Phonological degrees of labiality

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Abstract

A [+round] or [labial] feature is traditionally viewed as an elementary phonological unit that has different phonetic realizations depending on the height and backness of the segment that realizes it (Clements and Hume 1995, McCarthy 1988, Halle 1995, Kaun 1997 among others). In this paper, I make two claims: a) qualitatively different lip-gestures are phonological in some languages, and b) there is more faithfulness to more extreme lip gestures.

1 Introduction

While it has long been known that rounding is not realized uniformly across vowel heights, this fact has been considered purely phonetic. This paper proposes an analysis of a phonological phenomenon involving a transfer of labiality from a vowel to a consonant under certain conditions. I argue that the Karata data support the idea that differences in rounding can be phonological[1].

Karata (*kirʟ̄i mat̄s'i*, Russian *karatinskij jazyk*)[2] is an understudied Nakh-Daghestanian language originally spoken in 10 'auls' (i.e. mountain-top villages) in western Daghestan.[3] The available literature on Karata consists of a grammatical sketch [Magomedbekova, 1971] , and a dictionary (Karata to Russian) [Magomedova and Khalidova, 2001]. The data presented in this paper come from fieldwork that I carried out in June 2011 and July 2012 and from the above mentioned sources.

The structure of the paper is the following. Section 2 gives an overview of the phenomenon investigated and its proposed analysis. Section 3 provides background information on the phonology of Karata. Section 4 is dedicated to the OT analysis of the Karata. In section 5, I motivate the idea that differences in rounding can be phonological. Finally, in section 6, I show that other analyses fail to account for the Karata facts.

[1] This idea was presented in Author 2013 and Author 2014.

[2] The variety of Karata described in this paper is the language as it is spoken in the aul of Karata, western Daghestan. Like the other Andic languages Karata has no writing tradition, but can be written by means of an adaptation of the Avar version of the Cyrillic alphabet.

[3] These villages are Karata, Archo, Anchikh, Rachabalda, Mashtada, Chabakoro (a.k.a. Verkhnee Enkhelo or Upper Enkhelo), Ratsitl', Nizhnee Enkhelo (or Lower Enkhelo), Siukh, and Tukita [Magomedbekova, 1971]. The territory inhabited by the Karatas is part of a larger homogeneous cultural area which is mostly Avar and traditionally associated to the use of Avar as the regional *lingua franca*. The Karatas are traditionally Sunni Muslims. The first and last census of their population as a distinct people (from the Avars) dates back to 1926 [Kolga, 2013]. The number was then 5,305. Since then, the Karatas have been counted as Avars. Magomedova and Khalidova in their 2001 dictionary give the approximate number of 20,000 speakers. In the 2010 census (available at http://www.gks.ru/), the Karatas are counted as a subtype of Avars and the number given is 4,787.

2 Overview of the proposal

The purpose of this section is to introduce the core of the problem this paper is about and to give an overview of the solution I propose. Because this section is meant to be a (brief) overview, assumptions are made and not justified yet (e.g. the recognition of the underlying form of verb stems). The elements of this section will be taken up later and argued for more in depth.

2.1 Problem

In Karata verb stems (-VC(V)...-)[4], the consonant must be labialized when both of the following conditions are met:

(i) the preceding vowel is underlyingly round and high, e.g. /u/

(ii) this vowel becomes unround (as a result of its assimilation to the C prefix added to the stem)

In (1), both conditions (i) and (ii) are met, for instance the consonant in the underlying stem /*utʃ˜*/ is realized as labialized once the stem-initial vowel has assimilated (delabialized) to the prefix *j*-. In these examples (and in the rest of the paper), unless otherwise indicated, verbs are presented in the infinitival form, suffixed with the infinitival morpheme /aʟ̝̊a/ glossed 'INF'.

(1) Labialization of stem consonant

	Underlying form	Surface form	Meaning
(a)	j-utʃ˜-aʟ̝̊a	jitʃʷãŋʟ̝̊a	bathe
(b)	j-utʃ'ã-aʟ̝̊a	jitʃ'ʷãːŋʟ̝̊a	open
(c)	j-uʟ̥̄'˜-aʟ̝̊a	jiʟ̥̄'ʷãŋʟ̝̊a	share

Only the [+round] feature that was underlyingly linked to a high vowel can be linked to the following consonant. The [+round] feature that was underlyingly linked to the mid vowel is deleted (2).

(2) The stem consonant is not labialized

	Underlying form	Surface form	Meaning
(a)	j-oχ̄a-aʟ̝̊a	jeχ̄aːʟ̝̊a	thrust
(b)	j-oʔ˜-aʟ̝̊a	jeʔãŋʟ̝̊a	go
(c)	j-oʟ̥̄'-aʟ̝̊a	jeʟ̥̄'aʟ̝̊a	warm up

As examples (c) in (1) and (2) show, whether the consonant can be labialized does not depend on the consonant (most consonants have labialized counterparts as shown in section 3.1.2)[5] but

[4]The majority of Karata verb stems that can undergo this process follows the pattern VC(V).

[4]The stem *-utʃ˜-* 'bathe' comes with a floating nasal feature. The nasal feature is realized on the first suffixal vowel or on the suffixal consonant if it is either one of /b, l, r/ (somewhat surprisingly, it never docks on /d/).

[5]It is however difficult to find pairs of the form prefix-VC like (1c) and (2c), where C remains constant while V is either /u/ or /o/. It is not clear to me why, and it therefore seems there is no deeper explanation than just sheer randomness. Studying the distribution of [u] and [o] does not reveal any obvious restrictions on the consonant that can follow them: as far as I can tell [u] and [o] can be followed by a consonant of any place or manner of articulation, central or lateral. It just so happens that, given a specific consonant C and a specific prefixal class marker CM, there are very few pairs of words that meet the conditions of having [u]/[o] after CM and before C.

is purely a function of the preceding vowel: upon vowel delabialization, the adjacent consonant is labialized only if the underlying (round) vowel is high.

Traditionally, labialization (a.k.a. rounding) is treated as categorical (Clements and Hume 1995, McCarthy 1988, Halle 1995, Kaun 1997 among others). For instance, as shown in (3), given a language with a 5-vowel system /u, o, i, e, a/, which is what Karata happens to be, it is common to represent the difference between /u/ and /o/ as a difference in height – /u/ is specified as [+high] whereas /o/ is specified as [-high] – while both are specified as [+round].

(3) Possible featural analysis of a 5-vowel system

$$\begin{array}{ccccc} /u/ & /o/ & /i/ & /e/ & /a/ \\ \begin{bmatrix} \text{+high} \\ \text{-low} \\ \text{+round} \end{bmatrix} & \begin{bmatrix} \text{-high} \\ \text{-low} \\ \text{+round} \end{bmatrix} & \begin{bmatrix} \text{+high} \\ \text{-low} \\ \text{-round} \end{bmatrix} & \begin{bmatrix} \text{-high} \\ \text{-low} \\ \text{-round} \end{bmatrix} & \begin{bmatrix} \text{-high} \\ \text{+low} \\ \text{-round} \end{bmatrix} \end{array}$$

The analysis in (3) correctly captures that in many languages /u/ and /o/ form a natural class: the class of [+round] vowels. And there is reason to think that in Karata too /u/ and /o/ form a natural class as I show in section 3. But under this view, the consonant labialization asymmetry in (1) and (2) is mysterious.

2.2 Sketch of proposal

There is general consensus on the fact that rounding varies as a function of height. In this paper, I argue:

(i) that vowel aperture (a.k.a. height) is indexed on the [labial] feature, and

(ii) that faithfulness to [labial$_x$] is higher than to [labial$_{x-1}$]

Figure 1 gives an idea of how vowel height in Karata can be mapped to degrees of aperture.

Figure 1: Karata has a 3-apperture vowel system.

aperture 3	i u
aperture 2	e o
aperture 1	a

A way to formalize the dependency of the degree of rounding on the degree of aperture of the vowel is to posit that if a vowel is specified for the feature [labial$x$], [labial$x$] agrees in value with aperture$x$. Languages then vary in the extent to which they allow degree mismatching (e.g. cross-height and parasitic rounding harmony).

The analysis developed in most detail in this paper hinges on the fact that there is particular faithfulness pressure to preserve the privative [labial] feature of a high vowel. In Karata, both high and non-high vowels become unrounded as a result of their assimilation in place of articulation to the preceding palatal glide: that is the [labial] feature has been delinked from both vowels /u/ and /o/. The claim is that because the rounding gesture that was realized on the high vowel /u/ is more salient [Steriade, 2001] (*see* 5.4), there is greater faithfulness to keep it in the output than other labial features.

3 Overview of Karata phonology

The purpose of this section is to give some relevant background on the phonology of Karata.

3.1 Segmental phonology

3.1.1 Vowels

Karata has five ‘basic’ vowels, each of which has a long counterpart. In addition, any vowel, short or long, can be nasalized. The extent to which they are nasalized varies: from lightly nasalized followed by a distinctly articulated nasal consonant to true nasal vowels with no trace of a consonantal constriction (as are found in French, Portuguese or Polish for instance).

Vowels are more or less nasalized depending on their position in the word. Clear nasal vowels occur word-finally. In all other positions, if the phonetic nasal vowel is followed by a consonant in the coda of the same syllable, a nasal consonant may still be perceived.

Figure 2: Phonological table of Karata vowels.

	front		back	
high	i	iː	u	uː
mid	e	eː	o	oː
low		a aː		

3.1.2 Consonants

Karata has both central and lateral sounds. Central sounds are articulated in various places whereas lateral sounds are all velar or dental. For the sake of conciseness, I present both central and lateral sounds in the same table (figure 4). In addition, all the phonemes (except bilabial and palatal phonemes) have labialized counterparts which are separate phonemes. I justify the analysis of [Cw] sequences as complex phonemes in subsection 3.1.3.

A macron on a consonant indicates a *fortis* consonant[6]. Only voiceless consonants can have that feature. The phonetic realization of the *fortis* characteristic or feature depends on the manner and place of articulation of the consonant that bears it. It can be realized as frication, gemination or length but for some consonants (e.g. affricates) the realization of the *fortis* feature is better characterized as an increase in energy, in the sense that the articulators are more rigid. In the transcriptions, I transcribe *fortis* consonants with a macron[7].

[6] In the literature on Nakh-Daghestanian languages, these consonants are called ‘strong consonants’. There is consensus on the fact that the strong character of a consonant is a phonological feature [Charachidzé, 1981]. How this phonological feature is realized is however still to be investigated systematically.

[7] An anonymous reviewer suggests that it would be best to represent fortis consonants with either a length mark or a feature [tense]. Since no phonetic measurement on Karata consonants has been performed I prefer to refrain from using a symbol that might suggest a potentially inaccurate realization of the fortis consonants.

Figure 3: Phonological table of Karata non-labialized consonants.

				Central									Lateral	
				Bilabial	Dental	Alveolar	Post-alv	Palatal	Velar	Uvular	Pharyngeal	Glottal	Dental	Velar
plosives	voiceless	aspirated	weak	p	t	ts	ʧ		k					
			strong			t̄s	ʧ̄		k̄	q̄				ʟ̥̄
		glottal	weak	p’	t’	ts’	ʧ’		k’			ʔ		ʟ̥’
			strong			t̄s’	ʧ̄’		k̄’	q̄’				ʟ̥̄’
	voiced			b	d		ʤ		g					
fricatives	voiceless		weak			s	ʃ			χ	ħ	h		ʟ̝̊
			strong			s̄	ʃ̄		x̄	χ̄				ʟ̝̊̄
	voiced					z	ʒ			ʁ	ʕ			
nasals				m	n									
non-nasal sonorants					r			j	w				l	

Figure 4: Phonological table of Karata labialized consonants.

				Central							Lateral	
				Dental	Alveolar	Post-alv	Velar	Uvular	Pharyngeal	Glottal	Dental	Velar
plosives	voiceless	aspirated	weak	t^w	ts^w	ʧ^w	k^w					
			strong		ts̄^{w}	ʧ̄^{w}	k̄^{w}	q̄^{w}				ʟ̥̄^{w}
		glottal	weak	t’^{w}	ts’^{w}	ʧ’^{w}	k’^{w}			ʔ^w		ʟ̥’^{w}
			strong		ts̄’^{w}	ʧ̄’^{w}	k̄’^{w}	q̄’^{w}				ʟ̥̄’^{w}
	voiced			d^w		ʤ^w	g^w					
fricatives	voiceless		weak		s^w	ʃ^w		χ^w	ħ^w	h^w		ʟ̝̊^{w}
			strong		s̄^{w}	ʃ̄^{w}	x̄^{w}	χ̄^{w}				ʟ̝̊̄^{w}
	voiced				z^w	ʒ^w		ʁ^w	ʕ^w			
nasals				n^w								
non-nasal sonorants				r^w							l^w	

3.1.3 The analysis of [Cw] sequences

In my presentation of the consonantal inventory of Karata in section 3.1.2, I took for granted that Karata has labialized consonants but [Cw] sequences could potentially be analyzed either as a sequence of two independent phonemes /Cw/ (4a) or indeed as one phoneme /C^w/ (4b).

(4) (a) Sequence of phonemes hypothesis: a [Cw] sequence constitutes two phonemes underlyingly, i.e. /Cw/
(b) Labialized consonant hypothesis: a [Cw] sequence constitutes one phoneme underlyingly, i.e. /C^w/

In this section, I present arguments to justify the analysis of [Cw] sequences as labialized phonemes which is crucial for the analysis of the phenomenon this paper is mainly concerned with.

In Karata, the labial glide [w] occurs independently in onset position, word initially (5a) or not (5b), and in coda position, word finally (5c) or not (5d).

(5) Labio-velar glide /w/ in different positions

	Underlying form	Surface form	Meaning	Position in syllable
(a)	waʃa	wa.ʃa	boy	}onset
(b)	ħawuz	ħa.wuz	spring, well[8]	
(c)	ʃiʃaw	ʃi.ʃaw	bottle	}coda
(d)	awlaq̄	aw.laq̄	lowland	

It is also found after consonants except bilabial consonants (i.e. /p/, /p'/, /b/ and /m/). To my knowledge, there is no other restriction on manner, place of articulation or other properties such as voicing, glottalization and the *lenis*/*fortis* opposition (6).

(6) [Cw] sequences regardless of manner, place of articulation, voicing and the *fortis*/*lenis* distinction of C.

	Underlying form	Surface form	Meaning
(a)	ʃ^{w}alja	ʃwalja	river, stream
(b)	x̄^{w}ane	x̄wane	horse
(c)	t̄s'^{w}abdi	t̄s'wabdi	stars
(d)	d^{w}ahã-al̥̪a	dwahãːŋl̥̪a	to massage

Two main arguments justify the recognition of complex labialized consonants in Karata. First, the distribution of [Cw] sequences is much more restricted than that of [w]: [Cw] sequences are only found preceding the low vowel [a] whereas [w] is found before more vowels: mainly [u], [o], and [a] (7) and exceptionally (in loanwords mainly) before [i] and [e] (7b). It should be noted that while [wV] sequences are abundant when [w] is the class I prefix, [wV] sequences where [w] is not a morpheme (7b) are much rarer.[9]

[8] Loan, see Khalikov and Efendiev 2002.

[9] I am aware of only one word with the sequence [wi], *witru* 'witr prayer', which is a loan word. Words with [we] are few and far between, I am only aware of two: the one in (7b) and the word *sewer* 'north' which is clearly a loan from Russian. Surprisingly, words with [wu], where [w] is not the prefix, are, as far as I know all loanwords and I am not aware of any word starting with [wu] where [w] is not the class marking prefix. At this point I do not have an explanation for why [wu], where [w] is not the class I prefix, are not more attested in Karata.

(7) Distribution of [w]

(a) the prefix /w/

	Underlying form	Surface form	Meaning
(a)	w-iʃãq̄-aʟ̞̊a	wuʃãq̄aʟ̞̊a	work
(b)	w-uʧ˜-aʟ̞̊a	wuʧãʟ̞̊a	bathe
(c)	w-eʟ̥̄’˜-a-aʟ̞̊a	woʟ̥̄’ãːʟ̞̊a	make fit
(d)	w-oʟ̥̄-aʟ̞̊a	woʟ̥̄aʟ̞̊a	walk
(e)	w-aʃa-aʟ̞̊a	waʃaːʟ̞̊a	assess

(b) non-prefixal occurrences of [w]

	Underlying form	Surface form	Meaning
(a)	witru	witru	witr prayer (loan)[10]
(b)	kawu	kawu	gate (loan)[11]
(c)	weʟ̥̄’aruq̄an	weʟ̥̄’aruq̄an	ploughman
(d)	wore	wore	watch out!
(e)	warʧ’ami	warʧ’ami	hello

Before all other vowels, [w] in the sequence [Cw] assimilates with the following vowel:

a. if the following vowel is [-low] : the [+round] feature attaches to the vowel, thus making it round.

b. if the following vowel is [+low] : the [+round] feature does not attach to the vowel since the language has no [+low+round] vowel in its inventory. Therefore the [+round] feature remains attached to the consonant.

These processes are visible when the [Cw] sequence is at a morpheme boundary and a morpheme (suffix) is added to it (8)[12].

(8) (a) ʦ’ĩk’ʷaʟ̞̊a ‘hurt, sting (for a tooth)’

	Underlying form	Surface form
future	ʦ’ĩk’ʷ-as̄	ʦ’ĩŋk’was̄
imperfective	ʦ’ĩk’ʷ-ida	ʦ’ĩŋk’uda
perfective	ʦ’ĩk’ʷ-e	ʦ’ĩŋk’o
imperative	ʦ’ĩk’ʷ-ej	ʦ’ĩŋk’oj

(b) biʁʷãʟ̞̊a ‘be upset’

	Underlying form	Surface form
future	biʁʷ˜-as̄	biʁʷãs̄
imperfective	biʁʷ˜-ida	biʁũnda
perfective	biʁʷ˜-a	biʁʷã
imperative	biʁʷ˜-i	biʁũ

(c) biʔʷaʟ̞̊a ‘break’

[11] Loan, see Khalikov and Efendiev 2002. This is the only word with the sequence [wi] I am aware of in Karata.

[11] Loan, see Khalikov and Efendiev 2002. In fact, all [wu] sequences I am aware of, excluding the cases where [w] is the class I prefix, are in loanwords from Arabic, Persian, Turkish, or Kumyk.

[12] The verb root *biʁʷ˜*- has a floating nasal feature that is realized on the first C of the suffix if the C is one of /b, l, r/ or on the first vowel of the suffix if there is no such C.

	Underlying form	Surface form
future	b-iʔ^w-as̄	biʔ^{w}as̄
imperfective	b-iʔ^w-ida	biʔuda
perfective	b-iʔ^w-i	biʔu
imperative	b-iʔ^w-i	biʔu

By comparison, when the verb root ends in a consonant (with no [w]), the suffixes are transparently added (9).

(9) (a) bak'ãḁa 'bend'

	Underlying form	Surface form
future	b-ak'˜-as̄	bak'ãs̄
imperfective	b-ak'˜-ida	bak'ĩnda
perfective	b-ak'˜-a	bak'ã
imperative	b-ak'˜-i	bak'ĩ

(b) biʁaḁa 'stop'

	Underlying form	Surface form
future	biʁ-as̄	biʁas̄
imperfective	biʁ-ida	biʁida
perfective	biʁ-e	biʁe
imperative	biʁ-i	biʁi

(c) biʔaḁa 'know'

	Underlying form	Surface form
future	b-iʔ-as̄	biʔas̄
imperfective	b-iʔ-ida	biʔida
perfective	b-iʔ-a	biʔa
imperative	b-iʔ-i	biʔi

I have not found any occurrences of [Cw] sequences followed by a round vowel. Note that if [Cw] was a cluster, then the labialization of the suffixal vowels in (8) could be regarded as a case of coalescence of two segments [Casali, 1996], [w] and a vowel, [i] or [e]. There are clear cases of coalescence in Karata where two vowels are merged into one vowel that shares characteristics of both underlying vowels to resolve an underlying hiatus created by the suffixation of a vowel-initial suffix to a vowel-final verb stem.[13] In these cases (10), the resulting vowel is long. The (assimilation) phenomenon illustrated in (8) does not give rise to such compensatory lengthening unlike true cases of coalescence. This difference follows if we analyze [Cw] sequences as labialized consonants as opposed to clusters of a consonants and the segment [w].

(10) Coalescence gives rise to compensatory lengthening in Karata
(a) bibaḁa 'yell'

[13] My observations on the verb system of Karata has come to the following conclusion: if a verb stem ends in a vowel, this vowel is /a/. This could be due to the history of verbs in Karata but more research is needed.

	Underlying form	Surface form
future	biba-as̄	bibaːs̄
imperfective	biba-ida	bibeːda
perfective	biba-i	bibeː
imperative	biba-a	bibaː

(b) baʧ̄ʷaːʟ̞̊a ‘carry’

	Underlying form	Surface form
future	b-aʧ̄ʷa-as̄	baʧ̄ʷaːs̄
imperfective	b-aʧ̄ʷa-ida	baʧ̄oːda
perfective	b-aʧ̄ʷa-e	baʧ̄ʷeː[14]
imperative	b-aʧ̄ʷa-a	baʧ̄ʷaː

Second, in the language game I designed (described below), speakers consistently treated [CwV] sequences in the same way they treated [CV] or [C’V] sequences. (Note that the argumentation behind the language game depends on the type of syllable allowed in Karata which I discuss later in section 3.3.1.)

I asked two adult native speakers of Karata to respond to my questions by e-mail after my last field trip in 2012.[15] These two speakers (a woman and a man) were born in Karata, they spent their childhood there and went to school there where they learned to write and read Russian as well as Avar, the regional vehicular language. Both still speak Karata daily being married to Karata speakers. Other than that, they have different backgrounds: the woman is a university professor in the Daghestanian capital (Makhachkala) while the man lives in Karata.

Speakers were instructed in Russian to look at existing words of Karata, take the last two sounds (not letters, because one sound may be rendered by more than one letter) and put those at the beginning of the word. The instructions are translated in (11).

(11) Language game instructions:
Take the last two sounds of each word (and not letters) and put them at the beginning of the word. For example, according to the rules of this game, the word ‘кекьи’ becomes ‘кьике’ (and not ‘ьикек’ because ‘кь’ constitutes one sound). Another example is the word ‘берка’ which becomes ‘кабер’.

Four examples illustrating the instructions were provided (12). They do not contain [Cw] sequences in the last/critical syllable and there are words where the two critical sounds (at the end) are rendered by more than two cyrillic symbols (12c, d) thus making it clear that the instructions are not about the letters but about the sounds. Speakers only saw the cyrillic columns.

[14] Why the sequence /ʧ̄ʷeː/ does not turn to /ʧ̄oː/ is not clear to me. Word-finally, long vowels seem to behave differently from short vowels with respect to assimilation/rounding.

[15] It should be noted that every person in the village I have met knows how to read and write Russian at least and most middle-aged and older people know how to read and write Avar. From their knowledge of the Avar writing system, they can read and write Karata. How used they are to reading and writing Karata varies however greatly. While a few Karatas write poetry and songs in Karata, others do not have any use for it. For my (written) questionnaire, I chose two speakers who are very competent at writing in Karata. In addition, it should be pointed out that almost everyone in Karata has a smartphone with internet access and many households have (at least had in 2012) internet access with a computer.

(12) Examples given to speakers

	Meaning	Real words		Results	
		IPA	cyrillic	IPA	cyrillic
(a)	a closet	[q̄'ore]	къоре	[req̄'o]	рекъо
(b)	hat	[q̄'wapa]	къвапа	[paq̄'wa]	пакъва
(c)	glove	[kwaɬ̥a]	квальа	[ɬ̥akwa]	льаква
(d)	something	[hedjaʧ'e]	гьедйач1е	[ʧ'ehedja]	ч1егьедйа

I gave 11 words to perform the task on (examples are provided in 13).

(13) Sample of test items given to speakers

	Meaning	Real words		Results	
		IPA	cyrillic	IPA	cyrillic
(a)	a nail	[haŋk'wa]	гьанк1ва	[k'wahã]	к1вагьан
(b)	ashes	[ɬ̥̄'eχwa]	кьехва	[χwaɬ̥̄'e]	хвакье
(c)	the end	[baq̄ẽn]	бахъен	[q̄ẽnba]	хъенба
(d)	clean!	[beχ̄wan]	бехxван	[χ̄wanbe]	хxванбе
(e)	a bottle	[ʃiʃaw]	шишав	[awʃiʃ]	авшиш

The predictions of the two competing hypotheses in (4) are presented in (14).

(14) Predictions: Given the word гьанк1ва in (13a),
(a) if Karata speakers analyze [Cw] sequences as one phoneme, we expect them to derive the word к1вагьан
(b) if however Karata speakers analyze [Cw] sequences as sequences of two phonemes, we expect them to derive the word вагьанк1

In (13a), speakers derived к1вагьан as predicted by the labialized consonant hypothesis. This is confirmed by (13b). Example (13c) further shows that speakers have the intuition that nasalized vowels count as one segment even though a remnant nasal consonant can still be perceived (at least to my ears). Example (13d) contains a [Cw] sequence and a nasalized vowel, speakers treated those as one segment each. Finally (13e) shows that my informants did not just take the last (whole) syllable and put it at the beginning of the word since they treated the sequence [aw] as a sequence of two sounds. Both speakers responded in exactly the same way, reported in (13). The results clearly indicate that a consonant followed by the velo-labial semiconsonant is treated by Karata speakers as one segment.

In conclusion, I take the distribution facts and the language game results to support an analysis of [Cw] sequences as complex phonemes.

3.2 Stress

Both in the existing grammar [Magomedbekova, 1971] and in the dictionary [Magomedova and Khalidova, 2001], Karata is described as having lexical stress. However, it is not obvious at this point in my research on Karata that this is indeed the case. Of course this could just be that the linguist writing these lines has just failed to hear stress in this language. This is a possibility and one needs to proceed carefully in future work on the language. There are however a few ways in which the seeming lack of stress in Karata (in opposition to what is described in the dictionary and grammar) is yet plausible. First, it is not only the linguist writing these lines who has failed to hear stress, colleagues too have not heard any obvious stress system in the language (although of course their opinion is based on the listening of (just) one text and minimal pairs). Second, while the dictionary [Magomedova and Khalidova, 2001] indicates a stressed syllable for each word, there are clear inconsistencies. Third, verifications of reported minimal pairs (in the grammar and dictionary) and conversations with the second author of the dictionary, who is a native speaker of the language, point towards a situation different from that found in other Daghestanian languages and more specifically in the more closely related Andi languages[16], namely a situation where prosody seems to be entirely dependent on intonation. For these reasons, I do not indicate stress in this paper, though it is not a settled issue.

3.3 Phonotactics

Phonotactic restrictions give rise to morpho-phonological 'repair' processes when these restrictions would otherwise be violated. In the next section, I give more details about some of these processes. In this section I limit myself to giving examples of the phonotactic restrictions relevant to the phenomenon analyzed in this paper.

3.3.1 Syllable structure

The maximal syllable template is: C G V G C (C). Complex codas are found in loanwords, as in (15h) from Russian.

(15) List of syllable types and examples

	syllable type	underlying form	surface form	Meaning
(a)	CV	hane	ha.ne	village
(b)	CGV	dunjal	du.ɲal	world
(c)	GV	j-ah^{w}a-e	ja.hweː	she played
(d)	CVC	bert'in	ber.t'in	cheese
(e)	CVG	w-oʒ-ud-o-w	wo.ʒu.dow	trustful
(f)	CVGC	ʕajb	ʕajb	guilt
(g)	GV	waʃa	wa.ʃa	boy
(h)	CVCC	port	port	harbor

3.3.2 Restrictions on sequences of consonants across syllables

Sequences of labialized consonants in onset positions are generally not allowed (16).

[16] For instance, the grammar of Bagvalal [Kibrik, 2001] describes a situation in which Bagvalal words are divided into three sets when it comes to their behavior with respect to stress: (i) words with a clearly emphasized syllable ('as in Russian' according to speakers); (ii) words with a less clearly emphasized syllable which speakers call 'weak stress'; and (iii) words with no stress whatsoever. It is of course possible that a similar partition exists in Karata and that I have either missed it or that I just happened to tap into class (iii) when working on accentual minimal pairs according to the Karata dictionary [Magomedova and Khalidova, 2001].

(16) Sequences of labialized onsets are not allowed

	'tie'		'play'	
	underlying form	surface form	underlying form	surface form
Verb stem	-ax̄ʷ˜-	-	-ahʷa-	-
Class I	w-ax̄ʷ˜-aɭ̥a	wax̄ãɭ̥a	w-ahʷa-aɭ̥a	wahaːɭ̥a
Class II	j-ax̄ʷ˜-aɭ̥a	jax̄ʷãɭ̥a	j-ahʷa-aɭ̥a	jahʷaːɭ̥a
Class III	b-ax̄ʷ˜-aɭ̥a	bax̄ʷãɭ̥a	b-ahʷa-aɭ̥a	bahʷaːɭ̥a
Class IV	b-ax̄ʷ˜-aɭ̥a	bax̄ʷãɭ̥a	b-ahʷa-aɭ̥a	bahʷaːɭ̥a
Class V	r-ax̄ʷ˜-aɭ̥a	rax̄ʷãɭ̥a	r-ahʷa-aɭ̥a	rahʷaːɭ̥a

Such sequences do however arise in words that seem to be the result of reduplication (17) as in onomatopoeia and so-called 'iterative' forms.

(17) Reduplicated words

Onomatopoeic words

	underlying form	surface form	Meaning
(a)	q̄ʷ'ãq̄ʷ'a	q̄ʷ'ãq̄ʷ'a	throat
(b)	gʷãgʷa	gʷãgʷa	rattle

Iterative forms of verbs

	underlying form	surface form	Meaning
(a)	be-χʷa-χʷaɭ̥a	beχʷaχʷaɭ̥a	pull several times
(b)	ĩ-kʷa-kʷaːɭ̥a	ĩkʷakʷaːɭ̥a	feed (lit. make eat) several times
(c)	re-kʷa-kʷaɭ̥a	rekʷakʷaɭ̥a	burn several times

More research is needed to determine what exactly is reduplicated but there is evidence that the reduplication process applies to the surface form of the corresponding non-reduplicated verb. Take the verb *beχʷaɭ̥a* 'pull' in (18) for instance. If the reduplicated form with class I prefix *w-* and imperfective suffix *-ida* is derived from the surface form [woχuda] – the correct form *woχu-χu-da* is predicted (18a). If however the reduplicated form is derived from the underlying form – /w-eχʷ-ida/ –, we predict a wrong reduplicated surface form (18b).

(18) Reduplicated form of *beχʷaɭ̥a* 'pull'

	source of iterative derivation		result of iterative derivation	
			underlying form	surface form
(a)	[woχuda]	→	/wo-χu-χuda/	[woχuχuda]
(b)	/w-eχʷ-ida/	→	/w-eχʷ-eχʷ-ida/	*[woχoχuda]

It therefore seems that reduplication is a process that takes as input the surface form of the simple verb in a prefix-suffix combination and derives the iterative form of the same prefix-suffix combination. We can therefore keep the conclusion that there is a phonotactic constraint against sequences of labialized onsets which applies to non-reduplicated surface forms. However, it does not apply to forms that are further derived by reduplication.

3.3.3 Restrictions on sequences of vowels and consonants

VC Generally, a round vowel cannot be followed by a labialized consonant whether coda or onset (i.e. I have not found any examples of a round vowel followed by a labialized consonant).

CV A glide – /w/ or /j/ – or a labialized consonant – /Cʷ/ – cannot be followed by a vowel that disagrees in place of articulation. In such a configuration, the (non-low) vowel assimilates in place of articulation to the preceding segment. This is illustrated in (19) where C=/w/ and in (20) where C=/j/.[17]

(19) The glide [w] cannot be followed by a heterorganic vowel

	underlying form	surface form	Meaning
(a)	w-ut-aʟ̝̊a	wutaʟ̝̊a	untie
(b)	w-uʟ̥̄’˜-aʟ̝̊a	wuʟ̥̄’ãʟ̝̊a	share, divide
	underlying form	surface form	Meaning
(a)	w-oʟ̥̄-aʟ̝̊a	woʟ̥̄aʟ̝̊a	walk
(b)	w-oʟ̥̄’-aʟ̝̊a	woʟ̥̄’aʟ̝̊a	heat up, become hot
(c)	w-oʟ̥’-aʟ̝̊a	woʟ̥’aʟ̝̊a	be ill
	underlying form	surface form	Meaning
(a)	w-ak’˜-aʟ̝̊a	wak’ãʟ̝̊a	bend
(b)	w-aʟ̥’-aʟ̝̊a	waʟ̥’aʟ̝̊a	get dressed
	underlying form	surface form	Meaning
(a)	w-eʁã-aʟ̝̊a	woʁãːʟ̝̊a	win over, beat
(b)	w-eʟ̥’ara-aʟ̝̊a	woʟ̥’araːʟ̝̊a	get thinner
	underlying form	surface form	Meaning
(a)	w-it͡ʃa-aʟ̝̊a	wut͡ʃaːʟ̝̊a	soak
(b)	w-iʟ̥’-aʟ̝̊a	wuʟ̥’aʟ̝̊a	die (an animal)

(20) The glide [j] cannot be followed by a heterorganic vowel

	underlying form	surface form	Meaning
(a)	j-ut-aʟ̝̊a	jitʷaʟ̝̊a	untie
(b)	j-uʟ̥̄’˜-aʟ̝̊a	jiʟ̥̄’ʷãʟ̝̊a	share, divide
	underlying form	surface form	Meaning
(a)	j-oʟ̥̄-aʟ̝̊a	jeʟ̥̄aʟ̝̊a	walk
(b)	j-oʟ̥̄’-aʟ̝̊a	jeʟ̥̄’aʟ̝̊a	heat up, become hot
(c)	j-oʟ̥’-aʟ̝̊a	jeʟ̥’aʟ̝̊a	be ill
	underlying form	surface form	Meaning
(a)	j-ak’˜-aʟ̝̊a	jak’ãʟ̝̊a	bend
(b)	j-aʟ̥’-aʟ̝̊a	jaʟ̥’aʟ̝̊a	get dressed
	underlying form	surface form	Meaning
(a)	j-eʁã-aʟ̝̊a	jeʁãːʟ̝̊a	win over, beat
(b)	j-eʟ̥’ara-aʟ̝̊a	jeʟ̥’araːʟ̝̊a	get thinner
	underlying form	surface form	Meaning
(a)	j-it͡ʃa-aʟ̝̊a	jit͡ʃaːʟ̝̊a	soak
(b)	j-iʟ̥’-aʟ̝̊a	jiʟ̥’aʟ̝̊a	die (an animal)

[17] These examples also show that only underlying /u/ induces labialization of the following C if it delabializes, while neither unchanged underlying /u/ nor unchanged or changed /o/ (nor any other vowel) does so.

The fact that labialized consonants cannot be followed by heterorganic vowels is illustrated in (8). This predicts that if a stem-final consonant is labialized as a result of the prefixation of the class 2 marker *j-* and this consonant precedes a suffixal non-low short heterorganic vowel – /i/ or /e/ – then this vowel is labialized. This is what we find as (21) shows.

(21) Labialized consonants cannot be followed by a heterorganic vowel

butʃãl̥a 'wash'

	underlying form	'intermediate form'	surface form
Class I	w-utʃ˜-ida	wutʃ˜-ida	wutʃĩnda
Class II	j-utʃ˜-ida	jitʃ^w˜-ida	jitʃũnda
Class III	b-utʃ˜-ida	butʃ˜-ida	butʃĩnda
Class IV	b-utʃ˜-ida	batʃ^w˜-ida	batʃũnda
Class V	r-utʃ˜-ida	ratʃ^w˜-ida	ratʃũnda

In (21), the prefixation of the class II, IV, and V markers delabializes the stem-initial vowel which triggers the labialization of the following consonant, which in turn triggers the labialization of the suffix-initial vowel.[18]

Notice that in (21) and (23c) the back vowel /u/ after the class IV and V prefixes undergoes lowering to [a]. The same occurs with /o/ (23d). For the front vowels /i/ and /e/, the situation is diverse: some verbs do undergo lowering (23a-b), others do not (24).

(23) The plural class markers /b/ and /r/ trigger lowering of the vowel.

	Underlying form	Surface form	Meaning
(a)	b-iχ̄ʷ-al̥a	baχ̄ʷal̥a	stay
(b)	r-ek̄ʷa-al̥a	rak̄ʷaːl̥a	set
(c)	b-utʃ˜-al̥a	batʃʷãŋl̥a	bathe
(d)	r-oq̄-al̥a	raq̄al̥a	remove

(24) The plural class markers /b/ and /r/ do not trigger lowering of the vowel.

	Underlying form	Surface form	Meaning
(a)	r-iʃ˜-al̥a	riʃãl̥a	defeat
(b)	b-el̥̄'ã-al̥a	bel̥̄'ãːŋl̥a	cross

[18]Consistent with what goes on in (21) is what goes on in (22) with *bah^{w}aːl̥a* 'play' found in the dictionary.

(22) bah^{w}aːl̥a 'play'

	underlying form	'intermediate form'	surface form
Class I	w-ah^{w}a-ida	w-ah^{w}eda	wahoda
Class II	j-ah^{w}a-ida	j-ah^{w}eda	jahoda
Class III	b-ah^{w}a-ida	b-ah^{w}eda	bahoda
Class IV	b-ah^{w}a-ida	b-ah^{w}eda	bahoda
Class V	r-ah^{w}a-ida	r-ah^{w}eda	rahoda

The verb stem ends in the low vowel [a]. Suffixing the imperfective morpheme *-ida* would result in hiatus but this is avoiding by merging the low vowel [a] and the high front vowel [i] into the central front vowel [e]. The labialized consonant labializes this vowel into [o].

The imperfective form [ahoda] is given in the dictionary with a short [o] vowel contrary to what I described earlier (i.e. the result of coalescence gives a long vowel). I do not know whether this is a typo or whether the vowel is indeed short. If the transcription is correct, then there must be some cases of coalescence that result in a short vowel. If however, the transcription is wrong and coalescence always results in a long vowel then we must explain why this long vowel here can become round whereas it does not in (10b). Notice though that, under the assumption that there has been a typo, the sequence /h^{w}eː/ in (22) is not word-final which would be consistent with what we observed earlier in (10b), namely that (long) /eː/ does not assimilate with a previous labialized consonant in word-final position. Here again more research is needed.

In other words, if the verb-initial vowel is /i/ or /e/, depending on the verb, it undergoes lowering or not. If the verb-initial vowel is /u/ or /o/, it always lowers to [a]. Two analyses are possible. Two stems could be posited for the majority of verbs, the fact that some verbs' initial vowel does not lower, would then be explained. The other possible analysis is that there are two kinds of plural prefixes: plural b- and r- with a floating [+low] feature each and plural b- and r- with no such feature plus each stem is specified for taking one or the other class marker. Deciding on one of these analyses is not crucial for this paper.

3.4 Morphophonology

The consonant labialization process this paper is about can potentially occur with any stem that can be prefixed with a class marker. There are two types of stems that can be prefixed with a class marker in Karata: verb stems and (underived) adjective stems.[19] Not all stems can be prefixed, this information is lexically specified. Unfortunately I have not (yet) found any example of an (underived) adjective stem starting with /u/ and which might thus let us observe consonant labialization in stems that are not verb stems.

(25) Examples of prefixable (underived) adjective[20]
b-eχ̄ela-b 'long'

	underlying form	surface form
Class I	w-eχ̄ela-w	woχ̄elaw
Class II	j-eχ̄ela-j	jeχ̄elaj
Class III	b-eχ̄ela-b	beχ̄elab
Class IV	b-eχ̄ela-baj	beχ̄elabaj
Class V	r-eχ̄ela-raj	reχ̄elaraj

This being said it should be noted that there are few underived adjective stems, that is adjectives that cannot be analyzed synchronically as being derived participial forms of verbs. Indeed verbs stems can be productively derived into participial forms[21] (used like adjectives) as in (26a) and into so-called 'masdar' forms (26b) in the Caucasian terminology, i.e. derived nouns that retain some syntactic properties of the verb they are derived from like case assignment. In these derived forms too, the consonant labialization phenomenon we are interested in is at work.

(26) Examples of prefixable words derived from prefixable verb stems

[19] I should say that most prefixable adjectives in Karata look like past/present participles, i.e. forms derived from verbs (with the suffix -o and a suffixal class marker), as in (26a). What is more, it sometimes happens that a verb has a cognate adjective (or a cognate noun). In that case it is difficult to decide whether the verb derives from the adjective (or the noun) or whether the adjective (or the noun) derives from the verb (see Author 2011). Here too more descriptive work is needed.

[20] Past participles are derived from verbs by adding the suffix -o to the stem followed by a class marker (26a). Here I treat this adjective as underived because the vowel before the suffixal class marker is not /o/. Therefore it seems that *b-eχ̄ela-b* is not a participle derived from a verb. Furthermore the verb 'get longer' is *b-eχ̄ela-L̥̊-aL̥̊a* with the -L̥̊- morpheme used to derive verbs from adjective and nouns (Author 2011). This morpheme is likely historically derived from the verb become *beL̥̊aL̥̊a*. If the adjective were derived from the verb, this suffix should have been kept in the derived form. In particular notice that it *is* kept in the masdar form of this verb *b-eχ̄ela-L̥̊-er* 'length' (**b-eχ̄ela-r*). It therefore seems like the sequence of derivation is adjective-verb-masdar in this order and that the adjective is not derived from the verb. Again the status of this adjective as non-derived is predicated on the accuracy of the reasoning just exposed. It could be that what I take to be the base stem -*eχ̄ela*- is in fact -*eχ̄el*- with the causative suffix -*a*. More research is needed here too.

[21] Participles all end in a class marker which are identical to the prefixal class marker except class IV and class V marker which are respectively -*baj* and -*raj*, see table (29) for more details.

(a) Participles

- boʟ̥̄aʟ̞̊a ‘happen’

	underlying form	surface form
Class I	w-oʟ̥̄-o-w	woʟ̥̄ow
Class II	j-oʟ̥̄-o-j	jeʟ̥̄oj
Class III	b-oʟ̥̄-o-b	boʟ̥̄ob
Class IV	b-oʟ̥̄-o-baj	baʟ̥̄obaj
Class V	r-oʟ̥̄-o-raj	raʟ̥̄oraj

- buʧãʟ̞̊a ‘bathe’

	underlying form	surface form
Class I	w-uʧ˜-id-o-w	wuʧĩdow
Class II	j-uʧ˜-id-o-j	jiʧũndoj
Class III	b-uʧ˜-id-o-b	buʧĩndob
Class IV	b-uʧ˜-id-o-baj	baʧũndobaj
Class V	r-uʧ˜-id-o-raj	raʧũndoraj

(b) Masdars

- boʟ̥̄aʟ̞̊a ‘walk’

	underlying form	surface form
Class I	w-oʟ̥̄-e-r	woʟ̥̄er
Class II	j-oʟ̥̄-e-r	jeʟ̥̄er
Class III	b-oʟ̥̄-e-r	boʟ̥̄er
Class IV	b-oʟ̥̄-e-r	boʟ̥̄er
Class V	r-oʟ̥̄-e-r	roʟ̥̄er

- buʧãʟ̞̊a ‘bathe’

	underlying form	‘intermediate form’[22]	surface form
Class I	w-uʧ˜-a-r	w-uʧan	wuʧan
Class II	j-uʧ˜-a-r	j-uʧan	jiʧʷan
Class III	b-uʧ˜-a-r	b-uʧan	buʧan
Class IV	b-uʧ˜-a-r	b-uʧan	baʧʷan
Class V	r-uʧ˜-a-r	r-uʧan	raʧʷan

Because, clear unambiguous underived adjectives are (pending more research) difficult to come by and because at the moment I do not have any example of such a clear unambiguous case of an underived adjective whose first vowel is /u/, I focus my discussion on verbs. There are two types of verbal stems in Karata: consonant-initial and vowel-initial stems (figure 5). There’s a lexical distinction between vowel-initial stems that have a morphological slot for a gender prefix and those that do not. Verb stems in Karata are overwhelmingly monosyllabic (VC or CVC), occasionally bisyllabic, and rarely longer. The TAM markers are suffixed to the verb stems.

[22] The stem *-uʧ˜-* ‘bathe’ comes with a floating nasal feature, which docks on /r/ turning it into [n]. This is very common. The nasal feature can dock on only three consonants /b, l, r/ (somewhat surprisingly, it never docks on /d/).

Figure 5: Verb stems in Karata (underlying forms)

Vowel-initial stems		Consonant-initial stems
VC		CVC
_-VC	VC	
_-ah- ‘buy’	aba- ‘sprinkle’	barka- ‘congratulate’
_-iʁ- ‘stop’	ij- ‘attach’	bih˜- ‘heat up’
_-eʔ- ‘ripen’	er- ‘lean on’	beʟ̥̄’- ‘plough’
_-ut’- ‘hollow out’	urʁ- ‘miss’	bur̠- ‘rise’
_-oq̄’- ‘remove’	ob- ‘shake’	borʃ̄˜- ‘peel’

Karata has ergative alignment and the prefix (for stems that have them) marks the class (a.k.a. gender) of the unmarked absolutive argument. In (27), the verb ‘play’ shows the agreement prefix for ‘non-human plural’ which is the class of the unique argument *mak’i* ‘children’. In (28), the absolutive argument is the patient *ʦ’ãt’ur* ‘plate’ the gender of which, neuter, is reflected in the verb prefix.

(27) Intransitive construction

mak’-i	r-ah-oda	idja.
child-PL$_{nH^+}$	nH$^+$-play-IPF	COP

The children are playing.

(28) Transitive construction

den-a	urʁeːda	b-iʔ^w-aː	ʦ’ãt’ur.
I-ERG	on_purpose	N-break-CAUS.PF	plate$_N$

I broke the plate on purpose.

As shown in (29), there are 5 classes, thus 5 class markers: male singular (M), feminine singular (F), neuter singular (N), human plural (H$^+$), and non-human plural (nH$^+$).

(29) Class markers

sg				pl		
class	morpheme	gloss		class	morpheme	gloss
I	/w/	M	male human	} IV	/b/, /b(aj)/ as suffix	H$^+$
II	/j/	F	female human			
III	/b/	N	remainder	V	/r/, /r(aj)/ as suffix	nH$^+$

As we have already seen above, non-low stem-initial vowels undergo a number of assimilation processes depending on the class marker that precedes them. Vowels following the class I marker *w-* are rounded, those following the class I marker *j-* are unrounded, and those following the class IV and V markers *b-* and *r-* are lowered to [a] with some verbs[23]. Because only the neuter singular marker *b-* (class III) can be followed by any of the five vowel qualities (30-31), the form of the verb stem following this marker is taken to be its underlying form. It is worth noting that this form, the class III or singular neuter form, is the citation form in the dictionary [Magomedova and Khalidova, 2001]. Prefixable stems never appear on their own without a class marker prefix.

(30) Prefixable VC(V) stems

[23]Which verbs get their initial vowel lowered when combined with these prefixes seem to be lexically specified.

	‘lay’	‘wilt’	‘clean’	‘untie’	‘appear’
UR	-iʟ̞̊-	-etʃ’˜-	-at͞s’a-	-ut-	-oχ̄-
Class I	wuʟ̞̊aʟ̞̊a	wotʃ’ãʟ̞̊a	wat͞s’aːʟ̞̊a	wutaʟ̞̊a	woχ̄aʟ̞̊a
Class II	jiʟ̞̊aʟ̞̊a	jetʃ’ãʟ̞̊a	jat͞s’aːʟ̞̊a	jit^{w}aʟ̞̊a	jeχ̄aʟ̞̊a
$\boxed{\text{Class III}}$	biʟ̞̊aʟ̞̊a	betʃ’ãʟ̞̊a	bat͞s’aːʟ̞̊a	butaʟ̞̊a	boχ̄aʟ̞̊a
Class IV	baʟ̞̊aʟ̞̊a	batʃ’ãʟ̞̊a	bat͞s’aːʟ̞̊a	bat^{w}aʟ̞̊a	baχ̄aʟ̞̊a
Class V	raʟ̞̊aʟ̞̊a	ratʃ’ãʟ̞̊a	rat͞s’aːʟ̞̊a	rat^{w}aʟ̞̊a	raχ̄aʟ̞̊a

(31) Prefixable VC^{w}(V) stems

	‘stay’	‘be’	‘play’	-	-
UR	-ix^{w}-	-ek̄^{w}-	-ah^{w}a-	-	-
Class I	wuxaʟ̞̊a	wok̄aʟ̞̊a	wahaːʟ̞̊a	-	-
Class II	jix^{w}aʟ̞̊a	jek̄^{w}aʟ̞̊a	jah^{w}aːʟ̞̊a	-	-
$\boxed{\text{Class III}}$	bix^{w}aʟ̞̊a	bek̄^{w}aʟ̞̊a	bah^{w}aːʟ̞̊a	-	-
Class IV	bax^{w}aʟ̞̊a	bak̄^{w}aʟ̞̊a	bah^{w}aːʟ̞̊a	-	-
Class V	rax^{w}aʟ̞̊a	rak̄^{w}aʟ̞̊a	rah^{w}aːʟ̞̊a	-	-

In non-prefixable verb stems, the labialized consonant will only interact with suffixed morphemes (as described in 3.1.3).

(32) Non-prefixable VC(^{w}) stems

VC	VC^{w}
itaʟ̞̊a ‘let’	ix^{w}atʃaʟ̞̊a ‘feed’
eraʟ̞̊a ‘freeze’	-
ahãʟ̞̊a ‘boil’	ãʁ^{w}aːʟ̞̊a ‘deafen’
urʁaːʟ̞̊a ‘think’	-
obaʟ̞̊a ‘shake’	-

(33) Non-prefixable CVC(^{w}) stems

CVC	CVC^{w}
mit͞s’aːʟ̞̊a ‘sweeten’	mik’^{w}aːʟ̞̊a ‘reduce’
ʟ̥’emaːʟ̞̊a ‘enlarge’	ʟ̥’ek’^{w}aːʟ̞̊a ‘economize’
gahaʟ̞̊a ‘do’	gãːʁ^{w}ãʟ̞̊a ‘tighten’
guraʟ̞̊a ‘bend’	-
gotʃaʟ̞̊a ‘roam’	-

Other non-prefixable verb stems are longer than just one syllable. There too, depending on whether the final consonant is labialized (34) or not (35), suffixes undergo assimilation.

(34) ʁiziχ̄^{w}aʟ̞̊a ‘get dirty’

	Underlying form	Surface form
future	ʁiziχ̄^{w}-as̄	ʁiziχ̄^{w}as
imperfective	ʁiziχ̄^{w}-ida	ʁiziχ̄uda
perfective	ʁiziχ̄^{w}-i	ʁiziχ̄u
imperative	ʁiziχ̄^{w}-i	ʁiziχ̄u

When the verb root ends in a non-labialized consonant, the suffixes are transparently added (35).

(35) reʟ̞̊eχ̄aʟ̞̊a ‘smile’

	Underlying form	Surface form
future	reʟ̞̊eχ̄-as̄	reʟ̞̊eχ̄as̄
imperfective	reʟ̞̊eχ̄-ida	reʟ̞̊eχ̄ida
perfective	reʟ̞̊eχ̄-a	reʟ̞̊eχ̄a
imperative	reʟ̞̊eχ̄-i	reʟ̞̊eχ̄i

3.5 Conclusion and summary

When an underlying stem-initial round vowel has lost its round specification as a result of assimilation to the class prefix, its round feature reassociates to the next consonant. This reassociation only happens if the round feature comes from a vowel that is underlyingly high (i.e. /u/) (53).

(36) The adjacent consonant is labialized

	underlying form	surface form	Meaning
(a)	j-uʧ˜-aʟ̞̊a	jiʧʷãŋʟ̞̊a	bathe
(b)	j-uʧ’ã-aʟ̞̊a	jiʧ’ʷãːŋʟ̞̊a	open
(c)	j-ut-aʟ̞̊a	jitʷaʟ̞̊a	untie
(d)	j-uʟ̥̄’˜-aʟ̞̊a	jiʟ̥̄’ʷãŋʟ̞̊a	share

(37) The adjacent consonant remains unlabialized

	underlying form	surface form	Meaning
(a)	j-oχ̄a-aʟ̞̊a	jeχ̄aːʟ̞̊a	thrust
(b)	j-oq̄-aʟ̞̊a	jeq̄aʟ̞̊a	remove
(c)	j-oχ̄-aʟ̞̊a	jeχ̄aʟ̞̊a	appear
(d)	j-oʟ̥̄’-aʟ̞̊a	jeʟ̥̄’aʟ̞̊a	warm up

As (36d) and (37d) show, the difference in labialization patterns does not seem to be due to the consonant itself. It is however difficult to find pairs of the form prefix-VC... like (36d) and (37d), where C remains constant while V is either /u/ or /o/. It is not clear to me why at the moment. Studying the distribution of [u] and [o] does not reveal any obvious restrictions on the consonant that can follow them: as far as I can tell [u] and [o] can be followed by a consonant of any place or manner of articulation, central or lateral. It just so happens that, given a specific consonant C and a specific prefixal class marker CM, there are very few pairs of words that meet the conditions of having [u]/[o] after CM and before C. Furthermore, as shown above in section 3.1.3, any non-labial consonant can be labialized.

I therefore conclude that the only correlate of the possibility to labialize a consonant is the height of the vowel that precedes the consonant. When preceded by the palatal glide, the round feature of the high round vowel /u/ is dettached and further reassociates to the adjacent consonant. However, while the round feature of the mid round vowel /o/ is dettached, it does not reassociate to the following consonant. In the remainder of this paper, I propose a theoretical account of this phenomenon and motivate the existence of scalar [labial] features.

4 An OT analysis

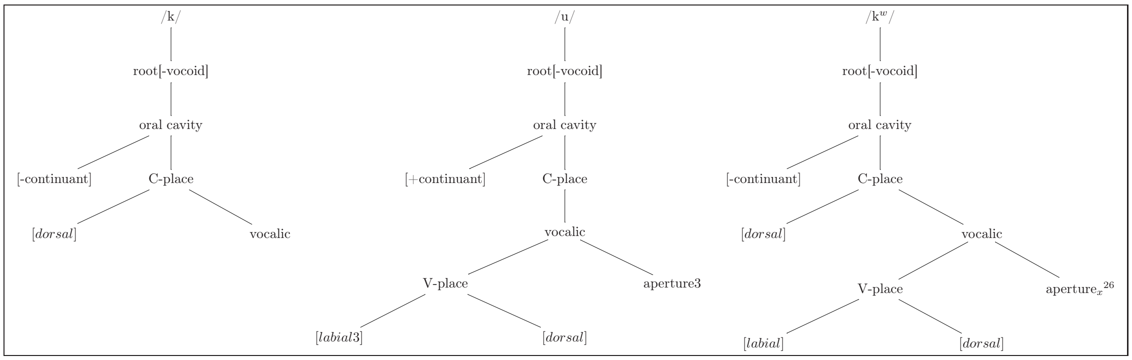
4.1 Some representational assumptions

4.1.1 Feature geometry

I assume Clements and Hume [1995]'s unified feature geometric representation for both consonants and vowels. In figure 6, the phoneme /k/ has a Consonantal-place node specified for the [dorsal] articulation. The phoneme /u/ has a C-place node specified for a vocalic articulation only; the vocalic node contains an aperture node specifying the degree to which the oral cavity is closed and a Vocalic-place node specifying the place of articulation of the vowel, here [dorsal] and [labial]. A complex segment with a secondary articulation contains both a place feature for the C-place articulation and a vocalic node.

I discuss the aperture node in subsection 4.1.2 and the feature [labial$x$] in section 5.

Figure 6: Feature geometric representations of /k/, /u/ and /k^w/ in Karata.



The insight of such a representation is that vowels and consonants use the same constriction places. There are two kinds of features: place features are privative whereas [±continuant], [±sonorant], for instance, are binary.

The major articulation in any complex consonant is interpreted with the values of the stricture features [continuant, approximant, sonorant] present in the higher structure, and the minor articulation is assigned its non-contrastive degree of closure by independent phonetic rules and principles. In other words, when the C-place node has a place specification, the degree of closure indicated by the aperture node is purely phonetic as opposed to segments in which the C-place node has no place specification where the aperture node indicates contrastive degrees of closure.

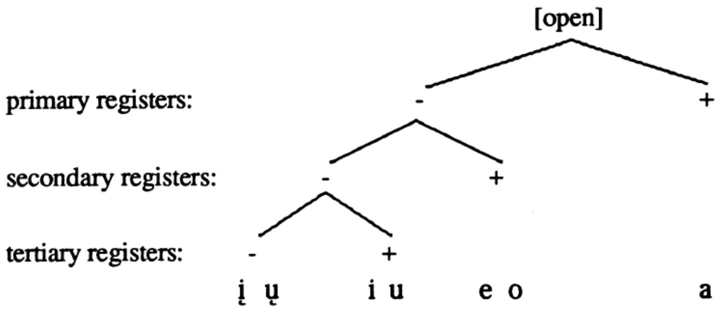
4.1.2 Vowel height

I adopt a simplified version of Clements' view of vowel height [Clements, 1991, Clements and Hume, 1995]. I first present Clements' system as developed to account for four-height vowel systems and assimilatory vowel raising in terms of autosegmental spreading. Then I show the simplified version I adopt in my analysis.

Clements' theory of vowel height Clements proposes a new formalization of vowel height in terms of the 'aperture' of the oral cavity. To express various degrees of vowel height, the bivalent feature [±open] is arrayed on several rank-ordered tiers (or registers) as figure 7 illustrates. Vowel height is thus characterized along a uniform phonetic and phonological dimension in a way that direct-realism theories like articulatory phonology advocate.

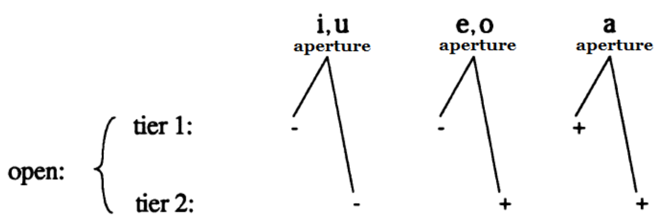
[26] An anonymous reviewer asked whether the aperture node of /k^w/ in figure 6 should be 'aperture 3'. The answer I give to this question is no because I do not make the claim that the degree of aperture of the secondary articulation of labialized consonants in Karata is phonologically specified. Likewise, I assume that the labial feature in the V-place node of a consonant is not specified. Rather, I assume that labialized consonants, having a primary place of articulation, have unspecified aperture for their secondary articulation.

Figure 7: Vowel height (Clements 1991)



Natural classes are defined in terms of feature values on each tier: low vowels are those which are [+open] on tier 1, high vowels are [-open] on tier 2. Three-height vowel systems have two tiers whereas four-height vowel systems have three such tiers.

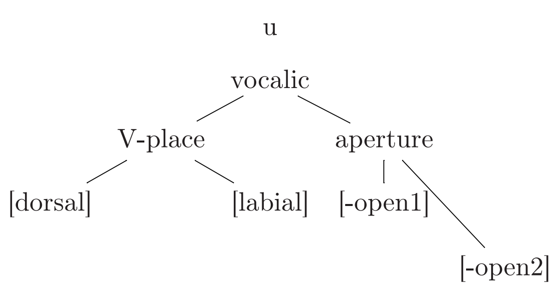
Figure 8: A three-height vowel system.



Such a system does away with the traditional [±high] and [±low] features which make the false predictions that the combination [+high][+low] should pick out a natural class of vowels. It also eliminates the use of [±ATR] to describe four-height vowel systems.

Thus, Clements' representation of the high back round vowel /u/ in a three-height vowel system like Karata's is as in (9).

Figure 9: Clements' representation of a high back round vowel /u/ in a three-height vowel system.



View of vowel height in this paper In a system such as Clements', each set of [±open] features corresponds to one vowel height, that is to one degree of aperture. I make this explicit by numerically marking the aperture node with a degree index. Karata vowels are represented as in (10).

Figure 10: Karata vowels.

	i u	e o	a
[open] tier 1	-	-	+
[open] tier 2	-	+	+
	aperture 3	aperture 2	aperture 1

Assuming Clements' system, positing that there is an index on the aperture node is redundant but remains consistent with his approach. It also makes sense articulatorially if we take 'aperture' as referring to the degree to which the oral cavity is closed as a function of the jaw position. In the remainder of this paper, I do not represent the [±open] features below the aperture node.

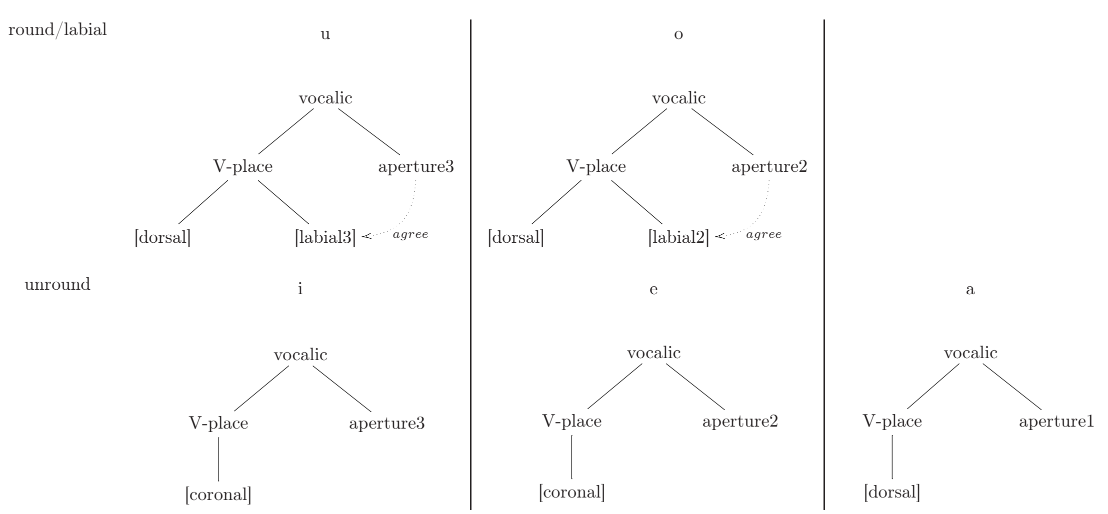
Figure 11: Representation of the degrees of vocalic aperture in Karata.

aperture 3	i u
aperture 2	e o
aperture 1	a

4.1.3 On the relation between aperture and [labial]

In this language, if a vowel has a [labial] feature (i.e. a round vowel), I propose that the [labial] feature agrees in degree with the aperture node of the same vowel (*see* figure 12).

Figure 12: Representation of the five oral vowels in Karata.



To enforce agreement between the aperture degree and the [labial$x$] feature, I posit the markedness constraint in (38). This constraint, like all other constraints in OT, is violable and languages differ in how high or low they rank this constraint.

(38) Anti-mismatch contraint (abr. *aperture$_\alpha$/labial$_{\neg\alpha}$)

$$\begin{array}{c} \text{*aperture}_\alpha \\ | \\ \text{x} \\ | \\ \text{labial}_{\neg\alpha} \end{array}$$

Assign a violation mark to each output rootnode which is linked to an aperture node and a labial feature which disagree in value.

Kaun [1997] uses a constraint which might appear at first sight to be similar and which she calls *the uniformity constraint*.

(39) Uniform[Rd]

The autosegment [+round] may not be multiply linked to vowel positions which are distinctly specified for height.

Kaun is concerned with rounding harmony and she does not assume that [labial] or [+round] may have different phonological degrees[27]. The constraint Uniform[Rd] thus says nothing about individual vowels taken separately: it is only violated once the [+round] feature is linked to more than one vowel. The violable antimismatch constraint used in my analysis makes a broader claim: a [labial$x$] feature, whatever its degree, may only be linked to one or several vowels whose aperture degree matches the labial degree. That is, it regulates any linkage between a [labial$x$] feature and a segment specified for aperture. While this constraint is necessary for my analysis, no crucial candidate ever violates it so it will not appear in the tableaux.

4.2 Analysis

My analysis is couched in Optimality Theory [Prince and Smolensky, 1997]. Specifically, I assume a cyclic application of OT [Kiparsky, 2000]. The same grammar applies first to roots (cycle 1), then to derived/inflected forms (cycle 2): each time a morpheme is added to a stem, the obtained form is evaluated.

I also assume that feature geometry is the result of restrictions on how Gen combines features. The Gen module produces candidate sets from an input by arranging features according to a supposedly universal pattern. As mentioned above, I will only consider candidates whose [labialx] degree and aperture degree agree. I assume the inputs in (40) for cycle 2. I explain in section 4.2.3 how those inputs are obtained from cycle 1.

(40) Outputs of cycle 1 / Inputs to cycle 2

ik	ik^w	uk	-
ek	ek^w	ok	-
	ak	ak^w	

[27] In fact, Kaun explicitly considers recognizing different [+round] features and rejects this possibility on account of the round vowels behaving as a natural class whatever their height. While Kaun's concern is reasonable, recognizing different [labial] features does not, in my opinion, challenge the idea of a round-vowel natural class, it just says that within this natural class there are smaller natural classes.

4.2.1 Analysis of consonant labialization

Assimilation is spreading and delinking The unround non-low vowels /i/ and /e/ become round and back when they are preceded by the masculine class marker /w/[28] (41-42). The low vowel /a/ does not assimilate (43).

(41) The sequence /w-i/ becomes [wu]

	underlying form	surface form	Meaning
(a)	w-iʟ̞̊-aʟ̞̊a	wuʟ̞̊aʟ̞̊a	lay
(b)	w-iʁ-aʟ̞̊a	wuʁaʟ̞̊a	stop
(c)	w-ik̄-aʟ̞̊a	wuk̄aʟ̞̊a	hold
(d)	w-is˜-aʟ̞̊a	wusãŋʟ̞̊a	find

(42) The sequence /w-e/ becomes [wo]

	underlying form	surface form	Meaning
(a)	w-eʧ'˜-aʟ̞̊a	woʧ'ãŋʟ̞̊a	shed hair
(b)	w-eʟ̞̊-aʟ̞̊a	woʟ̞̊aʟ̞̊a	drive, walk something
(c)	w-ek̄-aʟ̞̊a	wok̄aʟ̞̊a	give
(d)	w-eʟ̥̄'ã-aʟ̞̊a	woʟ̥̄'ãːŋʟ̞̊a	cross

(43) The low vowel /a/ does not assimilate.

	underlying form	surface form	Meaning
(a)	w-at̄s'a-aʟ̞̊a	wat̄s'aːʟ̞̊a	clean
(b)	w-ahʷa-aʟ̞̊a	wahaːʟ̞̊a	play
(c)	w-aʒara-aʟ̞̊a	waʒaraːʟ̞̊a	manage
(d)	w-aʁ-aʟ̞̊a	waʁaʟ̞̊a	crumble

The prefixation of the feminine singular class marker /j/ to a round-vowel initial stem triggers the delabialization of the vowel and its concomitant fronting (44-45). The low vowel /a/ does not assimilate (46).

(44) The sequence /j-u/ becomes [ji]

	underlying form	surface form	Meaning
(a)	j-uʧ˜-aʟ̞̊a	jiʧʷãŋʟ̞̊a	bathe
(b)	j-uʧ'ã-aʟ̞̊a	jiʧ'ʷãːŋʟ̞̊a	open
(c)	j-ut-aʟ̞̊a	jitʷaʟ̞̊a	untie
(d)	j-utsa-aʟ̞̊a	jitsʷaːʟ̞̊a	knead

(45) The sequence /j-o/ becomes [je]

	underlying form	surface form	Meaning
(a)	j-oχ̄a-aʟ̞̊a	jeχ̄aːʟ̞̊a	thrust
(b)	j-oq̄-aʟ̞̊a	jeq̄aʟ̞̊a	remove
(c)	j-oχ̄-aʟ̞̊a	jeχ̄aʟ̞̊a	appear
(d)	j-oʔ˜-aʟ̞̊a	jeʔãŋʟ̞̊a	go

[28]The spreading of the labial feature of /w/ to the vowels produces a violation of the ANTIMISMATCH constraint (if we assume that /w/ is [labial3] and /o/ is aperture 2). I show later in the paper that this violation is not fatal because it avoids the violation of a higher ranked constraint.

(46) The low vowel /a/ does not assimilate

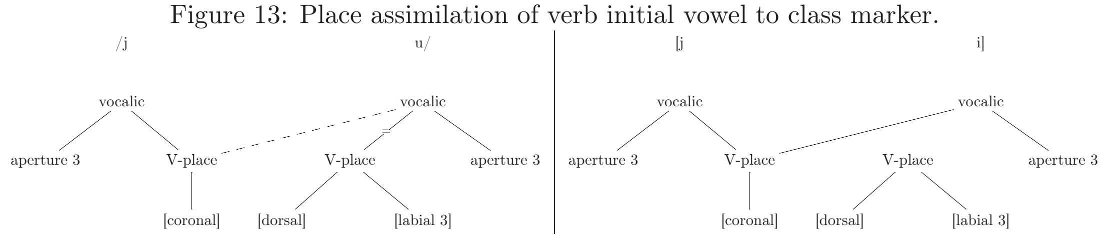
	underlying form	surface form	Meaning
(a)	j-at͡sʼa-aʟ̝̊a	jat͡sʼaːʟ̝̊a	clean
(b)	j-aʔ-aʟ̝̊a	jaʔaʟ̝̊a	reach
(c)	j-aʃa-aʟ̝̊a	jaʃaːʟ̝̊a	count
(d)	j-atʃ-aʟ̝̊a	jatʃaʟ̝̊a	tidy up

We can schematically summarize this pattern as in (47). .

(47) /j-u/ $\rightarrow$ [ji] $\succ$ *[ju]
/w-u/ $\rightarrow$ [wu] $\succ$ *[wi] /

In Karata an onset C with a V-place node (i.e. /j/, /w/ or /C^w/) cannot be followed by a nucleus whose V-place node is different (figure 13).

Figure 13: Place assimilation of verb initial vowel to class marker.



To enforce this assimilation, I posit the markedness constraint $^*O_\alpha N_{\neg\alpha_{PLACE}}$ defined in (48). Undominated faithfulness constraints ensure that the initial class marker surfaces faithfully (*see* 4.2.3).

(48) * O N (abr. $^*O_\alpha N_{\neg\alpha_{PLACE}}$)

V-place$_\alpha$V-place$_{\neg\alpha}$

Assign a violation mark to a syllable whose onset and nucleus do not share the same V-place node in the output.

Consonant labialization is the phonological process of docking the feature [labial$x$] to the next root node. The effect of docking a feature is thus the creation of an association line in the output that does not exist in the input. I posit the faithfulness constraint in (49)[29]. This constraint applies to all labial features. Everytime a feature [labial$x$] is linked to a rootnode to which it is not linked in the input, this constraint is violated.

[29]Other constraints could be posited to penalize spreading of the feature [labialx]. Two ideas come to mind. First, as I showed in figure 6, simplex consonants do not have an aperture node. However a labialized consonant must have an aperture node. Because in Karata labialization is only spreading of the feature [labial3], an aperture node must be epenthesized or rather [±open] features. A constraint forbidding the epenthesis of such features would *de facto* penalize the creation of a labialized consonant, thus having the same effect as IDENT-OI[labial$x$]. In fact as mentioned in 4.1.1, the aperture node of a secondary constriction is 'assigned its non-contrastive degree of closure by independent phonetic rules and principles' (Clements and Hume, 1995: 288).

Second, it could be the case that a markedness constraint prevents the creation of complex consonants. For instance, some studies make use of the constraint *Cw. In the current framework, *Cw is a constraint that penalizes

(49) IDENT-OI[labial$x$]

Assign a violation mark for every link between a [labial$x$] feature and a segment in the output that is not present in the input.

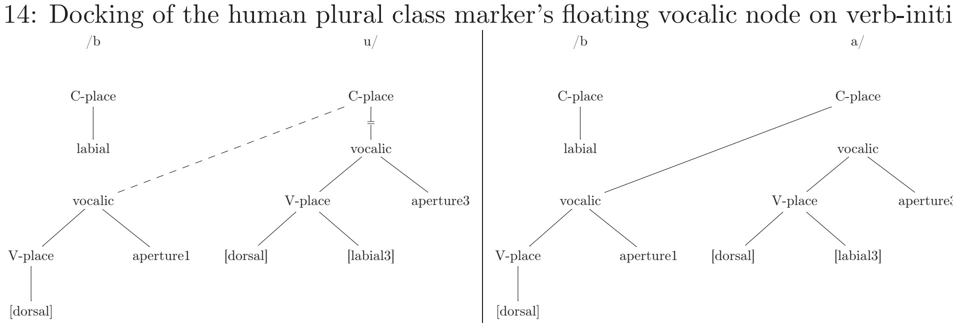
Assimilation of a vowel to its preceding glide is obligatory, even if it involves spreading a [labial x] feature.

(50) $^*O_\alpha N_{\neg\alpha_{PLACE}}$ >> IDENT-OI[labial$x$]

/ w i ʧ / [lab3]	$^*O_\alpha N_{\neg\alpha_{PLACE}}$	IDENT-OI[labial$x$]
a☞ w u ʧ [lab3]		*
b w i ʧ [lab3]	*W	L

The prefixation of a plural class marker containing a vocalic floating node specified for aperture 1 docks on the following vowel turning it into the only aperture 1 vowel that the language has (figure 14).

Figure 14: Docking of the human plural class marker's floating vocalic node on verb-initial vowel



More generally, it is the case that floating features in Karata have to be realized phonetically[30]. I use the constraint in (51) which is undominated.

(51) MAXFLOAT [WOLF, 2007]

Assign a violation mark to each feature that is floating in the input and not present in the output.

(52) MAXFLOAT>>IDENT-OI[labial$x$]

any consonant having a vocalic node containing [labial3] or [labial2]. But positing such a general constraint in Karata makes the prediction that labialized consonants should only be the result of the morpho-phonological process this paper is giving an account of, but this is not the case as Karata has labialized phonemes. Another solution would be to have a more specific markedness constraint: one that penalizes labialized consonants whose labial feature has value 2,*C[labial2]. I will discuss this possibility in 6.1.2

[30] A few Karata verbs and adjectives have a nasal floating features which docks preferably on heteromorphic /r, l, d/. If no such segment is available, then it docks on the closest heteromorphic vowel.

/ b u ʧ / [ap1] [lab3]	MaxFloat	Ident-OI[labial$x$]
a ☞ b a $ʧ^w$ [ap1] [lab3]		*
b b u ʧ ~~[ap1]~~ [lab3]	*W	L

Only a certain type of [labial$x$] feature reassociates. The round vowels /u/ (53) and /o/ (54) become unrounded as a result of their assimilation in place of articulation with the preceding palatal glide /j/. A delinked labial feature reassociates to the following consonant only if it comes from a high vowel (53).

(53) The adjacent consonant is labialized.

	underlying form	surface form	Meaning
(a)	j-uʧ˜-aʟ̝̊a	jiʧʷãŋʟ̝̊a	bathe
(b)	j-uʧ’ã-aʟ̝̊a	jiʧ’ʷãːŋʟ̝̊a	open
(c)	j-ut-aʟ̝̊a	jitʷaʟ̝̊a	untie
(d)	j-uʟ̥̄’˜-aʟ̝̊a	jiʟ̥̄’ʷãŋʟ̝̊a	share

(54) The adjacent consonant remains unlabialized.

	underlying form	surface form	Meaning
(a)	j-oχ̄a-aʟ̝̊a	jeχ̄aːʟ̝̊a	thrust
(b)	j-oq̄-aʟ̝̊a	jeq̄aʟ̝̊a	remove
(c)	j-oχ̄-aʟ̝̊a	jeχ̄aʟ̝̊a	appear
(d)	j-oʟ̥̄’-aʟ̝̊a	jeʟ̥̄’aʟ̝̊a	warm up

As (53b) and (54b) show, the difference in labialization pattern is not due to the consonant. In fact this would have been surprising since, as shown above in section 3.1.3, any non-labial consonant can be labialized. The only correlate of labialization is the height of the vowel. The pattern can be summarized as in (55).

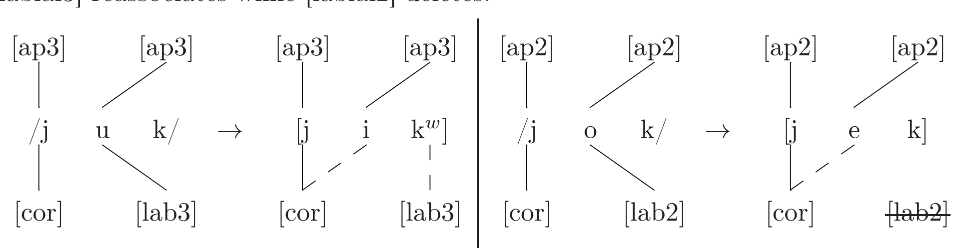
(55) (a) /j-uC/ $\rightarrow$ [jiC^w] $\succ$ *[jiC]

(b) /j-oC/ $\rightarrow$ [jeC] $\succ$ *[jeC^w]

When preceded by the palatal glide, the round feature of the high round vowel /u/ is detached and further reassociates to the adjacent consonant. However, while the round feature of the mid round vowel /o/ is detached, it does not reassociate to the following consonant.

In the proposed framework, this means that only [labial3] reassociates to the following consonant, whereas [labial 2] deletes; *see* (56).

(56) [labial3] reassociates while [labial2] deletes.



We want the constraints enforcing relinking of [labial3] to be ranked above the constraints prohibiting relinking, and we want the constraints enforcing relinking of [labial2] to be ranked below.

The conservation of [labial3] over [labial2] is insured by a faithfulness constraint which assigns a violation mark specifically if [labial3] is deleted (57). In fact I argue that there is a universal hierarchy Max[labial3]>>Max[labial2]>>Max[labial1] (*see* 5.4).

(57) Max[labial3]

Assign a violation mark for every [labial3] feature that is not present in the output.

Tableau (58) shows that it is better to preserve [labial3] and create a new association line than to delete it.

(58) Max[labial3] >> Ident-OI[labial$x$]

/ j u ʧ / | [lab3]	MAX[labial3]	Ident-OI[labial]
a ☞ j i ʧ^w | [lab3]		*
b j i ʧ ~~[lab3]~~	*W	L

It is better to delete a labial feature that is not specified for degree 3 than allow it to dock. A [labial2] feature will delete as in (59).

(59) /j-oχ̄al̝̊a/ ‘appear’
[jeχ̄al̝̊a] ≻ *[jeχ̄^{w}al̝̊a]

In tableau (60), it is better to delete [labial2] than to create an association line.

(60) Ident-OI[labial$x$] >> Max[labial2]

/ j o ʧ / | [lab2]	Ident-OI[labial$x$]	Max[labial2]
a j e ʧ^w / [lab2]	*W	L
b ☞ j e ʧ ~~[lab2]~~		*

It is never the case that a floating feature in Karata remains floating in the output. Therefore I use a constraint to penalize the existence of a floating feature/node in the output: *Float [Wolf, 2007].

(61) *Float

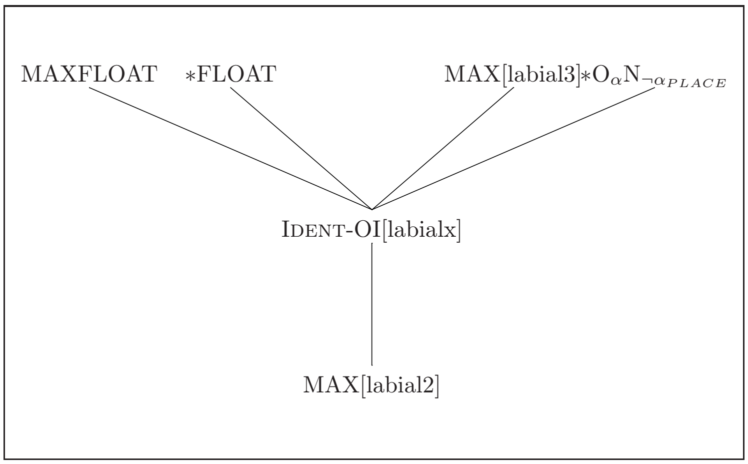
Assign a violation mark to each feature that is floating in the output.

(62) *Float >> Ident-OI[labial$x$]

/ j u ʧ / [lab3]	*Float	Ident-OI[labialx]
a☞ j i $ʧ^w$ [lab3]		*
b j i ʧ [lab3]	*W	L

Let's recapitulate the ranking arguments obtained so far with the Hasse diagram in (63).

(63) Hasse diagram 2



The following tableaux summarize the analysis so far.

(64) /j-uʧ/ → [jiʧ^w] summary

/ j u ʧ / [lab3]	MaxFloat	$*\mathrm{O}_{\alpha}\mathrm{N}_{\neg\alpha_{PLACE}}$	Max[labial$_3$]	*Float	Ident-OI[labial$x$]	Max[labial2]
a☞ j i $ʧ^w$ [lab3]					*	
b j i ʧ [lab3]				*W	L	
c j i ʧ ~~[lab3]~~			*W		L	
d j u ʧ [lab3]		*W			L	

(65) /j-oʧ/ → [jeʧ] summary

/ j o ʧ / [lab2]	MaxFloat	$*O_\alpha N_{\neg\alpha_{PLACE}}$	Max[labial$_3$]	*Float	Ident-OI[labial$x$]	MAX[labial2]
a j e $ʧ^w$ [lab2]					*W	L
b j e ʧ [lab2]				*W		L
c ☞ j e ʧ ~~[lab2]~~						*
d j o ʧ [lab2]		*W				L

(66) /b-uʧ/ → [ba$ʧ^w$] summary

/ b u ʧ / [ap1] [lab3]	MaxFloat	$*O_\alpha N_{\neg\alpha_{PLACE}}$	Max[labial$_3$]	*Float	Ident-OI[labial$x$]	MAX[labial2]
a b u ʧ [ap1] [lab3]				*W	L	
b b u ʧ ~~[ap1]~~ [lab3]	*W				L	
c ☞ b a $ʧ^w$ [ap1] [lab3]					*	
d b a ʧ [ap1] ~~[lab3]~~			*W		L	

(67) /w-eʧ/ → [woʧ] summary

/ [ap2] / w e ʧ [lab3]	MaxFloat	$*O_\alpha N_{\neg\alpha_{PLACE}}$	Max[labial$_3$]	*Float	Ident-OI[labial$x$]	MAX[labial2]
a☞ [ap2] w o ʧ [lab3]					*	
b [ap2] w e ʧ [lab3]		*W			L	

(68) /j-ik^w/ → [jik^w] summary

/ j i k^w / [lab3]	MaxFloat	$*O_\alpha N_{\neg\alpha_{PLACE}}$	Max[labial$_3$]	*Float	Ident-OI[labial$x$]	MAX[labial2]
a☞ j i k^w [lab3]						
b j i k^w [lab3]				*W		
c j i k ~~[lab3]~~			*W			

4.2.2 Analysis of labial dissimilation

In section 3.3, we have seen that Karata has a phonotactic restriction against two subsequent labialized onsets (69).

(69) Two labial onsets in a row are forbidden: the second dissimilates.

	Underlying form	Surface form	Meaning
(a)	/w-it'^{w}-aʟ̞̊a/	[wut'aʟ̞̊a]	collapse
(b)	/w-eʒ^w-aʟ̞̊a/	[woʒaʟ̞̊a]	believe
(c)	/w-aʧ^w-aʟ̞̊a/	[waʧaʟ̞̊a]	destroy

The constraint in (70) will penalize such sequences.

(70) * $O_{\sigma n}$ $O_{\sigma n+1}$ (abr. *$(OO)_{labialx}$)
| |
[labialx] [labialx]

Assign a violation mark to each output sequence of two onsets whose V-place contains a [labial$x$] feature.

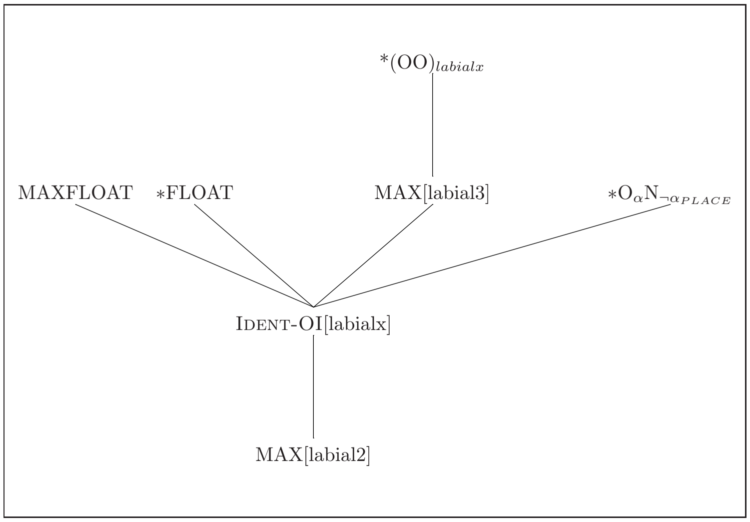
Example (71) shows that this constraint dominates all Max[labial$x$] constraints.

(71) *$(OO)_{labialx}$>>Max[labial3]

/ w a ʧ^w / | | [lab3] [lab3]	*$(OO)_{labialx}$	Max[labial3]
a☞ w a ʧ | [lab3] ~~[lab3]~~		*
b w a ʧ^w | | [lab3] [lab3]	*W	L

MaxFloat, *Float and *$O_\alpha N_{\neg\alpha PLACE}$ never conflict with Max[labial3] over the choice of the winner. Since [labial3] is never floating in the input, these constraints never interact.

(72) Hasse diagram 3



4.2.3 Labialization and richness of the base

I have presented and argued for a particular analysis of the labialization facts of Karata: consonant labialization only occurs as a result of vowel delabialization. Karata has contrastive [labial$x$] features and there is more faithfulness to more extreme degrees of labialization. Thus it is never the case that [labial2] docks on a consonant, this is why delabialization of /o/ never triggers labialization of the following consonant contrary to delabialization of /u/. Crucially, this account assumes that there are no underlying vowel-initial verb stems whose initial vowel is round and followed by a labialized consonant (i.e. *uC^w, *oC^w)[31]. However, in an optimality-theoretic framework where no restriction can be posited on the set of inputs to the grammar, language-specific patterns have to fall out from the constraints used.

In what follows I show that if we assume a cyclic version of OT, whereby the grammar applies cyclically 'as the word is built', then we can naturally (i.e. using only independently needed constraints) derive that Karata does not have verb stems of the form /uC^w/, /oC^w/ without restricting the set of possible inputs. Furthermore I show that cyclic OT must be used because keeping to a non-cyclic grammar overgenerates.

Cycle 1 This section aims to show how the grammar presented in 4.2.1 and 4.2.2 handles richness of the base (i.e. how we derive the fact that Karata has no underlying verb stems of the form uC^w, oC^w without actually restricting the set of inputs to the grammar). The set of verb stems input to cycle 2 (40) falls out from the phonotactic restrictions if we assume a cyclic version of OT in which the grammar applies cyclically to successively larger constituents. In other words, every time a morpheme has been added, Eval generates output candidates from that new form. As far as verbs are concerned, I assume that, at cycle 1, the grammar applies to bare stems, at cycle 2 (presented above) it applies to the prefixed stems.

In Karata, a labial vowel can never be followed by a labialized consonant. This restriction is formalized in (73).

[31] Karata provides no positive evidence that there are sequences such as /uC^w/ and /oC^w/. Furthermore, negative evidence confirms that such sequences are not allowed in the language.

(73) $*\mathrm{V}_{[labialx]}\mathrm{C}_{[labialx]}$

$$\begin{array}{cc} *[+\text{vocoid}] & [-\text{vocoid}] \\ | & | \\ [\text{labialx}] & [\text{labialx}] \end{array}$$

Assign a violation mark to a sequence of adjacent labial vowel and consonant.

This constraint could be satisfied by any of the following changes: a) delabialization of the vowel b) delabialization of the consonant c) both a. and b. In fact there is good evidence that change b) is chosen to satisfy the undominated $*\mathrm{V}_{[labialx]}\mathrm{C}_{[labialx]}$ constraint (*see* 71).

We have seen evidence that Karata applies greater faithfulness to the initial segment of an input. In section 4.2.1 for instance, $*\mathrm{O}_{\alpha}\mathrm{N}_{\neg\alpha_{PLACE}}$ is satisfied by changing the V-place specification of the vowel following the initial phoneme and never by changing the V-place of the class marker. In the input /juC/, $*\mathrm{O}_{\alpha}\mathrm{N}_{\neg\alpha_{PLACE}}$ is satisfied by remaining faithful to the feminine class marker /j/ (74).

(74) /j-uC/ $\rightarrow$ [jiC^w] $\succ$ *[wuC]

I posit the undominated constraints in (75) and (76) to enforce faithfulness to the initial segment of an input.

(75) MAX #V-PLACE

Assign a violation mark to an input-initial V-place node if the same V-place node is not present in the output.

(76) IDENT #V-PLACE

Assign a violation mark to an input-initial root node linked to a V-place node if its corresponding output rootnode is linked to a different V-place node.

Given these constraints, when the grammar applies to stems containing a round V followed by C^w, the winning candidate is one in which the C has been delabialized.

(77) IDENT #V-PLACE, MAX #V-PLACE, $*\mathrm{V}_{[labialx]}\mathrm{C}_{[labialx]}$ are undominated.

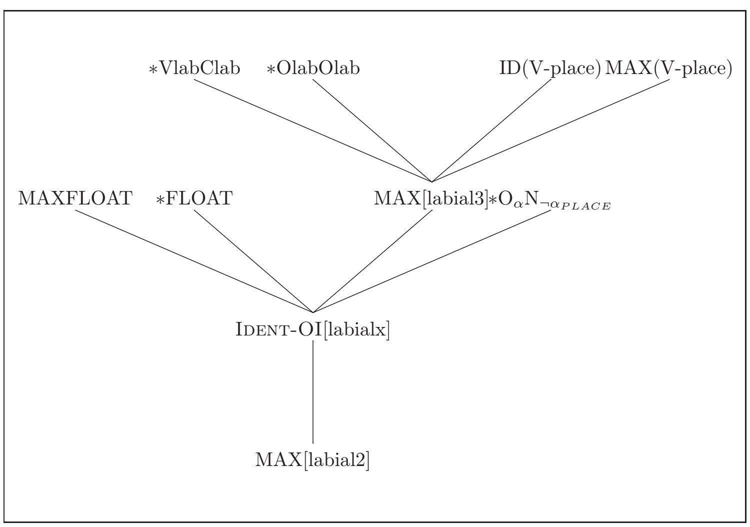
/ u k^w / [lab3][lab3]	IDENT #V-PLACE	MAX #V-PLACE	$*\mathrm{V}_{[labx]}\mathrm{C}_{[labx]}$	MAX[labial3]
a ☞ u k [lab3]~~[lab3]~~				*
b u k^w [lab3][lab3]			*!	
c i k^w ~~[lab3]~~[lab3]		*!		*
d i k^w [lab3][lab3]	*!			

/o k^w/ [lab2][lab3]	IDENT #V-PLACE	MAX #V-PLACE	$*V_{[labx]}C_{[labx]}$	MAX[labial3]
a ☞ o k [lab2]~~[lab3]~~				*
b o k^w [lab2][lab3]			*!	
c e k^w ~~[lab2]~~[lab3]		*!		
d e k^w [lab2][lab3]	*!			

Given richness of the base, I do not make the claim that, in languages, labialized consonants are always [labial3]. Though it would make the analysis much simpler, my analysis does not restrict labialized consonants to being specified for only [labial3] (the impossibility of linking [labial 2] to a consonant resulting from more general restrictions (i.e. undominated constraints) on the consonantal inventory of Karata). First, this assumption would go counter to Clements and Humes' claim that the degree/aperture of secondary articulations is specified in the phonetics. Secondly, I discuss this possibility in 6.1.2 and show that this analysis is not well motivated in light of the array of segments that can be labialized, and lacks explanatory power.

Therefore my analysis does not make a claim about the compatibility of certain features. It makes a claim about the preferrence for one type of labialization process over another.

(78) Final Hasse diagram



I have shown that cyclic OT may be resorted to to account for why verb stems are never of the form /uC^w/, /oC^w/. In the following section, I show that in fact we must resort to cyclic OT.

The need for cyclic OT Given richness of the base, a fair assumption would be that 'consonant labialization' is not the result of a phonological process, rather it reflects what the feature specification of the input is. In other words, one could assume that what seems to be a process of consonant labialization is in fact not a process at all but the mere consequence of the fact that the underlying consonant is already labialized in the input. Under such an account, paradigm alternations of the type *wuC* ~ *jik*^{w} would be derived from a verb stem of the type /uk^w/. When this verb stem is prefixed with a class marker, Eval eliminates candidates which violate phonotactic constraints. The phonotactic constraints in (70) are enough to deal with inputs of the *uC*^{w} type: the consonant can be delabialized or the stem-initial vowel can be delabialized via assimilation to the preceding glide.

(79) Two ways of satisfying the phonotactic constraint $*(OO)_{labialx}$ in CM-uC^w

		$*(OO)_{labialx}$	$*O_\alpha N_{\neg\alpha PLACE}$
	/wuC^w/		
a.	wuC^w	*	
b.☞	wuC		
	/juC^w/		
a.	juC^w		*
b.☞	jiC^w		

A problem arises if we assume verb stems of the type /oC^w/ whose initial vowel is round and not high. When the feminine singular marker *j-* is prefixed to it and assimilation of /o/ occurs, we would wrongly predict two possible outputs: *jeC*^{w} and *jeC*, but only the latter is attested. The $*(OO)_{labialx}$ phonotactic constraint will not be enough to bar the wrong output *jeC^w in (80b).

(80) Failure of $*(OO)_{labialx}$ to yield the right output for CM-oC^w

		$*(OO)_{labialx}$	$*O_\alpha N_{\neg\alpha PLACE}$
	/woC^w/		
a.	woC^w	*	
b.☞	woC		
	/joC^w/		
a.	joC^w		*
b.X	jeC^w		
c.☞	jeC		

Parallel OT can't handle richness of the base to yield the Karata facts. As (80) shows, given an input /j-oC^w/, parallel OT predicts both [jeC^w] and [jeC] to be winners when in fact only [jeC] is. Descriptively, this asymmetry could be captured by saying that Karata has the verb stems in (81): there are underlying /uC^w/ stems but no underlying /oC^w/ stems. Such a description posits an asymmetry which does not seem to be motivated (indeed we know that the language prohibits sequences of a round vowel and a labialized consonant). Moreover in an optimality-theoretic framework where no restriction can be posited on the set of inputs to the grammar, language-specific pattern have to fall out from the constraints used. A constraint specifically targeting oC^w sequences would do the job but would be less motivated than the more general $*V_{[labialx]}C_{[labialx]}$.[32]

[32] An anonymous reviewer notes that a *oCw constraint would be consistent with the Anti-mismatch constraint.

(81) Alternate possible description of underlying forms in Karata

Initial front vowel		Initial back rounded vowel	
/iC/	/iC^w/	/uC/	/uC^w/
/eC/	/eC^w/	/oC/	-
	/aC/	/aC^w/	

To conclude with, an OT analysis where inputs are evaluated at each ‘morphological layer’ accounts for the Karata data in a uniform and independently motivated way.

5 The indexed [labial$x$] feature

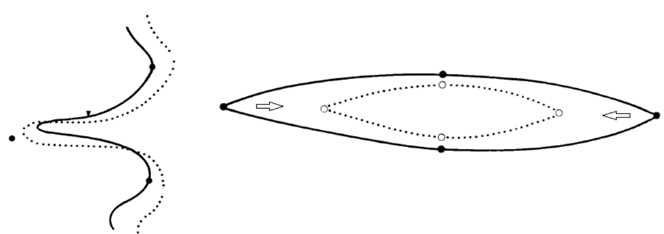
I have presented an analysis according to which, upon the delinking of [labial3] and [labial2], only [labial3] relinks to a consonant because faithfulness to [labial3] is universally higher ranked than faithfulness to [labial2]. Crucially, this account assumes the existence of different degrees of labiality. In this section I examine the evidence for their existence.

5.1 Phonetic differences

5.1.1 Articulatory evidence

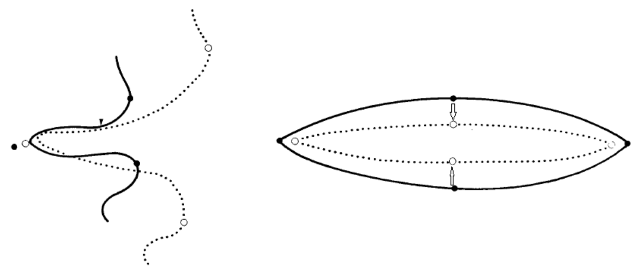
Linker [1982] studied labial activity in vowels for five different languages: English, Cantonese, Finnish, French, and Swedish. Her data involved measurements of 24 distinct dimensions taken from still photographs of the side and front view of the mouth. She identified three articulatory dimensions of lip position which are typically involved for distinguishing vowels within each of the languages studied: horizontal opening, vertical opening, lip protrusion. With the help of a computer program (CANON), she isolated a set of canonical factors of lip position relevant to the five languages studied. Canonical factor 1 involves horizontal opening and canonical factor 2 involves vertical opening and protrusion.

Figure 15: The effects of Canonical Factor 1 (Linker 1982)



That is indeed the case since the Anti-mismatch does not apply to sequences of segments but only to individual segments.

Figure 16: The effects of Canonical Factor 2 (Linker 1982)



She observed that across all five languages high rounded vowels display narrower horizontal and vertical opening than do the non-high rounded vowels, in other words high vowels involve more extreme lip-rounding gestures than non-high vowels. Moreover, according to the same criteria, back rounded vowels are more rounded than their front counterparts.

Although such measurements would have to be performed on Karata to be sure, we can reasonably posit that /u/ is more rounded than /o/ on account of /u/ being higher than /o/ and because, as is well known (*see* Lindau 1978 for instance), vowels that are characterized as being phonologically high and back are in fact articulated a little further to the back than vowels characterized as being phonologically non-high and back.

5.1.2 Perceptual evidence

Terbeek [1977] investigated the factors which contribute to perceptual distance in the vowel space of 12 monophthongs [i, e, æ, ɑ, o, u, ɚ, y, ø, ɨ, ɑ˞, ʌ[33]]. Subjects (about 35) were speakers of five languages: English, German, Thai, Turkish, and Swedish. Some but not all monophtongs were similar to vowels occuring in the listener's native language. The data consisted of triadic comparisons of the test vowels in the context [bəb_]. The task was to determine which of the three stimuli sounded the most *distinct* from the others. From the responses collected, dissimilarity matrices were constructed and the analysis yielded five factors relevant to the identification of vowels[34]:

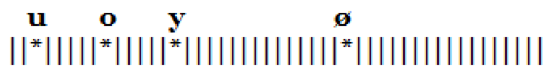
1. back vs. non-back
2. low vs. non-low
3. high vs. non-high
4. round vs. non-round
5. peripheral vs. central

The results of Terbeek's study indicate that along the round vs. non-round continuum, the round vowels are arranged as shown schematically in (17) (relative distance is approximated).

[33] Swedish speakers were tested on [ʉ, œ] instead of [ɑ˞, ʌ].

[34] The analysis actually yielded six factors but this additional factor is the result of the Swedish vowels patterning in a separate back vs. non-back dimension.

Figure 17: The round vs. non-round continuum [Terbeek, 1977]



These results clearly show that the back vowels [u] and [o] are perceived as more rounded than their front counterparts [y] and [ø] and that the high vowels [u] and [y] are perceived as more rounded than the non-high [o] and [ø]. These results are consistent with Linker's results: the greater the magnitude of the rounding gesture, the greater its salience.

5.2 Phonologized differences

5.2.1 Different lip rounding gestures for same height

If indeed some languages make use of contrastive labial features as opposed to always deriving degree of rounding from vowel height, we would expect some of those languages to have round vowels that are the same with respect to height and backness, but contrast in terms of how rounding is realized. The independence of labiality degree or gesture with regard to aperture is evinced by the fact that, in certain languages, round vowels of the same height have distinct constrastive labial gestures. I give several examples taken from Ladefoged and Maddieson 1996.

- Assamese has two low back round vowels, 'one of which sounds like British English [ɑ] as in 'father" and the low back vowel [ɒ̹], which 'has a slightly different tongue position – more like that of British English [ɔ] as in 'caught' - but is accompanied by close lip rounding like that in [u]'.

- Swedish has two high front round vowels [yː, ʉ]. The symbol [ʉ] is used here to specify a high front vowel, rather than a high central one. It has similar tongue positions to [yː] but [yː] has a more open and protruded lip position; [ʉ] has a fairly close approximation of the upper and lower lip, but without protrusion [Linker, 1982].

Languages like Assamese and Swedish provide evidence that, within a constant vowel height or aperture, lip gestures can vary independently.

5.2.2 Parasitic rounding harmony

The existence of the Anti-mismatch constraint (38) predicts the existence of [labial$x$] features (see 4.1.3). Languages with parasitic rounding harmony provide independent evidence for this constraint and therefore for the existence of [labial$x$] features.

In Yawelmani Yokuts and Kachin Khakass[35], vowels harmonize for rounding only if they agree in height or aperture. This can be modeled by positing that in the phonology of these languages, the anti-mismatch constraint outranks the constraint enforcing rounding harmony, e.g. Extend[labial$x$] Kaun [1997] defined in (82).

[35] The data come from Kaun 1997.

(82) EXTEND[labial$x$]

Assign a violation mark to each output vowel which is not linked to a [labial$x$] feature.

The phonology of Yawelmani Yokuts distinguishes two apertures of vowels.

(83) Yawelmani Underlying Vowel Inventory

aperture 2	i	u
aperture 1	a	o

In Yawelmani Yokuts, suffixal vowels are rounded following a root round vowel only if both vowels have the same aperture: In (84a), the faithful candidate b loses because harmony has not occured and EXTEND(LAB) is violated, the same occurs in (84b), the feature [labial1] can spread without violating the ANTI-MISMATCH constraint since the target vowel in the suffix has aperture 1. In (84c) however, satisfying EXTEND(LAB) by spreading [labial2] to the suffixal vowel violates the ANTI-MISMATCH constraint since the suffixal vowel has aperture 1. It is therefore better not to spread and incur a violation of EXTEND(LAB) than to spread and violate the ANTI-MISMATCH constraint.

(84) Parasitic rounding harmony in Yawelmani Yokuts

(a) high-high harmony

/muṭ + hin/: [muṭhun] $\succ$ *[muṭhin]

[ap2] [ap2] /m u ṭ/ + /h i n/ [lab2]	*aperture$_\alpha$/labial$_{\neg\alpha}$	EXTEND(LAB)
a. ☞ [ap2] [ap2] [m u ṭ h u n] [lab2]		
b. [ap2] [ap2] [m u ṭ h i n] [lab2]		*

(b) low-low hamony

/gop + taw/: [goptow] $\succ$ *[goptaw]

[ap1] [ap1] /g o p/ + /t a w/ [lab1]	*aperture$_\alpha$/labial$_{\neg\alpha}$	EXTEND(LAB)
a. ☞ [ap1] [ap1] [g o p t o w] [lab1]		
b. [ap1] [ap1] [g o p t a w] [lab1]		*

(c) no harmony

/muṭ + taw/: [muṭtaw] $\succ$ *[muṭtow]

[ap2] [ap1] /m u ṭ/ + /t a w/ [lab2]	*aperture$_{\alpha}$/labial$_{\neg\alpha}$	EXTEND(LAB)
a. [ap2] [ap1] [m u ṭ t o w] [lab2]	*	
b. ☞ [ap2] [ap1] [m u ṭ t a w] [lab2]		*

Kachin Khakass phonology distinguishes two aperture degrees for vowels (85).

(85) Kachin Khakass Underlying Vowel Inventory

aperture 2	i	y	ɯ	u
aperture 1	e	ø	a	o

In this language too, suffixal vowels become rounded following a rounded root vowel if they have the same aperture. However there is a further requirement: the root vowel must have aperture 2. In (87a), the faithful candidate a loses because it violates EXTEND[lab], the winner is candidate b which satisfies all the constraints. In (87b) however, the suffixal vowel has aperture 1, so satisfying EXTEND[lab] by spreading [labial2] leads to a violation of the ANTI-MISMATCH constraint. It is therefore better to violate EXTEND[lab] by not spreading the labial feature. The same occurs in (87c) where spreading the root [labial1] to the suffixal vowel, specified *aperture 2*, leads to a violation of the ANTI-MISMATCH constraint. Finally, rounding harmony does not occur in (87d) because spreading [labial1] to the suffixal vowel yields a further violation of the markedness constraint against vowels which are both *aperture 1* and labial (86). Here again, it is better not to spread and violate EXTEND[lab].

(86) (abr. *ap1/lab$x$)

*aperture1
|
x
|
labial$x$

Assign a violation mark to each output rootnode which is linked to an aperture node with degree 1 and a labial feature.

(87) Parasitic rounding harmony in Kachin Khakass only if trigger is high

(a) high-high harmony

/kuʃ+ tɯŋ/: [kuʃtuŋ] ≻ *[kuʃtɯŋ]

[ap2] [ap2] /k u ʃ/ + /t ɯ ŋ/ [lab2]	*ap1/labial$_x$	*ap1/lab$x$	EXTEND[labial$x$]
a. [ap2] [ap2] [k u ʃ t ɯ ŋ] [lab2]			*W
b. ☞ [ap2] [ap2] [k u ʃ t u ŋ] [lab2]			

(b) high-low harmony failure

/kuzuk + ta/: [kuzukta] ≻ *[kuzukto]

[ap2] [ap2] [ap1] /k u z u k/ + /t a/ [lab2]	*ap$_\alpha$/labial$_{\neg\alpha}$	*ap1/lab$x$	Extend[labial$x$]
a. ☞ [ap2] [ap2] [ap1] [k u z u k t a] [lab2]			*
b. [ap2] [ap2] [ap1] [k u z u k t o] [lab2]	*W	*W	L

(c) low-high harmony failure

/ok + tɯŋ/: [oktɯŋ] ≻ *[oktuŋ]

[ap1] [ap2] /o k/ + /t ɯ ŋ/ [lab1]	*ap$_\alpha$/labial$_{\neg\alpha}$	*ap1/lab$x$	Extend[labial$x$]
a. ☞ [ap1] [ap2] [o k t ɯ ŋ] [lab1]		*	*
b. [ap1] [ap2] [o k t u ŋ] [lab1]	*W	*	L

(d) low-low harmony failure

/pol + za/: [polza] ≻ *[polzo]

[ap1] [ap1] /p o l/ + /z a/ [lab1]	*ap$_\alpha$/labial$_{\neg\alpha}$	*ap1/lab$x$	Extend[labial$x$]
a. ☞ [ap1] [ap1] [p o l z a] [lab1]		*	*
b. [ap1] [ap1] [p o l z o] [lab1]		**W	L

Parasitic rounding harmony is directly predicted by the Anti-mismatch constraint being ranked above the constraint that triggers harmony: harmony will occur so long as the Anti-mismatch constraint is not violated. Additionally, in Kachin Khakass, non-high round vowels are penalized by a markedness constraint ranked above the constraint triggering harmony.

One may wonder how my proposal then handles cases of cross-height rounding harmony. But my proposal is not that all languages have phonologized degrees of rounding. Languages with cross-height rounding harmony can therefore be viewed as languages in which either different [labial] features are not contrastive or, if phonological degrees of rounding are emergent, then languages with cross-height rounding harmony are languages in which those features have not emerged. In any case, any theory of rounding harmony (e.g. [Kaun, 2004]) will handle this state of affairs and make the right predictions.

5.3 Discussion: what gesture(s) does [labial$x$] correspond to?

We have seen evidence that the rounding gesture involves a number of subgestures. Linker's study showed that lip-rounding involves three such subgestures: vertical opening, protrusion and to a lesser extent horizontal opening. From their wide-ranging typological study Ladefoged and

Maddieson [1996] concluded that [labial] corresponds to two lip position parameters for vowels: vertical lip compression and protrusion (figure 18).

Figure 18: The features of vowel rounding (Ladefoged and Maddieson [1996])

Rounding	
vertical compression	protrusion
[compressed]	[protruded]
[separated]	[retracted]

Linker [1982], on the one hand, and Ladefoged and Maddieson [1996], on the other hand, note that, in the great majority of languages, those subgestures are realized together. Only a few languages do rounding with one or two of the subgestures (e.g. Japanese, Swedish). In this context, one might wonder what subgestures [labial3] and [labial2] in Karata correspond to. It is conceivable that Karata could be a language in which /u/ is realized with both compression and protrusion and /o/ is realized with compression only. If this were the case, we could analyze consonant labialization in Karata as the result of the transmission of protrusion onto the consonant. This would then account nicely for the C labialization asymmetry between /u/ and /o/. Further research on the articulatory phonetics of Karata will have to answer this question. The prediction of my account is clear though: the rounding gesture made when Karatas pronounce /u/ is more extreme than that made when they pronounce /o/. In this sense, [compressed] refers to a more extreme gesture than [separated] and [protruded] to a more extreme gesture than [rectracted].

The fact that [labial$x$] glosses over the distinctions made by Ladefoged and Maddieson [1996] is therefore a way to capture the fact that high vowels are more rounded than non-high vowels without committing to what the exact nature of the lip gestures is in Karata since no measurement is available.

5.4 Motivation for the [labial$x$] fixed ranking

5.4.1 The P-Map: Motivation for docking of [labial$x$]

The central claim of the P-map theory [Steriade, 2001] is that the degree to which a change is unfaithful is related to the perceptual distance involved in that change: a highly perceptible change is more unfaithful than a less perceptible change. Under that assumption, the change from [u] to [i] is more unfaithful than the change from [o] to [e] (88) since 'contrastive rounding among non-high vowels is perceptually more subtle than constrastive rounding among high vowels' [Terbeek, 1977]. In other words, delinking [labial3] is more unfaithful than delinking [labial2][36].

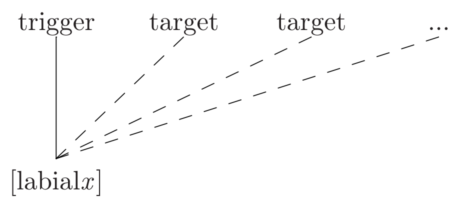
[36]The reader may object that similarly *linking* [labial3] to an initially non-labial segment is more unfaithful than *linking* [labial2] (i.e. labializing a consonant by docking [labial3] is more unfaithful than labializing with [labial2]). This is indeed a prediction that a theory like the P-map makes. Under the view that [labial$x$] features are privative, delinking a feature [labial$x$] violates Ident[labial$x$] *to the input* only, whereas linking a [labial$x$] feature violates Ident-OI[labial$x$] *to the output* (*see* discussion in footnote 8 for more detail). Here I am only considering faithfulness to the input as I am only considering the delinking part that is induced as a result of assimilation of the vowel to the class marker.

More generally, as pointed out by Albright (p.c.), my analysis proposes to solve a markedness effect (i.e. the impossibility of the sequences *[ju]/[jo]) by creating another markedness effect (i.e. the creation of a labialized consonant). While I share this concern, I also deem plausible that OI-faithfulness to (non-) labialized consonants is ranked lower than IO-faithfulness to the existence of the feature [labial3]. This is in fact the claim of the analysis

(88) Faith(u)>>Faith(o)

Figure 19 is a representation of the process known as rounding harmony: a feature [labial$x$] associated to a trigger spreads to other vowels (targets) in the word by creating new association lines. The result is one single feature associated to several targets' root nodes[37].

Figure 19: Rounding harmony



Following Suomi [1983] and [Kaun, 2004], I take rounding harmony to be perceptually motivated. Harmony gives rise to an extension of the temporal span associated with some perceptually vulnerable quality, represented above as [labial$x$]. By increasing the listener's exposure to the quality in question, harmony increases the probability that the listener will accurately identify that quality. In (89) I give a summary of the typological tendencies (related to vowel height) in rounding harmony as given in [Kaun, 2004].

(89) Typological tendencies in rounding harmony along with a summary of their corresponding perceptual explanations

	Tendency	Perceptual explanation
1.	a good trigger is [-high]	the round gesture 'wants' to be realized more saliently (Kaun 1997, Kimper 2011)
2.	a good target is [+high]	a high vowel realizes the lip-rounding gesture best [Terbeek, 1977]
3.	same-height rounding harmony	a single [labial] should have a uniform phonetic realization across the word [Boyce, 1988]

In Karata just as in languages with rounding harmony, [labial3] associates to another segment. However, unlike rounding harmony, [labial3] does not spread to a vowel , it delinks from the vowel it is originally attached to and attaches onto the following consonant.

presented in this paper.

[37] Kaun [1997]reports that Boyce [1988] studied vowel-to-vowel coarticulation in English and Turkish uCu utterances. These two languages were chosen because there is good reason to believe that segmentally identical sequences may be assigned distinct phonological representations. Turkish, as a rounding harmony language, arguably represents uCu sequences as containing a single [+round] autosegment whereas English, which lacks rounding harmony, would plausibly be expected to represent the same sequence with two independent [+round] specifications. Boyce showed that the two representations corresponded to two articulatory distinct patterns. English has a 'trough' pattern: the lips attained a position of protrusion in the articulation of the first rounded vowel, then receded during the articulation of the consonantal sequence then once again attained a position of protrusion for the second vowel. Turkish has a 'plateau' pattern: the lips attained a position of protrusion during the articulation of the first rounded vowel and remained protruded throughout the utterance. One plausible interpretation of these results is that whereas English speakers execute two lip-rounding gestures, Turkish speakers execute one.

The behavior of [labial3] in Karata and vowel harmony languages (i.e. [labial3] relinking vs. spreading) falls out from the same faithfulness preference:

- if [labial3] is linked to a vowel, its articulatory magnitude gives it very salient perceptual correlates, so [labial3] does not 'need' to spread.

- if [labial3] is delinked, it has no perceptual correlates but its articulatory magnitude renders it more 'persistent', so more pressure applies for it to stay in the output (by relinking to another segment in Karata).

In Karata, markedness is sufficiently high ranked to make both [labial3] and [labial2] delink from the vowel they were linked to. Because [labial3] has greater magnitude than [labial2], there is more faithfulness pressure (to the input) to make [labial3] stay in the output (via re-linking) (90). Re-linking [labial3] is a better solution than deleting it (while deleting [labial2] is the more optimal strategy)[38].

(90) Max(labial3)>>Max(labial2)(>>Max(labial1))

5.4.2 Vowel elision in hiatus

In this section, I show that having scalar features of labiality ranked on a scale of faithfulness solves a false prediction of Casali [1996]'s theory of hiatus resolution in Yoruba.

Using the two families of constraints in (91) and (92), Casali [1996] compiles a typology of vowel elision in hiatus and shows how different patterns can be accounted for.

(91) PARSE(F)
Preserve an input feature F in the output.

(92) Segment Integrity (Seg-Int)
If one feature of a segment is preserved, all its features are preserved

One predicted pattern is (93) [Casali, 1997, p. 79]. When Seg-Int is undominated, elision of one vowel is predicted (rather than coalescence). Furthermore because of the particular ranking of PARSE(F) in Casali's typology, a combination of ordinary Elision and Feature-Sensitive Elision is predicted. Consider for example a five-vowel language with the single ranking PARSE(-high) >> PARSE(+high)-$[_w$ and undominated Seg-Int. These rankings would ensure that in combinations involving a word-final non-high vowel and a word -initial high vowel, the non-high vowel would be preserved in its entirety, i.e. we would have the realizations in (93a); note that these appear to manifest V2 Elision. With all other input sequences, however, the result will be V1 Elision (93b).

(93) a) V2 elision
a+i>a a+u>a
e+i>e e+u>e
o+i>o o+u>o[39]
b) V1 elision

[38]For this reason, Ident constraints to [labial$x$] are not enough because they can be satisfied by deleting [labial$x$].

	e+a > a	o+a > a	i+a > a	u+a > a
a+e > e		o+e > e	i+e > e	u+e > e
a+o > o	e+o > o		i+o > o	u+o > o
				u+i > i
			i+u > u	

Casali notes that this predicted pattern is, to his knowledge, not attested, although Yoruba comes really close. In fact, Yoruba differs from the predicted pattern in just one interesting instance:

- /u/ + /i/ coalesce into [u], not [i] as predicted (*see* 94)
- /o/ + /e/ coalesce into [e]

Here's a tableau illustrating how Casali's analysis predicts this pattern.

(94) Casali's analysis 1

		SEG-INT	PARSE(-high)	PARSE(+high)$[_w$	PARSE(-high)$[_w$
I.	/u+i/				
a X☞	~~u~~ i				
b	u ~~i~~			*	
II.	/o+e/				
a☞	~~o~~ e				
b	o ~~e~~				*

Candidate b of input I violates PARSE(+high)$[_w$ because the vowel in the output is +high and is not at the beginning of a word. Candidate b of input II violates PARSE(-high)$[_w$ because the vowel in the output is -high and not the at the beginning of a word.

As Casali points out in a footnote, while /o+e/ does result in [e], /u+i/ actually result in [u] in Yoruba. Casali notes that adopting an additional interleaved ranking PARSE(labial) >> PARSE(+high)-$[_w$[40], as illustrated in (95), would correctly yield the realization of /u+i/ as [u], but would generate a pattern which differs from that of Yoruba in other respects. In particular, such a ranking would cause /o+e/ to be realized as [o] (assuming, as we have been, that Seg-Int is undominated), whereas the attested realization of /o+e/ in Yoruba is [e].

(95) Casali's analysis 2

		SEG-INT	PARSE(-high)	PARSE(lab)	PARSE(+high)$[_w$	PARSE(-high)$[_w$
	/u+i/					
a	~~u~~ i			*		
b ☞	u ~~i~~				*	
	/o+e/					
a	~~o~~ e			*		
b X☞	o ~~e~~					*

[39] In the original dissertation, 'o+i>o' is repeated here. I take this to be a typographical error.

[40] Actually, in the footnote Casali writes 'PARSE(round) » PARSE(front)-$[_w$'. It is not clear to me why he wrote PARSE(front)-$[_w$, and I will consider this was just an oversight.

This unexpected pattern can be accounted for in Casali's analysis if different [labial] features are recognized, and if FAITH(labial3) is ranked over FAITH(labial2)[41] (96).

(96) Casali's analysis (modified)

	SEG-INT	PARSE(-high)	PARSE(lab3)	PARSE(+high)$[_w$	PARSE(-high)$[_w$	PARSE(lab2)
/u+i/						
a ~~u~~ i			*			
b ☞ u ~~i~~				*		
/o+e/						
a ☞ ~~o~~ e						*
b o ~~e~~					*	

We have seen that if Yoruba has contrastive labial features and applies more faithfulness to [labial3] than to [labial2], we can account for its hiatus pattern and solve an incorrect prediction of Casali's theory.

6 About potential alternative solutions to the labialization asymmetry in Karata

In this section, I explore several potential alternative ways of analyzing consonant labialization with both indexed and unindexed labial features. I show that in the former case, the alternative analyses make wrong predictions, and, with respect to the latter analyses, that they are not explanatory and require an unmotivated constraint.

6.1 Potential alternative solutions with [labial$x$]

6.1.1 Parasitic docking

In this section I tentatively explore an account inspired by parasitic vowel harmony in which consonants have a degree of aperture and the docking of [labial$x$] is contingent on the consonant having the same degree of aperture x. This account assumes a slight modification of our representational assumptions: that all segments, vowels and consonants alike, are specified for aperture in the same way. The idea that consonantal stricture can be captured in terms of different degrees of aperture has been proposed by a few linguists already (Ladefoged 1971, Steriade 1993, Browman and Goldstein 1989). I present a summary of two existing proposals that posit that all sounds are specified phonologically for a degree of aperture or constriction then I sketch a tentative analysis of consonant labialization as 'parasitic docking'. In the end, I will discuss why this analysis, though attractive, cannot be right.

Degrees of aperture or degrees of constriction: theoretical background Steriade posits three types of aperture position. An aperture position is rather similar to the feature-geometric notion of root node: it anchors segmental features and connects segments to prosodic structures. Each aperture position is specified for a degree of opening of the oral cavity.

[41] Yoruba has a three-height system.

(97) Types of aperture positions

Closure (A_0)	total absence of oral airflow
Fricative (A_f)	degree of oral aperture sufficient to produce a turbulent airstream
Approximant (A_{max})	maximal degree of oral aperture in consonants

The idea Steriade explores is that plosives (stops and affricates) are phonologically represented as a sequence of two aperture positions, closure and release. In contrast, continuants (vowels, approximants and fricatives) are assumed to carry a single aperture position in phonological representations.

(98) Representation of a few classes of segments

Plain, released stop	A_0A_{max}
Affricate	A_0A_f
Unreleased stop	A_0
Approximant	A_{max}
Fricative	A_f

In articulatory phonology, there are 5 distinctive constriction degrees (99) arranged on a continuum and each articulator (of which one or several make a gesture) is specified for a constriction degree. The two most closed categories correspond to stops and fricatives. The other descriptors distinguish among vowels.

(99) Constriction degree descriptors

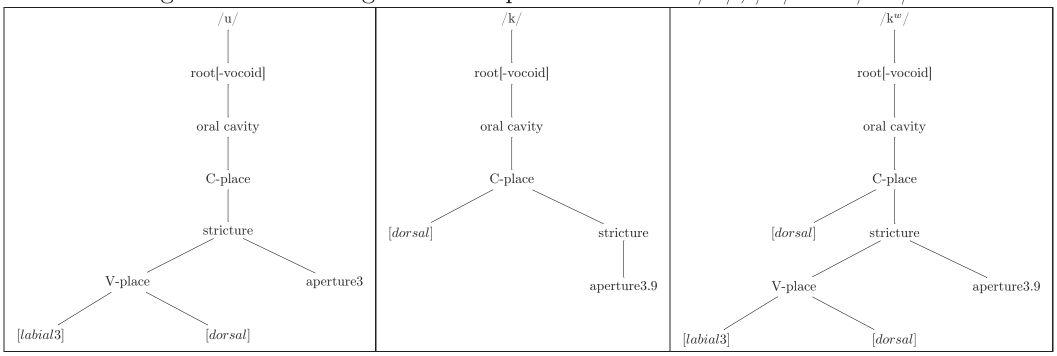
wide, mid, narrow, critical, closed

$max.\ airflow \longleftarrow no\ airflow$

While the intuition that all segments are specified for aperture or constriction seems very plausible, it appears that with non-lingual consonants, these two notions need to be teased apart. Indeed, pharyngeal consonants have a constriction degree equivalent to that of other (lingual) consonants but their aperture degree (i.e. jaw position) is similar to that of low vowels. In the following subsection, I present a tentative analysis in which docking of [labial$x$] on a consonant is only allowed if it does not create a mismatch with the aperture specification of the consonant.

Formalization of generalized constriction degrees In this section I make different assumptions (figure 20). I assume that constriction degree for both vowels and consonants is specified under the same aperture node. In the absence of a place feature linked to the C-place node, the aperture specification is interpreted with respect to the V-place node. When both C-place and V-place have featural specification(s), the aperture node is interpreted as referring to the primary articulator.

Figure 20: Feature geometric representations of /u/, /k/ and /k^w/.



There is a body of evidence to show that in many languages high vowels pattern with consonants. Phonetically speaking, there is a general consensus on the fact that there is no strict difference between the traditional labels of vowels and consonants, rather they describe the ends of a continuum, the center of which is occupied by the glides [j] and [w]. Articulatorily speaking, the high vowels are the least open of the category traditionally labeled 'vowels'. In (100), I illustrate this continuum of aperture with low vowels on one end and stops on the other. I also assign to each type of phone a (somewhat arbitrary) degree of aperture in order to capture the intuition formulated just above.

(100) Aperture in vowels and consonants.

1	2	3
low vowels	mid vowels	high vowels consonants

$+open \longleftarrow$ ——————————————— $-open$

3		3.5	3.9
vowels	glides	fricatives	stops
i u	j w	ç ʝ	c ɟ

I'm now going to present an account using the same constraints that have been defined previously. This accounts crucially makes use of *aperture$_\alpha$/labial$_{\neg\alpha}$. Because consonants (at least in Karata) have aperture 3, docking a [labial$x$] feature on a consonant does not violate *aperture$_\alpha$/labial$_{\neg\alpha}$ only if it is [labial3], all other [labial$x$] features will fatally violate it.

Analysis We know it is better to create a new association line between a [labial$x$] feature and a segment so both segments have the same V-place even though the segment's [labial$x$] feature and aperture node mismatch (101 and 102).

(101) /w-ek̄al̞̊a/ 'give'
[wok̄al̞̊a] $\succ$*[wek̄al̞̊a]

(102) *O$_\alpha$N$_{\neg\alpha_{PLACE}}$>> *aperture$_\alpha$/labial$_{\neg\alpha}$

/ [ap2] / | w e k | [lab3]	$^*O_\alpha N_{\neg\alpha_{PLACE}}$	*aperture$_\alpha$/labial$_{\neg\alpha}$
a☞ [ap2] | w o k |/ [lab3]		*
b [ap2] | w e k | [lab3]	*W	L

The winner in (103) violates Max[labial$x$][42]. The loser violates both *aperture$_\alpha$/labial$_{\neg\alpha}$ and Ident-OI[labial$x$]. I show this ranking disjunction in (104).

(103) /j-oχ̄aːl̝̊a/ 'thrust'
[jeχ̄aːl̝̊a] ≻*[jeχ̄^{w}aːl̝̊a]

(104) Ranking disjunction

a) *aperture$_\alpha$/labial$_{\neg\alpha}$ >> Max[labial$x$]

/ [ap3.9]/ | j o k | [lab2]	*aperture$_\alpha$/labial$_{\neg\alpha}$	Max[labial$x$]
a☞ [ap3.9] | j e k ~~[lab2]~~		*
b [ap3.9] | j e k^w | [lab2]	*W	L

or

b) Ident-OI[labial$x$] >> Max[labial$x$]

/ [ap3]/ | j o k | [lab2]	Ident-OI[labial$x$]	Max[labial$x$]
a☞ [ap3] | j e k ~~[lab2]~~		*
b [ap3] | j e k^w | [lab2]	*W	L

The following argument helps us solve this ranking disjunction (105 and 106).

[42] Max[labial$x$] here is a cover constraint for [labial3], [labial2] and [labial1].

(105) /j-utʃãʟ̝̊a/ ‘bathe’
[jitʃ^{w}ãʟ̝̊a] ≻ *[jitʃãʟ̝̊a]

(106) Max[labial$x$] >> Ident-OI[labial$x$]

/ [ap3] / | j u k | [lab3]	Max[labial$x$]	Ident-OI[labial$x$]
a☞ [ap3] | j i k^w | [lab3]		*
b [ap3] | j i k ~~[lab3]~~	*W	L

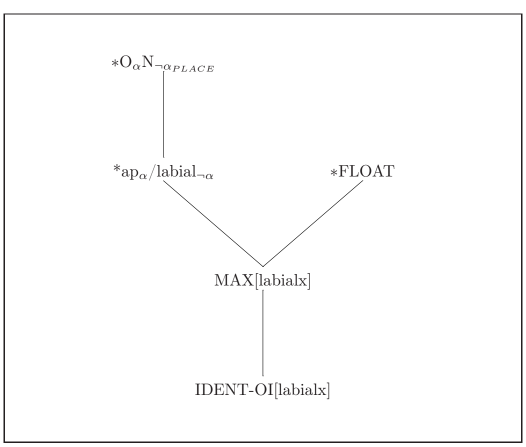
So we have *aperture$_\alpha$/labial$_{\neg\alpha}$ >> Max[labial$x$] >> Ident-OI[labialx]. Furthermore, it is better to delete a floating feature than to leave it floating (107 and 108).

(107) /j-oχ̄aːʟ̝̊a/ ‘thrust’
[jeχ̄aːʟ̝̊a] ≻*[jeχ̄aːʟ̝̊a] #[labial2]#

(108) *Float >> Max[labial$x$]

/ j o k / | [lab2]	*Float	Max[labial$x$]
a☞ j e k ~~[lab2]~~		*
b j e k^w [lab2]	*W	L

(109) Final Hasse diagram.



The following tableaux summarize the analysis.

(110) /j-uʧ/ → [jiʧ^w] summary

/j u ʧ/ [lab3]	*Float	*$O_\alpha N_{\neg\alpha PLACE}$	*ap_α/labial$_{\neg\alpha}$	MAX[labial$x$]	Ident-OI[labial$x$]
a ☞ j i ʧ^w [lab3]					*
b j i ʧ [lab3]	*W				L
c j i ʧ ~~[lab3]~~				*W	L
d j u ʧ [lab3]		*W			L

(111) /j-oʧ/ → [jeʧ] summary

/j o ʧ/ [lab2]	*Float	*$O_\alpha N_{\neg\alpha PLACE}$	*ap_α/labial$_{\neg\alpha}$	MAX[labial$x$]	Ident-OI[labial$x$]
a j e ʧ^w [lab2]			*W	L	*W
b j e ʧ [lab2]	*W			L	
c ☞ j e ʧ ~~[lab2]~~				*	
d j o ʧ [lab2]		*W		L	

This solution is interesting in that it generalizes parasitic assimilation to vowel-consonant interactions. While it demands one more representational assumption (than the previous analysis): it makes the claim that the aperture of all consonants is closest to the aperture of high vowels, it also dispenses with the universal ranking of faithfulness constraints to [labial$x$].

Under the assumption that segments are specified for 'aperture', the degree of aperture of laryngeal consonants is closest to the degree of aperture of low vowels, yet the pharyngeal consonants /ħ/ and /ʕ/ may only be labialized when the preceding vowel is underlyingly high, just like other consonants.

Under the assumption that segments are specified for 'constriction' (as opposed to jaw aperture) and that constriction is specified for each articulator, pharyngeal consonants are not a problem since the constriction in the larynx is of the same phonological degree as the constriction for, say, a velar fricative. But my analysis would then make a claim about the compatibility of constrictions in two locations (the constriction of the primary articulator and that of the lip) and it is not clear that constriction at the lips is dependent on constriction in the pharynx in the same way that it is dependent on aperture.

6.1.2 Restriction on the segment inventory: *C[lab2]

This analysis would crucially rely on the ranking of a markedness constraint against consonants being associated with a [labial2] feature being ranked above faithfulness to [labial$x$] features.

(112) *C[lab2]>>MAX[labial$x$]

The only motivation (phonetically speaking) for this constraint would be in the same vein as the motivation for the parasitic docking solution, which we saw was not well motivated because it is not clear why pharyngeal and glottal consonants, which aperture-wise are closer to low vowels, could not associate to lower [labial$x$] features.

6.2 Potential alternative solution with unindexed [labial] : opaque spreading of [labial] to a C from a high V

An anonymous conference abstract reviewer (Author 2014) wondered why I could not 'just assume that only round high vowels spread'. In parallel cyclic OT, the problem is that is predicts that every (high) round vowel should labialize the consonant that follows it. This makes the right prediction for verb stems whose first vowel is /u/ and which take a class marker (113, 114).

(113) Cycle 1:

/ u ʧ / [+lab]	IDENT-IO[leftmost]	IDENT-IO[labial]	*(high,+lab)(-lab)	*+lab+lab	IDENT-OI[labial]
a ☞ u ʧ^w [+lab]				*	*
b u ʧ [+lab]			*		
c i ʧ^w [+lab]	*	*			*
d i ʧ ~~[+lab]~~	*	*			

Cycle 2:

/ j u ʧ^w / [+lab]	FAITH-IO[leftmost]	FAITH-IO[labial]	*(high,+lab)(-lab)	*+lab+lab	FAITH-OI[labial]
a ☞ j i ʧ^w [+lab]		*			
b j i ʧ ~~[+lab]~~		**			
c w u ʧ^w [+lab]	*			*	*
d w u ʧ [+lab]	*	*	*		*

(114) Cycle 1:

/ o ʧ / [+lab]	FAITH-IO[leftmost]	FAITH-IO[labial]	*(high,+lab)(-lab)	*+lab+lab	FAITH-OI[labial]
a o ʧ^w [+lab]				*	*
b ☞ o ʧ [+lab]					
c e ʧ^w [+lab]	*	*			*
d e ʧ ~~[+lab]~~	*	*			

Cycle 2:

/ j o ʧ / [+lab]	FAITH-IO[leftmost]	FAITH-IO[labial]	*(high,+lab)(-lab)	*+lab+lab	FAITH-OI[labial]
a j e ʧ^w [+lab]		*			*
b ☞ j e ʧ ~~[+lab]~~		*			
c w o ʧ^w [+lab]	*			*	**
d w o ʧ [+lab]	*				*

However it wrongly predicts that verb stems whose first vowel is /u/ but which do not take a class marker should also undergo labialization (115).

(115) Cycle 1:

/ u ʧ ala/ [+lab]	FAITH-IO[leftmost]	FAITH-IO[labial]	*(high,+lab)(-lab)	*+lab+lab	FAITH-OI[labial]
a ☞ u ʧ^w ala [+lab]				*	*
b u ʧ ala [+lab]			*		
c i ʧ^w ala [+lab]	*	*			*
d i ʧ ala ~~[+lab]~~	*	*			

Cycle 2:

/u ʧ^{w} ala/ [+lab]	FAITH-IO[leftmost]	FAITH-IO[labial]	*(high,+lab)(-lab)	*+lab+lab	FAITH-OI[labial]
a ☞ u ʧ^{w} ala [+lab]				*	
b u ʧ ala [+lab]		*	*		
c i ʧ^{w} ala [+lab]	*	*			
d i ʧ ala ~~[+lab]~~	*	**			

In order to get rid of the wrong prediction illustrated in (115), we need stratal OT (with constraint reordering).

- At stratum 1: FAITH-IO(lab) >> *+lab+lab, so that labialization occurs
- At stratum 2: *+lab+lab >> FAITH-IO(lab), so that labialization be eliminated if the C is preceded by a round vowel

(116) Stratum 1:

/u ʧ ala/ [+lab]	FAITH-IO[leftmost]	FAITH-IO[labial]	*(high,+lab)(-lab)	*+lab+lab	FAITH-OI[labial]
a ☞ u ʧ^{w} ala [+lab]				*	*
b u ʧ ala [+lab]			*		
c i ʧ^{w} ala [+lab]	*	*			*
d i ʧ ala ~~[+lab]~~	*	*			

Stratum 2:

/u ʧ^{w} ala/ [+lab]	FAITH-IO[leftmost]	*+lab+lab	FAITH-IO[labial]	*(high,+lab)(-lab)	FAITH-OI[labial]
a u ʧ^{w} ala [+lab]		*			
b ☞ u ʧ ala [+lab]			*	*	
c i ʧ^{w} ala [+lab]	*		*		
d i ʧ ala ~~[+lab]~~	*		**		

To summarize, this solution requires two specific assumptions, which are not necessarily explanatory:

1. constraint reordering from one stratum to the other
2. a constraint triggering round spreading from high V only

Constraint reordering has been assumed to account for a number of opaque processes [Kiparsky, 2000], but the second assumption (i.e. the existence of the constraint triggering [labial] spreading from /u/ only) is ad-hoc and not motivated. The goal of my account is precisely to motivate this phenomenon.

7 Conclusion

I have argued that the Karata labialization patterns are best analyzed if we recognize that the magnitude of a rounding gesture can be phonologized, and that there is greater faithfulness to more extreme rounding gestures. This in fact falls out of slightly modifying Kaun [2004]'s UNIFORM(ROUND) constraint to the ANTI-MISMATCH constraint. By doing so, not only do we still capture the rounding harmony facts that Kaun captures, but we also account for the Karata facts and solve a false prediction of Casali's account of hiatus in Yoruba.

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