'* 'year-gen'

With high base-final vowels, the strategy is different — the schwa is not deleted. There is a rule that is described by Kozlov & Kozlov (2018) as a glide formation occurring after bases ending in /u/ or /i/ before vowel-initial suffixes. This can be characterized as a process of homorganic glide epenthesis: /v/ is inserted after /u/ and /j/ is inserted after /i/ (15).

(15) Homorganic glide formation (Kozlov & Kozlov 2018:42)

jožu + *əl'* ⟶ *jožuv-əl'* ‘smart-IPF’

t'εči + *ən'* ⟶ *t'εčij-ən'* ‘today-GEN’

The epenthetic /v/ and /j/ will be referred to as glides for the sake of simplicity, despite /v/ not being a glide phonetically. After Kozlov & Kozlov (2018), I assume, however, that that /v/ behaves as a glide in the phonology, since it can alternate with the vowel /u/ (see example 16 for a case of such an alternation in the lative suffix *u/v/i* ‘LAT’).

(16) Vowel-glide alternation in the lative suffix (Kozlov & Kozlov 2018:52)

LAT ⟷ *u*: $C_{[-pal]}$# __ *magazin-u* ‘shop-LAT’

LAT ⟷ *i*: $C_{[+pal]}$# __ *vir'-i* ‘forest-LAT’

LAT ⟷ *v*: V# __ *lavka-v* ‘shop-LAT’

A curious proviso to the glide formation rule is that no epenthesis happens with monosyllabic bases (17).

(17) *ši* + *ən'* ⟶ *ši-n'* ‘day-GEN’

mu + *əms* ⟶ *mu-ms* ‘find-INF’

vi + *əms* ⟶ *vi-ms* ‘bring-INF’

The behavior of glides in between /u, i/ and suffixal schwa is summarized in Table 6 below. A# corresponds to the non-high vowels /a, e, ε/.

	C#	A#	u#	i#
monosyllabic	*ən’*	*n’*	*n’*	*n’*
polysyllabic			*vən’*	*jən’*

Table 6: Suffix *ən’* ‘gen’ with different kinds of bases.

All monosyllabic bases exhibit the same behaviour — no glide epenthesis and no schwa, except after final consonants, in which case the schwa is preserved. Polysyllabic bases differ according to the final segment: after final consonants, the suffix appears with a schwa; after /u/ or /i/, the schwa remains and a homorganic glide appears; after other vowels, we find schwa deletion.

It is important to note that the glide formation is not synchronically productive, that is, it does not affect loanwords. The strategy for loanwords is to treat /u, i/ exactly like other vowels: to drop the schwa altogether (18). The syllable count is of no importance with loanwords: no glide appears either after the disyllabic toponym *soči* ‘Sochi’ or after the monosyllabic personal name *li* ‘Li’.

(18) *žuri* + *ən’* ⟶ *žuri-n’* ‘jury-gen’
soči + *ən’* ⟶ *soči-n’* ‘Sochi-gen’ (Kozlov & Kozlov 2018:42)
li + *ən’* ⟶ *li-n’* ‘Li-gen’ (online fieldwork)

Homorganic glide formation is not restricted to schwa-initial suffixes. It can also happen with the /a/-initial ones but in a different set of contexts. I proceed to a description of /a/-initial suffixes.

1.3 /a/-initial suffixes

The only non-high peripheral vowel found in suffix-initial position is /a/, which, for example, occurs in the agreement markers *-an* ‘1sg’ and *-at* ‘2sg’. These suffixes can appear on both verbal and nominal predicates (Kholodilova 2018; Toldova 2018). After base-final consonants, *-an*/*-at* always surface with a vowel (19).

(19) *-an/-at* after C# bases

van-an	'see-1SG'	*mašt-an*	'be able-1SG'
mɛr'g-at	'say-2SG'	*ruz-at*	'Russian-2SG'

After the vowels /a, ɛ/, the surface realization depends on the syllable count of the base: with monosyllables, the hiatus in broken up with the glide /j/ (20), whereas with polysyllabics, the vowels of the base and the suffix coalesce to produce just one /a/ (21). The latter phenomenon is referred to by Kozlov & Kozlov (2018) as */a/-coalescence*.

(20) /j/-insertion in the /Ca_a/ context

sa + *an* ⟶ *sajan* 'come-1SG'

šna + *an* ⟶ *šnajan* 'praise-1SG'

(21) a-coalescence in the /Ca_a/ context

jaka + *at* ⟶ *jakat* 'go-2SG'

at'ɛ + *an* ⟶ *at'an* 'old man-1SG'

Suffixes that begin with /a/ cause homorganic glide formation when attached to /u, i/-final polysyllabic bases, as shown in examples (22). The vowels /u, i/ are always unstressed in this environment, since they are followed by /a/ in the suffix.

(22) *jožu* + *an* ⟶ *jožuvan* 'smart-1SG'

vidi + *an* ⟶ *vidijan* 'sower-1SG'

After monosyllables ending in /u, i/, however, /j/ is inserted at all times, similarly to /a, ɛ/-final monosyllables (23).

(23) *mu* + *an* ⟶ *mujan* 'find-1SG'

li + *an* ⟶ *lijan* 'fly-1SG'

The pattern is summarised in Table 7.

<table>
<tr><th></th><th>C#, ə#</th><th>A#</th><th>u#</th><th>i#</th></tr>
<tr><td>monosyllabic</td><td rowspan="2">an</td><td>jan</td><td>jan</td><td rowspan="2">jan</td></tr>
<tr><td>polysyllabic</td><td>n</td><td>van</td></tr>
</table>

Table 7: Suffix *an* ‘NPST.1SG’ with different kinds of bases

After monosyllables, the vowel of the suffix is always preserved, with a glide inserted in hiatus contexts. With polysyllabic bases, we observe a pattern almost identical to that of schwa-initial suffixes — loss of the suffix’s vowel and homorganic glide formation. The suffix loses its vowel to a-coalescence after full vowels /a, ɛ/ but retains it after consonants. In /a+ə/ hiatus, schwa is deleted and /a/ remains. With final /u, i/, there is homorganic glide formation.

1.4 Summary

To summarise the behaviour of schwa- and /a/-initial suffixes, several different processes can be noted that happen at word-internal V+V boundaries formed by these suffixes with vowel-final bases (24–25). First, hiatus resolution can involve vowel deletion (see example (24) below).

(24) Vowel deletion in hiatus

a. Full vowel deletion (a-coalescence):

/ɛ+a/ $\longrightarrow$ /a/

at’ɛ + *an* $\longrightarrow$ *at’an* ‘old man-1SG’

/a+a/ $\longrightarrow$ /a/

ava + *an* $\longrightarrow$ *avan* ‘woman-1SG’

b. Schwa deletion when adjacent to heavy vowels:

/ə+a/ $\longrightarrow$ /a/

vir'-sə + an ⟶ vir'san 'forest-IN-1SG' (Kozlov & Kozlov 2018:40)

/a+ə/ ⟶ /a/

ava + ən' ⟶ avan' 'woman-GEN'

c. Schwa deletion after stressed light vowels:

/u+ə/ ⟶ /u/

mu + əms ⟶ mu-ms 'find-INF'

/i+ə/ ⟶ /i/

ši + ən' ⟶ ši-n' 'day-GEN'

When two heavy vowels form a hiatus, it is escaped by deleting one of them. In an /a+a/ sequence, just one vowel /a/ remains; in an /ɛ+a/ sequence, the second vowel — /a/ — is preserved (24a). Heavy vowel deletion in hiatus is restricted to polysyllabic words. Hiatus between a schwa and a heavy vowel is resolved by deleting the schwa, no matter its position (24b). Stressed light vowels behave in a similar way: the schwa is deleted after them (24c).

To generalize further, heavy vowels are subject to deletion only after non-initial syllables. Schwa, which is light, is deleted in hiatus next to a heavy vowel or a stressed light vowel.

Another group of strategies involved glide formation, which comes in two types (25).

(25) a. Homorganic glide formation (polysyllabic bases only):

/u+ə/ ⟶ /uvə/

kelu + ən ⟶ keluvən' 'birch-GEN'

/i+ə/ ⟶ /ijə/

t'ɛči + ən' ⟶ t'ɛčij-ən' 'today-GEN'

b. /j/-insertion (monosyllabic bases only):

/a+a/ ⟶ /aja/

sa + an ⟶ sajan 'come-1SG'

/u+a/ $\longrightarrow$ /uja/

mu + *an* $\longrightarrow$ *mujan* ‘find-1sg’

First, homorganic glide formation targets polysyllabic bases that end with /u/ or /i/ and makes a glide appear in the middle of the hiatus (25a). This glide is homorganic because its place of articulation depends on the base-final vowel: /v/ is inserted after /u/ and /j/ comes after /i/.

The other type of glide formation is not homorganic: it always involves /j/ and is restricted to monosyllabic bases (25b). It can take place only before /a/, which is heavy.

I will now pose several questions regarding vowel deletion and glide formation that my analysis aims to answer (26).

(26) Questions for phonological analysis

a. Schwa deletion happens both in the context of heavy vowels (24b) and after stressed light vowels (24c). What can put those into one natural class?

b. Is there a reason why homorganic glide formation only affects polysyllabic bases?

c. Can the non-homorganic insertion of /j/ be explained in a similar way?

d. Why are heavy vowels deleted in hiatus only after non-initial syllables?

I argue that a rule underpinning homorganic glide formation exists and it relies on the stress pattern: /u/ and /i/ can only spread when unstressed. Heavy and stressed light vowels fall into the same natural class because they are both long in the phonology. Schwa deletion and a-coalescence can be handled with VC reduction (Gussmann & Kaye 1993), given that schwa is assumed to be floating. The non-homorganic glide /j/ is inserted by a rule that is not stress-conditioned and bleeds homorganic glide formation and vowel deletion. The next section elaborates on the proposed analysis.

2 Hiatus resolution is conditioned by stress

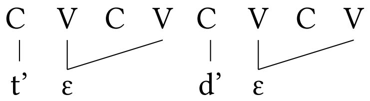
The core part of my proposal is that I treat the sonority-driven stress rule in Moksha as length-based.

I claim that the heavy vowels /a, o, ɛ, e/ are long; in Strict CV terms, they are associated to two CV slots. Light /u, i, ə/ are short (i.e. monopositional) and lengthened when stressed. The stress falls on the leftmost long vowel, and where there are no long vowels, an empty CV is inserted to the right of the leftmost vowel, which therefore becomes long.

The vowels that can trigger homorganic glide formation — both /u/ and /i/ — are light. At the end of a polysyllabic word, where homorganic glide formation happens, a light vowel is always short, since it cannot be stressed. In other words, what triggers glide formation are base-final unstressed light vowels.[10]

Consider several illustrations of vowel quality represented as bipositionality. In *t'ɛd'ɛ* 'mother', for example, both vowels are heavy, that is, bipositional, and the leftmost one is stressed (27).

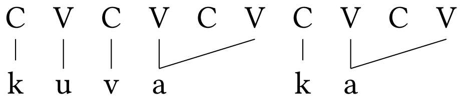
(27) *t'ɛd'ɛ* [ˈt'ɛd'ɛ] 'mother'



In *kuvaka* 'long', however, the first syllable contains a light vowel /u/, whereas the other two syllables have long vowels as nuclei. The /u/ in the initial syllable remains unstressed and hence phonologically short. The leftmost heavy vowel, which is in the second syllable, receives the stress (28).

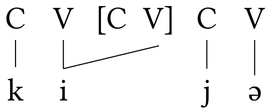
10. Except schwa, which is a light vowel that cannot produce a glide. Rather, it is deleted.

(28) *kuvaka* [kuˈvaka] ‘long’



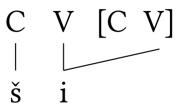
Finally, if there are no heavy vowels in the word, like in *kijə* ‘who’, the stress falls on the initial syllable. Since the vowel in the first syllable is light, it is lengthened by means of an inserted syllabic unit (29).[11]

(29) *kijə* [ˈkijə] ‘who’

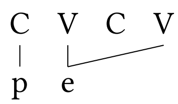


The assumption that stressed and heavy vowels are bipositional makes the vowels that do not participate in the glide formation, that is, heavy vowels and the stressed base-final light vowels (i.e. light vowels in monosyllabic bases) into a natural class: they share a property of being long. As shown in examples (30–32), both final light vowels, like in *ši* ‘day’, and final heavy vowels, like in *pe* ‘end’ and *ava* ‘woman’, are phonologically long.

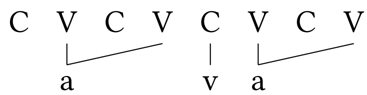
(30) *ši* [ˈši] ‘day’



(31) *pe* [ˈpe] ‘end’



(32) *ava* [ˈava] ‘woman’

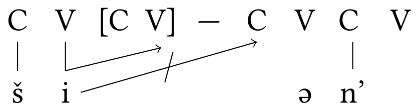


Representing stress and quality-dependent weight as length helps determine which vowels can and cannot spread. Long vowels cannot spread further than the two slots they already occupy, so no homorganic glide can appear after them. The restriction on triple association, or extra-long segments, as pointed out by an anonymous reviewer, is widely attested and may be universal (Chekayri & Scheer 2004; Enguehard 2018; Faust & Ulfsbjorninn 2018; Balogné Bérces & Ulfsbjorninn 2023).

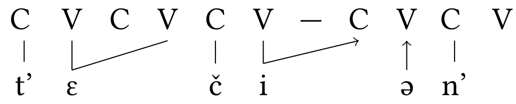
11. CV units in square parentheses are provided by stress.

The mechanism of glide formation proceeds by spreading a light vowel to the closest available C-slot, which belongs to the suffix. When the final light vowel is stressed and there is an empty V-slot provided by the stress CV, spreading onto a C-slot is not possible anymore (see example 33 for the derivation of *šin'* 'day.GEN'). When the vowel is not lengthened by stress, it can spread and form a glide, like in *t'ɛčijən'* 'today-GEN' (34).

(33) *ši* + *ən'* ⟶ *šin'* [šin']



(34) *t'ɛči* + *ən'* ⟶ *t'ɛčijən'* [t'ɛčijən']



I have demonstrated that the homorganic glide formation rule does not depend on syllable count, like it seems on the surface. The job of accounting for the distribution of homorganic glides after bases with final /u, i/ is done by the stress algorithm, which can only lengthen the final vowel of a monosyllabic base. Since long vowels are not expected to spread further, no glide formation occurs with them.

While long vowels are unable to spread, they participate in vowel deletion, which I propose to formalize via VC deletion.

2.1 Vowel deletion

Apart from glide formation, another hiatus avoidance strategy in Moksha is vowel deletion. Schwa is deleted in hiatus with any vowels that are phonologically long, i.e. heavy and light stressed vowels. Schwa deletion also happens in a hiatus of two schwas, both of which are short. Finally, /a/-coalescence, which is another case of vowel deletion, occurs in the hiatus of two long vowels, where the first one is in a non-initial syllable.

For schwa deletion, the virtual length analysis of stress provides a natural class: compare the rule with (35) and without the virtual length analysis of stress (36).

(35) **Schwa deletion rule (first attempt)**

ə ⟶ Ø / {a, ɛ, e, ə}_

ə ⟶ Ø / _{a, ɛ, e, ə}

ə ⟶ Ø / {u, i}_ (one σ)

ə elsewhere

(36) **Schwa deletion rule (revised with virtual length)**

ə ⟶ Ø / VV_

ə ⟶ Ø / _VV

ə ⟶ Ø / ə_ or _ə (equivalent)

ə elsewhere

Unless stressed high vowels are long together with the non-high peripheral vowels, the rule has to explicitly refer to vowel quality, as well as to syllable count. However, as soon as virtual length is introduced into the analysis, the rule becomes simple: schwa is deleted in hiatus with long vowels as well as with another schwa.

In Strict CV, the disjoint contexts for schwa deletion — next to long vowels and schwa — can be handled by a single process. I suggest that the schwa disappears after long vowels due to VC deletion — a process that erases empty VC sequences and has been introduced within Government Phonology by Vergnaud (1982) and Gussmann & Kaye (1993); see example (37) for the original formulation of this rule. VC deletion is common in Strict CV literature and is employed in analyses of various phenomena where some phonological interaction crosses a morpheme or word boundary (Faust *et al.* 2018; Faust 2018; Beausoleil & Newell 2022; Ulfsbjorninn 2022a; Faust 2023b).

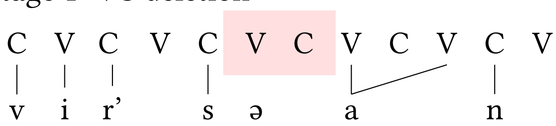
(37) Reduction (Gussmann & Kaye 1993:433)

An empty nucleus followed by a pointless onset are removed from any phonological representation in which they occur.

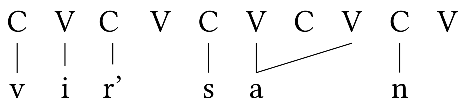
In the case of Moksha, VC deletion occurs when a long vowel is next to a schwa. Since schwas alternate with zero, both in hiatus and elsewhere (see Section 1), I assume that schwas are underlyingly floating. Hence, in the /ə+a/ sequence, there is an empty VC, which is reduced (38a).[12] What remains is just the /a/ of the suffix (38b).

(38) *vir'sə + an* 'forest.IN-1SG'

a. Stage 1: VC deletion

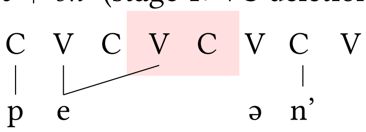


b. Stage 2: /ə/ not associated

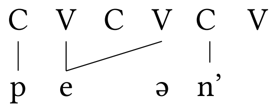


When a long vowel is followed by a schwa, the empty VC contains the second V-slot occupied by the long vowel and the initial empty onset of the suffix (39). When those are deleted, the long vowel remains, spreading to the V-slot of the suffix, to which the schwa can no longer be associated (40).

(39) *pe + ən'* (stage 1: VC deletion)



(40) *pe + ən'* (stage 2: /ə/ not associated)

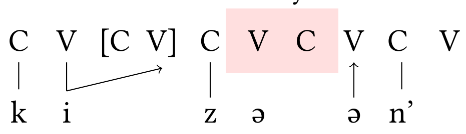


Schwa deletion also happens in the /ə+ə/ hiatus, which the rule in example (35) does not resolve, since schwa is a short vowel and cannot be lengthened in the hiatus-initial position, since it is never found in monosyllables. However, VC deletion helps avoid /ə+ə/

12. The second V-slots of long vowels are not uniformly recognized as empty. In Strict CV Metrics, they are considered empty despite being connected to a piece of melody with an association line, because second positions of long vowels must be available for incorporation and cannot project like filled V-slots. I take these slots to be empty.

hiatus as well: since both are floating and the empty VC at the base-suffix boundary is deleted, the remaining space is taken up by one of the schwas (41).

(41) *kizə + ən'* ⟶ *kizən'* 'year.GEN'



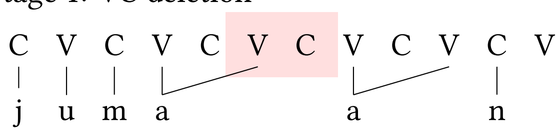
So, VC deletion manages the disappearance of schwas after long vowels as well as other schwas. These contexts are united by the presence of a final empty V, which belongs to a long vowel or a floating schwa, and an initial empty onset in the suffix.

Note that /a/-coalescence occurs in a context almost identical to that of schwa deletion — between a base ending in a long vowel and an /a/-initial suffix. The output is also similar: one vowel disappears. Thus, if VC deletion deletes the schwa in an /a+ə/ sequence, it should also work in the contexts for /a/-coalescence.

I suggest that the derivation proceeds as follows: first, the VC at the boundary is erased (42).

(42) *juma + an* 'get lost-1SG'

Stage 1: VC deletion

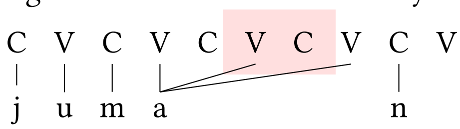


The result contains the segment /a/ associated to three V-slots in a row (43). Such a configuration is illicit due to violation of the Obligatory Contour Principle (OCP; (McCarthy 1986:208)), which prohibits adjacent identical elements on the melodic tier.[13] Another VC is subsequently deleted, producing the final form shown in example (44).

13. Since /a/-coalescence also applies to /ε+a/ sequences, I assume that /a/ and /ε/ share enough features to incur an OCP violation when associated to three slots in a row. This is backed up by the fact that /a, ε/ are in a nearly complimentary disctribution, where /ε/ co-occurs with palatalized consonants (Kukhto 2018). Contrast between /a, ε/ can be observed, for instance, in word-initial positions.

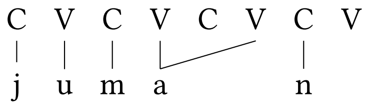
(43) *juma* + *an* 'get lost-1sg'

Stage 2: OCP violation rescued by another VC reduction



(44) *juma* + *an* 'get lost-1sg'

Final result



Thus, even though schwa deletion and /a/-coalescence happen in different contexts, they are driven by the same process — empty VC deletion. All inputs for VC deletion necessarily include a final long vowel (heavy or lengthened light) — a feature provided by virtual length. Several disparate rules of hiatus resolution are thus integrated into one process.

I will now address /j/-insertion, which happens exclusively in the context of /a/-initial syllables. I will show that this rule is unrelated to stress and requires an implementation outside of the virtual length analysis.

2.2 /a/-initial suffixes and insertion of /j/

Hiatus resolution with heavy-initial suffixes involves vowel deletion and glide epenthesis. The pattern of glide epenthesis is different from what we saw with the spreading of /u/ and /i/ before schwa: not all glides are homorganic. After monosyllabic bases, /j/ is inserted regardless of the base-final vowel (45a), whereas homorganic glide formation is limited to polysyllabic bases ending in /i/ and /u/ (45b).

(45) Distribution of /j/ and homorganic glides with *-an* '1sg'

a. Monosyllables: /j/ across the board, no homorganic glides

sa + *an* ⟶ *sajan*	'come-1sg' (Kozlov & Kozlov 2018:57)
šna + *an* ⟶ *šnajan*	'praise-1sg'
mu + *an* ⟶ *mujan*	'find-1sg'

b. Polysyllabic bases: homorganic glide formation possible

jožu + *an* ⟶ *jožuvan*	'smart-1sg'
vidi + *an* ⟶ *vidijan*	'sower-1sg'

With polysyllabics, the final vowel makes a difference: /u, i/ spread before *-an* 'npst.1sg', similarly to schwa-initial suffixes like *-ən'* 'gen', while other vowels are unable to spread. Monosyllabic bases, on the other hand, all share the pattern of /j/-insertion. If we take this common behaviour to be indicative of some shared property of base-final vowels, the outcome is unlike the stress-conditioned pattern of homorganic glide formation: stressed heavy vowels, like /a/ in *ˈšnajan* 'praise-1sg', would be grouped together with unstressed light ones, like /u/ in *muˈjan* 'find-1sg'. Phonological length is not a common feature in all /j/-insertion contexts.

I contend that the /j/ inserted in between heavy vowels has nothing to do with spreading or stress. The insertion of /j/ does not depend on stress placement. Final light vowels can only be long in monosyllabic bases with suffixes containing no heavy vowels — this is the only context where they can be stressed, lengthened and therefore non-spreading. In unstressed positions, light vowels can and do spread. With heavy vowels like /a/, on the other hand, the rule that singles out monosyllabic bases is not reducible to stress. Both mono- and polysyllabic bases can have a final stressed /a/: monosyllabic bases — by virtue of having just one syllable and the polysyllabic ones — if all vowels before the final /a/ are light. Consider the example of such a polysyllabic base, with a final stressed heavy vowel — *juma-* 'to get lost'; with this base, no /j/-insertion occurs before *-an*. Still, after monosyllabic bases, the glide does appear (46).

(46) *juma* + *an* ⟶ *juman* ‘get lost-1SG’
šta + *an* ⟶ *štajan* ‘wash-1SG’

So, the generalization that best approximates the data about /j/-insertion is that it targets monosyllables. As pointed out by an anonymous reviewer, this could be analyzed as an effect of word minimality: the reason that monosyllables are special is that it is important for them to retain their only vowel.[14]

The behaviour of the /a/-initial suffixes poses a challenge to the proposed analysis of glide formation before schwa-initial suffixes. The problem is that monosyllabic bases that end with /u/ and /i/ are subject to the exact same rules as the /a/-final ones, that is, /j/ appears after monosyllabic bases regardless of what the final consonant is; the glide is not homorganic and is therefore unlikely to come from spreading. Consider examples (47) that feature /u/ and /i/-final monosyllabic bases — the glide is always /j/.

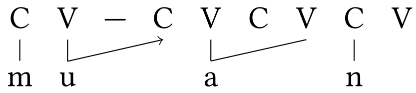
(47) *mu* + *an* ⟶ *mujan* ‘find-1SG’
li + *an* ⟶ *lijan* ‘fly-1SG’

Under the spreading-based analysis, the expected outcome in the /i+a/ and /u+a/ contexts is homorganic glide formation: /i/ and /u/ are always unstressed because they are followed by a heavy vowel, so they should be able to spread, but they do not. For instance, in *mujan* ‘find.1SG’, the light /u/ in the first syllable is not stressed, since the second syllable contains a heavy vowel /a/. An unstressed light vowel is monopositional and, in theory, will spread (see the hypothetical representation in example 48). Still, in *mujan* ‘find.2SG’, there is a non-homorganic /j/.

14. For an example of another morphophonological process that does not target monosyllables, see Becker *et al.* (2017) on the irregular *-al/aux* plurals in French, which are dispreferred in monosyllables due to the loss of the only vowel in the base.

(48) Expected:

mu + *an* ⟶ **muvan* ‘find-2sg’



In order to account for the behaviour of /a/-initial suffixes, the proposed analysis needs to be amended: stress and spreading alone are not enough to explain why there is /j/ in *mujan* ‘find.2sg’ and not /v/. On the other hand, the fact that the non-homorganic /j/ has nothing to do with stress also means that its behaviour is not a fatal counterexample for the stress-based analysis.

A possible line of reasoning that could account for the exceptional example *mujan* ‘find-2sg’ is to show that the vowel /u/ in the first syllable is actually long. That would immediately place this vowel in the long vowel class, and the fact that it patterns with /a/ in monosyllables would be explained. In order to show that, one could assume that Moksha stress is in fact not sonority-driven but fixed on the initial syllable.

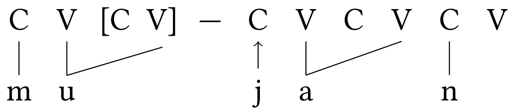
This would be backed up by phonetic evidence that comes from the survey of Moksha prosody by Aasmäe *et al.* (2013).[15] They conclude that the vowels /u/ and /i/ are shorter than others and are a little bit lengthened when stressed. The speakers occasionally stress the initial high vowels, but they are so much shorter than the low vowels that stressed /u/ and /i/ are shorter than unstressed /a/, for example, which might make initial stress less perceptible.

If Moksha stress is actually initial, this does not change the most important point of my analysis: stressed high vowels would still be restricted to the initial syllable. Also, the *mujan* counterexample would be explained: the vowel /u/ is stressed and therefore lengthened, so it cannot spread (49).

15. Aasmäe *et al.* (2013) is based on data from “sub-dialects of the central Moksha area”, and the present paper is based on a description of a northern-central dialect. These two sources report very close varieties of Moksha, if not the same dialect.

(49) Deriving *mujan* under the assumption of fixed initial stress

mu + *an* ⟶ *mujan* 'find-2sg'



In this case, the insertion of /j/ would only target the hiatus of two long vowels between the first and the second syllable. If the /u/ in *mujan* is stressed, it is long, so /j/-insertion is expected. *Mujan* will be the same context as, for example, *štajan* 'wash-1sg', where there is an /a+a/ sequence broken up by the glide /j/.

The hypothesis that Moksha has fixed initial stress is promising and works better with the virtual length proposal. Nevertheless, accepting it would involve conflating two conflicting descriptions. It is not unrealistic that signs of initial stress are observed in the dialect reported by Toldova & Kholodilova (2018) but making this claim requires additional phonetic evidence from that particular variety of Moksha. At the moment, the initial stress hypothesis remains a hypothesis.

I suggest to model the insertion of /j/ as a rule that targets monosyllables and adds a glide in hiatus before a heavy vowel (50).

(50) /j/-insertion rule

After monosyllables: $V \rightarrow Vj \ / \ \_V_{[+\text{long}]}$

If this rule is introduced, forms like *mu* + *an* 'find-1sg' will become contexts both for homorganic glide formation and /j/-insertion. Given a rule ordering where /j/-insertion precedes glide formation, *mujan* will be derived correctly, since the application of the rule in example (50) will bleed vowel spreading (51).

(51) Derivation of *mujan* 'find.1sg'

a. /j/-insertion

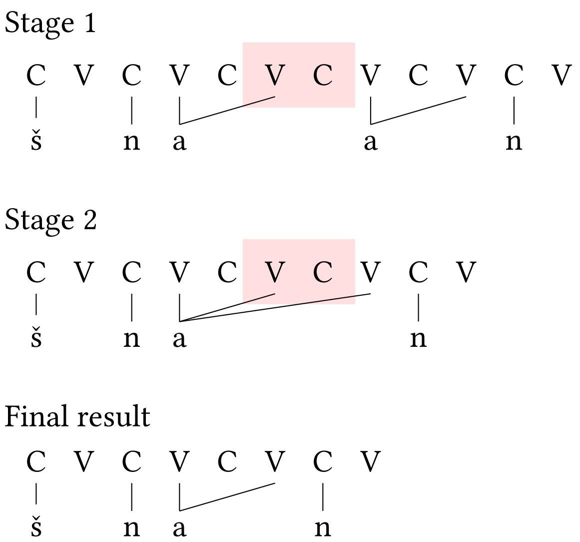
muan ⟶ *mujan*

b. Homorganic glide formation, bled by /j/-insertion

mujan ⟶ *mujan*

/j/-insertion also has to precede VC reduction, because otherwise we would observe a-coalescence with monosyllables, as shown in example (52). With monosyllables, the application of VC reduction is just as expected as after polysyllabic bases.

(52) Expected: *šnan* 'praise.1sg'



Like homorganic glide formation, VC reduction will be bled by /j/-insertion. Therefore, augmenting the analysis with a rule of /j/-insertion not only helps solve the problem of the lack of spreading in *mujan* 'find.1sg', but also simultaneously bans a-coalescence with monosyllables.

3 Conclusion

This paper presents a reanalysis of sonority-driven stress with virtual length which helps explain the choice of hiatus escape strategy. I suppose that heavy vowels that attract stress are underlyingly long, and so are all stressed vowels. I then show that hiatus resolution strategies such as homorganic glide formation and vowel deletion rely on the length distinction.

First, homorganic glides, which I argue to come from spreading of the high vowels /u, i/, only appear in contexts where those vowels are short. Next, schwa is deleted in vicinity of long vowels and other schwas. In my analysis, all vowel deletion is driven by the same process — VC reduction. Finally, I have discussed the limitations of my virtual length-based proposal, such as the exceptional behaviour of monosyllables with /a/-initial suffixes, and put forward a solution in the form of a glide-inserting rule that targets monosyllables and prevents the application of other hiatus resolution strategies.

Appendix

3.0 IPA correspondence table

IPA	Transcription
m	m
n̪	n
n̪ʲ	n’
p	p
b	b
t̪	t
t̪ʲ	t’
d̪	d
d̪ʲ	d’
k	k
g	g
x	x
f (ɸ)	f

IPA	Transcription
v (β)	v
s̪	s
s̪ʲ	s’
z̪	z
z̪ʲ	z’
ʃ	š
ʃʲː (ʃt͡ʃ)	šč
ʒ	ž
t͡s̪	c
t͡s̪ʲ	c’
t͡ʃ	č
ç	j̊
j	j
ɾ̥	r̥

IPA	Transcription
ɾ̥ʲ	r̥’
ɾ	r
ɾʲ	r’
ɬ̪	l̥
ɬ̪ʲ	l̥’
l̪	l
lʲ	l’
i	i
u	u
e	e
ə	ə
o	o
ɛ	ɛ
a	a

List of glossing abbreviations

1 first person
2 second person
3 third person
CAUS causative
CN connegative
DAT dative
EQU equative
FREQ frequentative
GEN genitive
IMPF imperfective
IN inessive case
INF infinitive
IPF imperfective
LAT lative case
NPST non-past
NZR nominalizer
PL plural
PST past
SG singular

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