Palatalization and glide strengthening as competing repair strategies: Evidence from Kirundi*

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Abstract Alternations involving place-changing palatalization (e.g. t+j → ʧ in spirit – spiritual) are very common and have been a focus of much generative phonological work since Chomsky & Halle's (1968) 'Sound Pattern of English'. The interest in palatalization and its mechanisms (see e.g. Sagey 1990; Chen 1996; Bateman 2007) has somewhat obscured the question of how these processes fit into a wider typology of segmental alternations. What happens when palatalization fails to apply? Do other processes take its place and apply under the same circumstances? In this paper, I argue for a close functional and formal affinity between place-changing palatalization and one such process, palatal glide strengthening (e.g. p+j → pc). As evidence I present data from Kirundi (Bantu) on the realization of consonant + palatal and velar glide sequences within and across morphemes. As will be shown, palatalization and glide strengthening in Kirundi work in parallel, affecting different subsets of consonants. Specifically, palatalization targets C+j sequences with laryngeals, velars, nasal coronals, and – across morpheme boundaries – non-nasal coronals. In contrast, glide strengthening targets C+j sequences with labials and – within morphemes – non-nasal coronals. In addition, glide strengthening applies to within- and across-morpheme consonant + velar glide sequences, producing a set of outputs (e.g. m+w → mŋ) similar to C+j sequences. I further present a unified Optimality Theoretic (Prince & Smolensky 1993/2004) account of these seemingly disparate phenomena as both arising from different rankings of constraints prohibiting consonant + glide sequences (parameterized by place and/or manner) and various feature-specific agreement and faithfulness constraints. Finally, I explore typological predictions of this account, reviewing several remarkably similar cases of C + glide resolution patterns from other languages, and outlining questions for further research on consonant-vowel/glide interactions.

Keywords: palatalization; glide strengthening; phonological typology; Optimality Theory; Kirundi

1 Introduction

Alternations involving place-changing palatalization[1] (e.g. t+j → ʧ in *spirit – spiritual*, g+i → ʤi in *analogue – analogy*) are cross-linguistically very common and have been a focus of much

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generative phonological work. One important intuition of the seminal 'Sound Pattern of English' by Chomsky & Halle (1968) is that palatalization is an assimilatory process (p. 424), and thus ought to be modeled as feature sharing between the participating segments. Much of subsequent work on palatalization, and particularly in the autosegmental framework of Feature Geometry in the late 80s and early 90s, focused on precisely this task – trying to model various palatalization processes through feature spreading and delinking. One of the heated debates at that time, for example, was whether palatalization is triggered by spreading the feature [–back] (under the Dorsal node) or the feature (V-Place)[Coronal] (Mester & Itô 1989; Broselow & Niyondagara 1990; Sagey 1990; Clements 1991; Hume 1992). Optimality Theory (OT; Prince & Smolensky 1993/2004) has shifted the focus from representation and rules to constraints and their interactions. This brought about a new way of conceptualizing phonological processes, such as segment deletion, epenthesis, metathesis, etc. Specifically, these could be seen as repair strategies, competing ways of responding to universal markedness constraints (e.g. Pater's 1999/2004 analysis of avoidance of nasal + voiceless obstruent clusters, *NÇ̥). Many OT analyses of palatalization, however, continued to maintain the autosegmental assumptions about the process, viewing it as being driven exclusively by assimilatory spreading of features or gestures (e.g. Zubritskaya 1994; Chen 1996; Rubach 2000; Morén 2006; Bateman 2007). Overall, the persistent focus on the featural substance of palatalization has somewhat obscured the question of how the process (and its various manifestations) fits into a wider typology of segmental changes. Are there more general structural causes of palatalization, other than the presumed need to spread features? How does palatalization interact or compete with other segmental processes? The goal of the paper is to argue that place-changing palatalization is functionally and formally related to other segmental processes, and particularly to palatal glide strengthening (glide hardening or fortition; e.g. p+j → pc). Both palatalization and glide strengthening, the argument goes, are competing strategies whose goal is to repair a highly marked structure C+pal – a combination of a consonant and a palatal segment (to be discussed in Section 1.2). As evidence I present data from Kirundi (Bantu) where consonant + palatal glide sequences are resolved by a combination of palatalization and glide strengthening, subject to morphological context and the target consonant's place or manner of articulation. I further show that these complex and seemingly disparate patterns can be straightforwardly analyzed as arising from interactions of a small set of standard faithfulness and place/manner-specific markedness constraints. I further explore typological predictions of the analysis by briefly examining interactions of these processes in other languages, as well as other alternative repair strategies.

1.1 Typology of palatalization and possible alternatives

To put the question of the relation between palatalization and other processes into perspective, it would be useful to review the typology of place-changing palatalization. Previous cross-linguistic surveys (Bhat 1978; Bateman 2007; Kochetov 2011) have shown that some places of articulation are more likely targets of palatalization than others. This is particularly relevant for

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[1] Palatalization is defined here as a phonological process triggered by front vocoids and resulting in the target consonant either acquiring secondary palatal articulation ('secondary palatalization') or shifting its primary place and/or manner ('place-changing palatalization'). The latter changes frequently result in posterior coronals (palatals, alveolopalatals, or palatoalveolars), but may also result in sibilant anterior coronals, such as [ʦ ʣ s z] (see Bhat 1978; Kochetov 2011). The focus in this paper is on place-changing palatalization, and specifically on the process triggered by the palatal glide.

place-changing palatalization – the process that shifts the target consonant's primary place of articulation (as opposed to adding secondary palatal articulation). Specifically, palatalization of labials (their shift to anterior/posterior coronals) implies palatalization of coronals (their shift to posterior coronals) and velars (their shift to anterior/posterior coronals). No such implicational relation is observed between coronals and dorsals: in some languages palatalization targets coronals but not dorsals and labials, while in others it targets dorsals, but not coronals and labials. This suggests 5 possible types of target place patterns with respect to place-changing palatalization in consonant + j sequences, as shown in (1). Type 1, which is typologically rare (given the exceeding rarity of labial palatalization), represents languages where palatalization targets all places – labials, coronals, and dorsals. Type 2 exhibits palatalization of coronals and dorsals, but not labials. Types 3 and 4 represent languages where palatalization targets either velars or coronals. Not shown is the type where palatalization fails to apply in any of the place contexts.

(1) Types of palatalization in consonant + j sequences.

	C = Lab	C = Cor	C = Dor
Type 1	Pal /pja/ → [ʧa], /mja/ → [ɲa]	Pal /tja/ → [ʧa], /nja/ → [ɲa]	Pal /kja/ → [ʧa], /ŋja/ → [ɲa]
Type 2	No change? /pja/ [pja], /mja/ [mja]	Pal /tja/ → [ʧa], /nja/ → [ɲa]	Pal /kja/ → [ʧa], /ŋja/ → [ɲa]
Type 3	No change? /pja/ [pja], /mja/ [mja]	No change? /tja/ [tja], /nja/ [nja]	Pal /kja/ → [ʧa], /ŋja/ → [ɲa]
Type 4	No change? /pja/ [pja], /mja/ [mja]	Pal /tja/ → [ʧa], /nja/ → [ɲa]	No change? /kja/ [kja] /ŋja/ [ŋja]

Of particular interest in (1) are the unshaded cells where palatalization does not apply. Presumably these preserve status quo, showing no phonological change. But is this indeed the case? Do other processes apply in cases where palatalization fails to apply? If we assume that palatalization is triggered by a phonotactic constraint, such as the incompatibility of consonants and the palatal glide or a front vowel (*C+j, *C+i, etc.), we may expect palatalization to be one of several possible ways of avoiding this marked structure. These are shown in (2) with corresponding schematic examples with labial stop/nasal + j. As we will see in subsequent sections, palatalization can indeed operate together with other processes. Particularly clear evidence exists for the close affinity between palatalization and glide strengthening, as manifested in Kirundi. While this interaction will be our primary focus, we will also review possible cases of interaction between palatalization and deletion, epenthesis, and metathesis.

(2) Possible strategies to avoid the sequence of C+j

	Strategy	*Schematic examples*
a.	palatalization	pja → ʧa, mja → ɲa
b.	glide strengthening	pja → pca, mja → mɲa
c.	deletion	pja → pa, mja → ma
d.	epenthesis	pja → pija, mja → mija
e.	metathesis	apja → ajpa, amja → ajma

1.2 Phonetic reasons for C+j markedness

A crucial assumption for the proposed line of reasoning is that consonant + palatal glide (as well as C + palatal consonant or front vowel) sequences are marked, cross-linguistically avoided. What is the reason for their markedness? First, these sequences can be considered articulatorily problematic: the palatal gesture (the tongue body raising and fronting towards the hard palate) and the other lingual gestures (the tongue tip and the tongue body making constrictions at the alveolar ridge or the velum) have inherently conflicting phonetic targets, and cannot be achieved without affecting each other (cf. Recasens 1999; Bateman 2007). Second, the sequences are acoustically and perceptually problematic, as the palatal glide (and front vowels) tend to obscure phonetic cues to place of articulation and induce affrication, ultimately leading to perceptual confusion (Ohala 1978; Kawasaki 1982; Guion 1996). The following examples from Korean C+j sequences serve to illustrate these two points.

Figure 1 presents electropalatographic (EPG) data with 6 nonsense words with lenis stops [p t k] with and without the following palatal glide /j/, as produced by a male native speaker of Korean (from Kang & Kochetov 2015). EPG uses an artificial palate with built-in electrodes that track the contact between the tongue and the palate in time. Each of the samples represent changes in the tongue-palate contact during a 350 ms interval starting from the midpoint of [a] in [maCjʌ] or [maCʌ] and ending at or after the offset of the [ʌ], with palate frames taken every 10 ms. The top of the palate image corresponds to the alveolar ridge, while its bottom – to the palatal/pre-velar region; the black colour indicates the tongue-palate contact in the corresponding area, while the white colour indicates no such contact. As can be seen in (a), the tongue does not touch the palate during the vowel [a] in [mapjʌ]. The contact in the posterior part of the palate appears about 30 ms (the 3rd palate frame) into the closure of [p] and peaks during the glide [j] interval; it is further reduced to the most posterior contact during [ʌ]. This contact overall is due to the raising and fronting of the tongue towards the palate for [j]. Notice that there is hardly any tongue-palate contact in (b), in the word [mapʌ], which doesn't have the palatal glide. Looking at (c), we can see that [t] preceding [j] in [matjʌ] has a closure at the alveolar ridge, accompanied by gradually increasing side contact in the palatal region. This is the result of the consonant's coarticulation with [j]. Note that in the absence of [j] in [matʌ] (d), the same stop hardly has any palatal side contact; moreover, its closure is more anterior, in the dental region (and thus not fully captured by the palate). Looking further at [makjʌ] (e), the stop [k] shows gradual fronting of the closure in the palatal region. This is again due to the consonant's coarticulation with [j], and the resulting consonant articulation can be considered palatal rather than velar. In contrast, the closure for [k] in [makʌ] (f) is much further back, beyond the artificial palate, and thus being a typical velar articulation. Altogether, these examples show that the palatal articulation of the glide overlaps in time with consonant articulations, drastically affecting the preceding consonants, and particularly the coronal and dorsal constrictions.

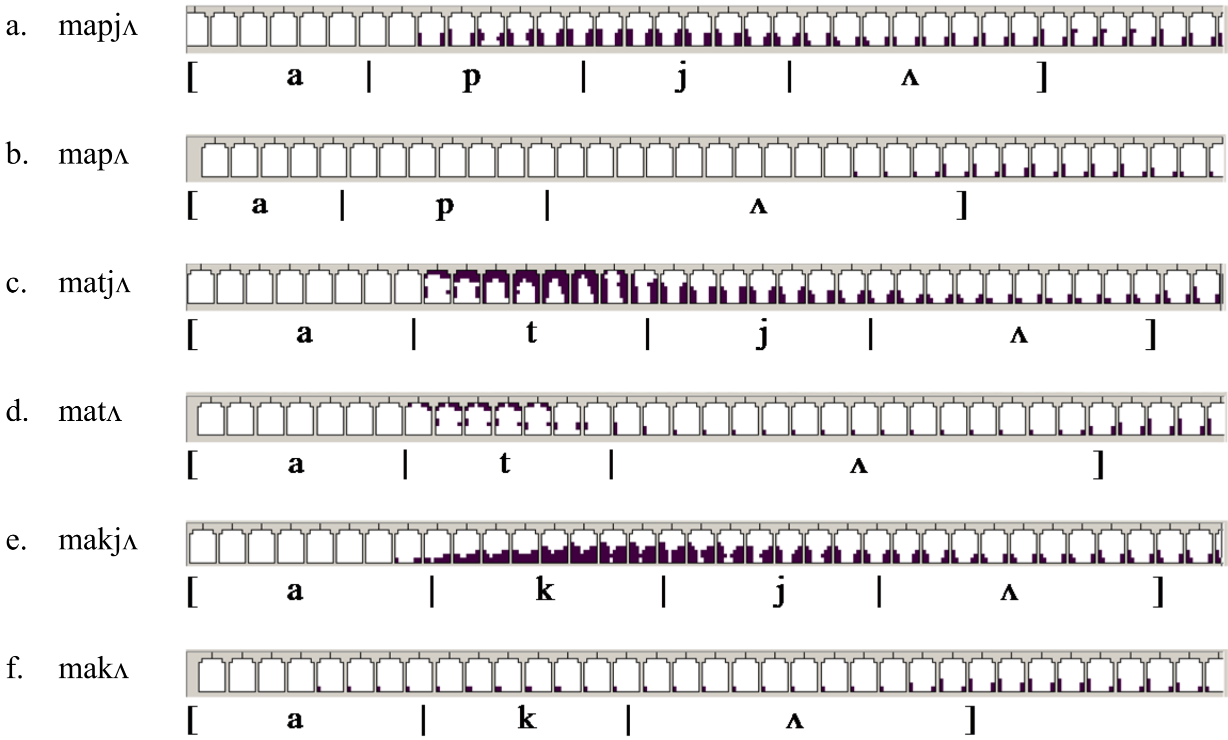

Figure 1. Temporal EPG displays for the Korean intervocalic lenis stops /p t k/ with and without a palatal glide /j/, produced in a carrier phrase [itsɛ ___ ɾako malhɛjo] 'Say ___ now' (see the text for details). Segment boundaries are based on the corresponding waveforms and spectrograms.

Figure 2 presents formants F1 and F2 tracked during 350 ms long VC(j)V intervals from the same 6 words – those with (a) and without the palatal glide (b). Values of the second formant F2 and differences between F2 and F1 are known to correlate well with consonant place of articulation distinctions as well as the front/back position of the tongue body (Stevens 1998). It can be seen in (a) that F2 is very high (approaching 2000 Hz) and F1 is low (below 500 Hz) following the stop closure, reflecting the high and front position of the tongue during the palatal glide. What is important, however, is that the differences between /p/, /t/, and /k/ in the following formant transitions are very small, especially if we consider the difference between the coronal /t/ and the other two places. In contrast, the distinction between the coronal and non-coronals in CV transitions is very robust in the words without the glide in (b). Note also the considerably higher VC transitions towards the consonants followed by the glide (particularly for /t/ and /k/) – an effect reflecting the more palatal-like nature of the consonant constriction. Altogether, this demonstrates that the following palatal glide dramatically reduces acoustic differences between places of articulation, leading to their perceptual confusion. Notably, this confusion is biased towards coronal articulations (and particularly towards palatals), as these are acoustically characterized by higher F2 and lower F1 values. Note also that stop releases (which are averaged and schematically represented in the plots) are longer for the stops followed by /j/ than for the single stops. This is because the former consonants are produced with a more gradual, narrower transition from the stop closure to the glide articulation (cf. Hall & Hamann 2006). This, in turn, adds to the place confusion, creating an additional bias towards a sibilant articulation (cf. Guion 1996; Flemming 2002).

a.

b.

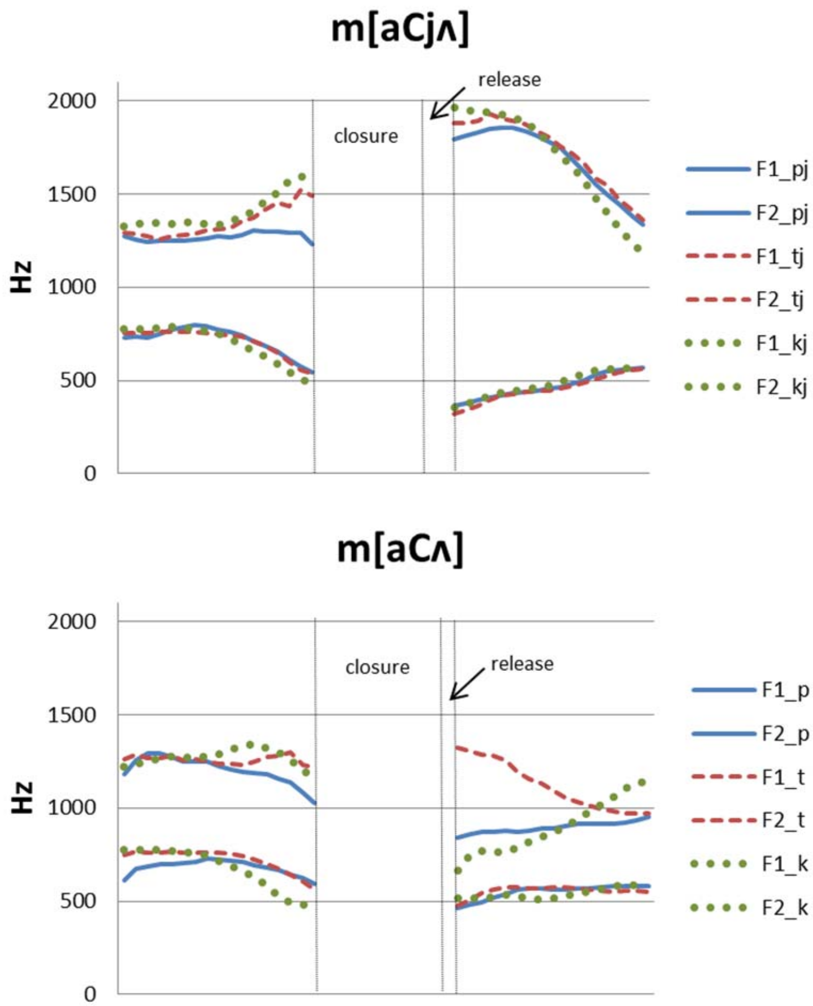

Figure 2. Formant F1 and F2 towards and from the stop closures for /p t k/ with (a) or without (b) the following glide /j/, audio from the articulatory data in Figure 1.

In sum, C+j sequences are articulatorily and acoustically/perceptually difficult. At least a subset of the same considerations holds for sequences of consonants with palatal consonants (as well as front vowels). This, presumably, makes C+j sequences, and C+pal sequences in general, phonologically marked, cross-linguistically avoided. Language-particular grammars may choose to yield to these phonetic pressures and resolve the marked structures through palatalization, a merger of the two input segments (e.g. atja → aʧa). Other grammars may choose a different route – to strengthen the glide to a palatal fricative or stop, while preserving the identity of the target consonant (e.g. atja → atça or atca). While this strategy may not fully eliminate the marked structure, it does reduce its markedness (as will be further discussed in Section 4.3). In the next section we will examine how a single language, Kirundi, used both palatalization and glide strengthening to deal with marked C+j sequences.

This paper is organized as follows. Section 2 presents data on the resolution of C+j sequences in Kirundi (2.1) and an OT analysis of the patterns (2.2). Section 3 presents related Kirundi data on the resolution of C+w sequences (3.1), and an analysis combining both sets of data (3.2). Section 4 discusses implications of the analysis, reviewing similar cases from other languages, refining the analysis, and extending it to other patterns.

2 Kirundi palatalization and /j/ strengthening

2.1 Data

Kirundi (Rundi) is a Bantu language classified as Zone J (Interlacustrine zone), spoken in Burundi (Bastin 2003). The consonant and vowel inventories of the language are shown in (3), adapted from Meeussen (1959) and Ntihirageza (1993).[2]

(3) Kirundi inventory (Meeussen 1959: 9-12; Ntihirageza 1993: 12-13).

	Lab	Cor		Dor	Lar
		anterior	posterior		
stops	p b	t d		k g	
affricates	pf	ʦ ʣ~z	ʧ ʤ~ʒ		
fricatives	f v	s	ʃ		h
nasals	m	n	ɲ		
liquids		r			
glides			j	w	

	front	back	
high	i i:		u u:
mid	e e:		o o:
low		a a:	

One striking characteristic of the Interlacustrine zone Bantu languages is the widespread post-consonantal strengthening of glides /j/ and /w/ (Bastin 2003; Hyman 2003; Maddieson 2003). Focusing on C+j sequences, these can occur in Kirundi across morpheme boundaries and within morphemes (prefixes and roots). The glide can be underlying or derived from front vowels in vowel hiatus contexts (/iV/, /eV/ → [jV]), as is typical for many Bantu languages (Hyman 2003). As the trigger behavior of underlying and derived glides is the same, I will not distinguish between them and will refer to both as /j/. The following data are based heavily on Ntihirageza (1993: 29-42) and cross-checked, where possible, with Meeussen (1959), Cox (1969), and Rodegem (1970). Transcriptions were confirmed with a Kirundi consultant, a female speaker from Bujumbura.

[2] Meeussen (1959: 10-11) provides the following details on the phonetic realization of consonants. All voiceless stops are phonetically aspirated ([p^h t^h k^h]), voiced non-labial stops are partly devoiced ([d̥ g̊]), while voiced labials /b/ and /v/ vary in their manner of articulation ([b~β] and [v~^{b}v] respectively). Coronals /t d̊ n/ are dental, while the other anterior coronals are alveolar. Voiced counterparts of /ʦ/ and /ʧ/ are variably realized as affricates or fricatives, i.e. /ʣ~z/ and /ʤ~ʒ/. The rhotic /r/ has a range of phonetic realizations: [r~ɾ~ɽ~l]. In addition to the consonants in (3), Ntihirageza (1993: 12) lists palatal stops /c/ and /ɟ/, the phonemic status of which is less clear.

Data in (4) illustrate realizations of C+j sequences across morpheme boundaries in perfective verb forms. Outcomes for each specific sequence are shown in the column on the right, as glide strengthening (GS), palatalization (Pal), or consonant deletion (C-Del). The highlighted patterns are particularly relevant for the discussion. As seen in (a), sequences of labials and /j/ are resolved by strengthening the latter to a palatal consonant, which agrees in voice and nasality with the preceding labial (which, in the case of stops, spirantizes to [f] or [v]). Most coronal + /j/ sequences (b) are resolved through palatalization, merging the consonant with the glide. The result of this is a posterior coronal or an anterior coronal affricate or fricative. The rhotic /r/ palatalizes (to [ʤ]) in forms with light roots (one mora) and gets deleted in forms with phonologically heavy roots (two moras: Broselow & Niyondagara 1990: 74). The latter process is thus consonant deletion. Sequences of dorsals + /j/ (c) and laryngeal /h/+/j/ (d) are resolved through palatalization, the outcome of which is either an anterior coronal affricate or a posterior coronal fricative, respectively.

(4) Kirundi heteromorphemic C+j sequences[3] in perfective forms (adapted from Ntihirageza 1993: 29-42); GS = glide strengthening, Pal = palatalization, C-Del = consonant deletion; tone is omitted.

a.	C=labial	p	/ja-pom**p**-**j**e/	[japo^{ɱ}**fc**e][4]	' s/he filled with air'	*GS*
		b	/ja-raa**b**-**j**e/	[jaɾaː**vɟe**]	's/he looked'	*GS*
		m	/ja-so**m**-**j**e/	[jaso**mɲ**e]	's/he read'	*GS*
b.	C=coronal	t	/ja-roo**t**-**j**e/	[jaɾoː**s**e][5]	's/he dreamt'	*Pal*
		d	/ja-do**d**-**j**e/	[jado**ʣ**e]	's/he banged'	*Pal*
		s	/ja-sa**s**-**j**e/	[jaʃa**ʃ**e][6]	's/he spread'	*Pal*
		z	/ja-too**ʣ** -**j**e/	[jatoː**ʤ**e]	's/he picked up with'	*Pal*
		n	/ja-so**n**-**j**e/	[jaʃo**ɲ**e]	's/he sewed'	*Pal*
		r	/ja-ko**r**-**j**e/	[jako**ʣ**e]	's/he worked'	*Pal*
			/ja-koo**r**-**j**e/	[jakoː**j**e]	's/he peeled'	*C-Del*
c.	C=dorsal	k	/ja-tee**k**-**j**e/	[jateː**ʦ**e]	's/he cooked'	*Pal*
		g	/ja-vu**g**-**j**e/	[javu**ʣ**e]	's/he spoke'	*Pal*
d.	C=laryngeal	h	/ja-ri**h**-**j**e/	[jaɾi**ʃ**e]	's/he paid'	*Pal*

The same kinds of alternations are triggered by the transitive/causative /-j-a/ and nominal /-ji/ suffixes, as, for example, in /ku-saab-j-a/ [gusaːvɟa] 'smash (transitive)', /umu-rim-ji/ [umuɾimɲi] 'farmer', /ku-hor-j-a/ [guhoʣa] 'console (transitive)', /iki-tuk-ji/ [igituʦi] 'an insult' (Ntihirageza 1993: 30, 34, 40).[7] It should be mentioned that alternations in (4) are triggered by a palatal glide only, not by (surface) front vowels. The palatalizing effect of /i/ and /e/ is different and limited to only velars (with /ki/, /ke/, /gi/, /ge/ being realized as [k^{j}i~ci], [k^{j}e~ce], [ɡ^{j}i~ɟi], [ɡ^{j}e~ɟe]; Meeussen 1959: 10). Front vowels as triggers will not be considered further. Note also that the strengthening shown in (4a) is specific to the post-consonantal /j/, and does not affect the palatal glide (underlying or derived) in other phonetic contexts, as, for example, in /i-andika/

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[3] Omitted from (4) are examples of posterior coronals /ʃ/ and /ʤ/ + /j/, which delete the glide (/ja-ɡiʃ-je/ [jagiʃe] 's/he drove cattle', /ja-miiʤ-je/ [jamiːʤe] 's/he sprinkled'; Ntihirageza 1993: 36). These sequences do not occur in the tautomorphemic context examined further, and therefore will not be discussed. Neither will be discussed cases of 'double palatalization' (/ja-hor-j-je/ [jahoʤeʤe] 's/he consoled'), where palatalization is further affected by long-distance consonant assimilation (see Ntihirageza 1993: 36-38 for details).

[4] Ntihirageza (1993) transcribes the /p+j/ and /b+j/ sequences phonetically as [f^{s}k^{y}] and [v^{z}g^{y}], which I interpret as the IPA [f^{s}c] and [v^{z}ɟ] (cf. Meeussen's 1959:14 [f^{s}y] and [v^{z}y]; Broselow & Niyondagara's 1990 [vdy]). An acoustic analysis of data from our Kirundi consultant (Kochetov et al. 2013) confirmed the presence of an obstruent palatal segment, albeit variably realized as [c~c^{ɕ}~ç] after [f] and [ɟ ~ɟ^{z}~ʝ] after [v], respectively. For simplicity, I will transcribe the outputs as the fully strengthened fricative-stop sequences [fc] and [vɟ]. In contrast, the /m+j/ sequence in our data was realized invariably as [mɲ], which is consistent with Ntihirageza (1993) and Meeussen (1959). Some acoustic examples of glide strengthening are presented in Figure A1 in the Appendix. See also Maddieson (2003) and Hyman (2003) on glide strengthening in Interlacustrine Bantu languages.

[5] There is a single example of /t/ palatalizing to [ʃ] instead of [s] (/ja-fat-je/ [jafaʃe] 's/he held'; Ntihirageza 1993: 33, 95). Broselow & Niyondagara (1990: 74) also mention /ja-mat-je/ [jamaʃe] 's/he stuck', which, other sources cite with [s] (Cox 1969: 105).

[6] In this form palatalization feeds long-distance sibilant assimilation (/ja-sas-je/ → [jasaʃe] → [jaʃaʃe] 's/he spread'; see also [jaʃoɲe] 's/he sewed'), a process that is beyond the scope of this paper. See Ntihirageza (1993).

[7] The voicing alternations in /iki-/ and /ku-/ are due to the dissimilatory Dahl's Law (Hyman 2003).

[ija^{n}dika] ‘writing system’, /ku-jaaga/ [kujaːga] ‘to chart’, and /ku-gaja/ [kugaja] ‘to be ungrateful’ (Ntihirageza 1993: 81).

Turning to tautomorphemic C+j sequences, these exhibit partly the same and partly different behaviour, as shown in (5) (Ntihirageza 1993; cf. Meeussen 1959: 13-14). In many, but not all of these cases, the glide is derived. It can be seen that the labial + /j/ sequences (a) are resolved by strengthening the glide, the same way as it is done in the heteromorphemic sequences in (4). An important difference here is with coronal + /j/ sequences (b), many of which are also resolved through glide strengthening (in contrast to palatalization in (4)). This happens in sequences where C_1 is an obstruent or a rhotic.[8] The strengthened glide after these consonants agrees with them in voice and consonantality. Some of these structures optionally simplify to the palatal element ([tc] → [c] and [ɾɟ] → [ɟ]). The nasal /n/ is the only coronal to undergo palatalization, with the output being its posterior coronal counterpart. Sequences of velars and laryngeal + /j/ (c and d) are resolved through palatalization to a posterior coronal affricate or fricative.

(5) The realization of tautomorphemic C+j sequences (adapted from Ntihirageza 1993: 30, 45-49); GS = glide strengthening, Pal = palatalization, C-Del = consonant deletion; j-Del = glide deletion; tone is omitted.

a.	C=labial	b	/i**bi**-aak-ji/ (> bj)	[i**vɟ**aːʦi]	‘grass (pl.)’	*GS*
		f	/ku-**fj**eta/	[gu**fc**eta]	‘to lick’	*GS*
		v	/ku-**vj**uura/	[ku**vɟ**uːɾa]	‘to wake up’	*GS*
		m	/i**mi**-aaka/ (> mj)	[i**mɲ**aːka]	‘years’	*GS*
b.	C=coronal	t	/gu-**tj**o/	[gu**tc**o]~[gu**c**o]	‘that way’	*GS*
		d	/i-n-**dj**a/	[i^{n}**dɟ**a]	‘food’	*GS*
		s	/ku-**se**-a/ (> sj)	[gu**sc**a]	‘to grind’	*GS*
		z	/i-n-**ʣj**a/	[i^{n}**ʣɟ**a]	‘pubic hair’	*GS*
		n	/ku-**ne**-a/ (> nj)	[ku**ɲ**a]	‘to defecate’	*Pal*
		r	/i-**ri**-ooja/ (> rj)	[i**ɾɟ**oːja]~[i**ɟ**oːja]	‘feather’	*GS*
			/ku-**ri**-a/ (> rj)	[ku**ɾɟ**a]~[ku**ɟ**a]	‘to eat’	*GS*
c.	C=dorsal	k	/i-**ki**-uuma/ (>kj)	[i**ʧ**uːma]	‘a piece of metal’	*Pal*
d.	C=laryngeal	h	/ku-**hi**-a/ (> hj)	[gu**ʃ**a]	‘to burn	*Pal*

To sum up, palatalization in Kirundi applies in heteromorphemic non-labial + /j/ sequences and tautomorphemic sequences of coronal sonorant, dorsal, or laryngeal + /j/. Glide strengthening applies in all labial + /j/ sequences, as well as in coronal obstruent or rhotic + /j/ sequences. It should be noted that the strengthened glide is phonetically manifested as a full-fledged consonant, comparable in duration to other coronal segments (see Figure A1 in the Appendix). The phonological patterns of palatalization and strengthening are summarized in (6), leaving aside the cases of deletion. Going back to the typology of palatalization outlined in Section 1,

[8] In a single form, /iri-iiso/ (> [irjiːso] >) [iʤiːʃo] ‘an eye’, the /r/ + /j/ sequence is resolved by palatalization (Ntihirageza 1993: 46-47). The reason for this exceptional realization us unclear, and could be due to an assibilating effect of the adjacent /i/ or a non-local interaction with the following sibilant.

note that Kirundi heteromorphemic C+j sequences belong to Type 2 in (1), while its tautomorphemic sequences belong to Type 3 (with the exception of n+j sequences).

(6) A summary, C+j: palatalization (Pal) and glide strengthening (GS).

	C = Lab	C = Cor			C = Dor/Lar
		obs.	/n/	/r/	
heteromorphemic	GS	Pal	Pal	Pal	Pal
tautomorphemic	GS	GS	Pal	GS	Pal

The range of segmental realizations of Kirundi palatalization is wide (7a), and these are not always predictable from the features of the participating consonant and /j/.What they have in common, however, is the feature [Coronal]; many also share either the [–anterior] or [+strident] specification, or both. In contrast, the strengthened glides are featurally uniform, sharing the features [Coronal, –anterior, –strident] (7b), which were present in the original /j/.[9] Unlike /j/, however, the outputs are [+consonantal, –continuant], as well as sharing the [±sonorant], [±voice], and [±nasal] specification with the preceding consonant.

(7) Feature specifications of outputs of palatalization and strengthened glides.

Feature	a. palatalization outputs								b. strengthened glide		
	[ʧ]	[ʤ]	[ʃ]	[ɲ]	[j]	[ʦ]	[ʥ]	[s]	[c]	[ɟ]	[ɲ]
[Coronal]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
[anterior]	–	–	–	–	–	+	+	+	–	–	–
[strident]	+	+	+	–	–	+	+	+	–	–	–
Input	/kj/	/ʥj/	/sj,hj/	/nj/	/rj/	/kj/	/gj,dj, rj/	/tj/	/pj, fj, tj, sj/	/bj, vj, dj, ʥj, rj/	/mj/

In this paper, I will not attempt to account for the complex feature mappings in palatalization and glide strengthening (but see some proposals in Broselow & Niyondagara 1990; Ntihirageza 1993; cf. Sagey 1990 on the related Kinyarwanda). Rather, the focus will be on how to capture the competition between these two processes in resolving the marked C+j structure.

2.2 Analysis

Palatalization and glide strengthening: Competing repair strategies

The analysis of Kirundi patterns proposed in this paper is inspired by Pater's (1999/2004) account of avoidance of nasal + voiceless obstruent clusters (*NC̥). Pater examined realizations of these clusters in Indonesian and several other related and unrelated languages, and came to the conclusion that this marked structure can be avoided in a number of ways – through nasal substitution, nasal deletion, vowel epenthesis, post-nasal voicing, and denasalization. Languages

[9] The palatal glide is assumed to be specified for [-syllabic, -consonantal, +sonorant, Coronal, -anterior].

differ in their selection of repair strategies, and a single language may use more than one strategy, depending on the morphological context. In Pater's (1999/2004) OT analysis of the data, these seemingly disparate effects were represented as competing strategies employed to repair the marked structure NÇ̥.

Building on Pater's analysis of NÇ̥ clusters, it is proposed here that both palatalization and glide strengthening are strategies employed to repair a marked structure C+pal (a palatal segment). The avoidance of this structure is enforced by a contextual markedness constraint *C+pal, which is defined in (8). This constraint is grounded in articulatory (conflicting articulatory targets) and acoustic/perceptual factors (reduced place contrasts and increased confusability) reviewed in Section 1.2. The constraint is fairly general, prohibiting any sequence of a consonant with a palatal glide, palatal consonant, or a front vowel. Presumably, finer markedness differences exist among these sequences, and a more detailed approach would use more specific constraints like *C+pal[–syllabic] (avoid consonants followed by a palatal consonant or glide), *C+pal[–syllabic, –consonantal] (avoid consonants with a palatal glide), etc. For expository reasons, however, we will use the general constraint *C+pal for our analysis, and will return to the question of more fine-grained distinctions in Section 4.3.

(8) *C+pal: avoid consonant + palatal segment sequences (*Cj, *Cɲ, *Ci, etc.).

Note that our proposal to employ a contextual markedness constraint *C+pal to trigger palatalization departs significantly from many other OT analyses of palatalization. These often employed palatalization-specific feature spreading, linking, or alignment constraints (e.g. Palatalize: spread [coronal] or [–back] in Chen 1996 and Rubach 2000; CV-Link[coronal] in Zubritskaya 1994; Align[coronal]/[–back] in Takatori 1997 and Morén 2006). Similarly, in Bateman's (2007) analysis, palatalization results from gestural overlap, being triggered by coordination constraints (CV-Coordination[palatal]). The contextual markedness approach to palatalization, however, is not entirely new. Itô & Mester (1999), for example, proposed phonotactic constraints *TI and *SI to account for the avoidance of anterior coronal obstruents /t d s z/ before the high front vowel /i/ in the Japanese lexicon. Hall & Hamann (2006) analyze cross-linguistic patterns of coronal stop assibilation as triggered by perceptually-based constraints referring to the target stop voicing and the trigger syllabicity - *tj, *ti, *dj, and *di. In a related approach, Hall & Hamann (2010) propose phonotactic constraints *rj and *rj-ri to account for the cross-linguistic avoidance of sequences or rhotic + palatal glide or high front vowel (cf. Hall 2000). Nevertheless, wider implications of such markedness-based approaches have not been fully explored. (See also Flemming 2002 and Padgett 2003 for a different, perceptual dispersion-based modeling of palatalization.)

The *C+pal constraint in our analysis is in conflict with a faithfulness constraint Uniformity-IO (9), which requires elements in the input string to map one-to-one onto elements in the output string (McCarthy & Prince 1999; Pater 2004). Thus, Uniformity-IO is satisfied in (10a), but is violated in (10b), where the input elements C_1 and C_2 are fused into a single output element. Ranking *C+pal above Uniformity-IO (11a) favours the palatalization candidate (ii) that fuses alveolar nasal /n/ and palatal /j/ into palatal nasal [ɲ]. In contrast, the faithful candidate (i) which preserves the original correspondence relation is ruled out, as it violates the higher ranked markedness constraint. Ranking *C+pal below Uniformity-IO preserves the one-to-one correspondence of the segments, blocking palatalization (11b) (cf. Pater 1999/2004).

(9) Uniformity-Input/Output (Uniform-IO): Output elements cannot correspond to more than one input element (McCarthy & Prince 1999; Pater 2004).

(10) Uniformity relations.

	a.	b.
Input:	C_1 C_2	* C_1 C_2
Output:	C_1 C_2	$C_{1,2}$

(11) Palatalization and blocking of palatalization in /n/+/j/ sequences (hypothetical data).

a.	/an$_1$j$_2$a/	*C+pal	Uniform-IO
i.	an$_1$j$_2$a	*!	
ii.	☞ aɲ$_{1,2}$a		*

b.	/an$_1$j$_2$a/	Uniform-IO	*C+pal
i.	☞ an$_1$j$_2$a		*
ii.	aɲ$_{1,2}$a	*!	

Alternative strategies to satisfy *C+pal would include the deletion of C_1 or C_2, epenthesis breaking up the C+j sequence, and metathesis switching the order of the consonant and the glide. These do not apply in Kirundi, presumably being blocked by the higher-ranked standard faithfulness constraints Max-IO, Dep-IO, and Linearity-IO (12), whose correspondence relations are illustrated in (13), with (a)-(d) showing the blocking C_2 or C_1 deletion, vowel epenthesis, and metathesis, respectively.

(12) a. Max-IO: Input elements must have output correspondents (that is, no deletion).
b. Dep-IO: Output elements must have input correspondents (that is, no epenthesis).
c. Linearity-IO (Lin): The output reflects the precedence structure of the input, and *vice versa* (Pater 1999; that is, no metathesis).

(13) Correspondence relations for alternative repair strategies.

	a.	b.	c.	d.
Input:	* C_1 C_2	* C_1 C_2	* C_1 C_2	* C_1 C_2
Output:	C_1	C_2	C_1 V C_2	C_2 C_1

The tableau in (14) illustrates a case where the palatalization candidate (b) wins, while the candidates that show no change (a), deletion (c and d), epenthesis (e), and metathesis (f) are blocked by higher ranked faithfulness constraints. This ranking holds for Kirundi /n/+/j/ sequences, as well all other heteromorphemic non-labial + /j/ sequences.

(14) Palatalization is preferred over other repair strategies and over no change in /n/+/j/ sequence (hypothetical data).

	/an$_1$j$_2$a/	Max-IO	Dep-IO	Lin-IO	*C+pal	Uniform-IO
a.	an$_1$j$_2$a				*!	
b.	☞ aɲ$_{1,2}$ a					*
c.	an$_1$a	*!				
d.	aj$_2$a	*!				
e.	an$_1$əj$_2$a		*!			
f.	aj$_2$n$_1$a			*!		

Although the ranking of *C+pal below Uniformity-IO maintains the original order of segments, the sequence in question is not immune from other changes, such as glide strengthening. This process is induced by another markedness constraint, Agree[F]-CC, which requires featural agreement among the elements in the cluster (15) (cf. Newton's 1972 rule of Consonantality in Greek glide strengthening[10]; see Lombardi 1999 and Baković 2006 on the use of Agree constraints to model assimilation in clusters). This agreement essentially involves all features of the two segments except [Place] and [continuant] (but see Footnote 11 and Section 4.3). The constraint is phonetically grounded in articulatory ease – avoiding sequences of conflicting gesture specifications.

(15) Agree[F]-CC: Consonants/glides in a cluster have the same values for consonantality, sonorancy, nasality, and voicing ([±consonantal, ±sonorant, ±nasal, ±voice]).

The tableau in (16) illustrates a case where the faithful candidate (a) loses to the glide strengthening candidate (c) due to the fatal violation of Agree[F]-CC (2 violations for the disagreement in [consonantal] and [nasal]). In contrast, candidate (c) incurs no violations of this constraint, fully agreeing with the preceding consonant in the required features. This analysis adequately captures the resolution of the Kirundi labial + /j/ sequences (see (4a) and (5a)). Note that the winning candidate does not satisfy the markedness constraint *C+pal per se, but wins because it is more harmonic in its featural composition. (See Section 4.3 for a revised analysis.)

(16) Post-consonantal glide strengthening in the /m/+/j/ sequence (see (4a, 5a)).

	/am$_1$j$_2$a/	Uniform-IO	*C+pal	Agree[F]-CC
a.	am$_1$j$_2$a		*	**!
b.	aɲ$_{1,2}$ a	*!		
c.	☞ amɲa		*	

So far we have abstracted away from violations of featural faithfulness constraints of the type Ident-IO[Feature], which would be inevitably violated by both the palatalization and glide strengthening candidates. This is shown in tableau (17) for the same /amja/ input. It can be seen that the palatalization candidate violates the lower-ranked faithfulness to the features [consonantal], [nasal], [continuant], and [Place] (4 violations in total). This is because the output

[10] Newton (1972: 157) formulates the 'consonantality' rule as follows: "A non-vocalic, non-strident, voiced, palatal, continuant segment agrees in consonantality, voice, and nasality with any preceding consonant segment; otherwise it is non-consonantal."

[ɲ] is [+consonantal, +nasal, -continuant] (unlike the input /j/), as well as [Coronal] (unlike the input /m/). The strengthening candidate violates Ident-IO[F] on 3 counts: for the disagreement in [consonantal], [nasal], and [continuant]. Another candidate is added to illustrate the relevance of featural faithfulness constraints. Candidate (d) shows both palatalization and strengthening (or place assimilation to the strengthened glide). This candidate fairs well, yet loses to the strengthening-only candidate given an additional place violation.[11] Apart from this case, Ident-IO[F] constraints do not affect outcomes in our analysis, and therefore will not be considered further.

(17) Post-consonantal glide strengthening in the /m/+/j/ sequence (see (4a, 5a)).

	/am$_1$j$_2$a/	Uniform-IO	*C+pal	Agree[F]-CC	Ident-IO[F]
a.	am$_1$j$_2$a		*	**!	
b.	aɲ$_{1,2}$ a	*!			****
c.	☞ amɲa		*		***
d.	aɲɲa		*		****!

Morphological effects

Recall that glide strengthening in Kirundi also applies in sequences with coronal obstruents, but only when those belong to the same morpheme. Following Pater (2004), among others, I assume that faithfulness constraints can refer to morphological information, with Morpheme Uniformity-IO (18) enforcing the correspondence relation within a given morpheme (root or affix; cf. Pater 2004: Root Uniformity-IO). Sandwiching the markedness constraint *C+pal between MorphUniformity-IO and the more general Uniformity-IO produces the needed effect. As shown in (19), the heteromorphemic sequence /s/+/j/ is resolved by palatalization (b), as the highly ranked *C+pal rules out the faithful candidate (a) and the glide strengthening candidate (c). The winning candidate (b), in turn, violates a lower-ranked Uniformity-IO constraint, as the segment [ʃ] involves a merger of segments /s/ and /j/. In contrast, palatalization is blocked in the same sequence tautomorphemically (20), given the higher ranked MorphUniformity-IO. This constraint penalizes the palatalization candidate (b), as it fuses segments occurring within a root. The tie between the faithful candidate and the one with glide strengthening is resolved in favour of the latter by the markedness constraint Agree[F]-CC (with 3 violations assigned to [asja] for the disagreement in values of [consonantal], [sonorant], and [voice]).

(18) Morpheme Uniformity-IO (MorphUniform-IO): The output reflects the precedence structure of the input *within a morpheme*, and vice versa.

[11] It is worth noting that some of the IO faithfulness, and specifically Ident-IO[Cor], would have to be ranked relatively high in order to rule out candidates showing glide strengthening accompanied by a place change (e.g. [amma]). This also opens a possibility that Agree[F]-CC is more general, involving agreement in all features, including [Place], yet the change of the latter is blocked.

(19) Palatalization in the *heteromorphemic* /s/+/j/ sequence (see (5b)).

	/as$_1$-j$_2$a/	MorphUniform-IO	*C+pal	Uniform-IO	Agree[F]-CC
a.	as$_1$j$_2$a		*!		***
b.	☞ aʃ$_{1,2}$ a			*	
c.	asca		*!		

(20) Glide strengthening in the *tautomorphemic* /s/+/j/ sequence (see (4b)).

	/a-s$_1$j$_2$a/	MorphUniform-IO	*C+pal	Uniform-IO	Agree[F]-CC
a.	as$_1$j$_2$a		*		***!
b.	aʃ$_{1,2}$ a	*!		*	
c.	☞ asca		*		

Place and manner effects

An important characteristic of the Kirundi data is that the choice between palatalization and glide strengthening is often determined by the place of the target consonant, and to some degree by its manner. Thus, dorsals and laryngeals always favour palatalization, while labials always favour glide strengthening. Coronals can do either, depending on their manner: nasals always get palatalized, while obstruents and /r/ either get palatalized or strengthen the following glide. These differences can be captured by rankings of place- and manner-specific *C+pal constraints as shown in (21).[12] These rankings are to some degree universal and to some degree language-specific. For example, the lower ranking of *Lab+pal is consistent with cross-linguistically documented avoidance of labial place-changing palatalization (Bhat 1978; Bateman 2007). The source of this is the lesser articulatory and acoustic/perceptual vulnerability of the labial place, as illustrated in in Section 1.2. The ranking of *Cor+pal below *Dor+pal is common, but not universal, as some languages show the opposite pattern (see (1); cf. Bateman's 2010 palatalization scale: Palatalize Dor, Palatalize Cor » Palatalize Lab). With respect to manner, the higher ranking of *n+pal is not surprising, given the general propensity of nasals to assimilate in place in various contexts (cf. Jun 1995, among others).

(21) Place/manner rankings in Kirundi.

a. *Dor+pal, *Lar+pal » *Cor+pal » *Lab+pal

b. *n+pal » *Cor+pal

The tableaux in (22)-(25) below illustrate how the different place and manner effects result from the rankings of specific *C+pal constraints with the markedness and faithfulness constraints introduced earlier. It can be seen in (22) that the higher ranking of *Lar+pal enforces palatalization of /h/ to [ʃ] over the strengthening of /j/ to [c]. Note that the input target sequence is tautomorphemic. The same outcome, however, is expected in heteromorphemic sequences, given the lower ranking of MorphUniformity-IO. The analysis provided for laryngeal /h/+/j/ can be fully extended to the dorsal /k/+/j/ and /g/+/j/ sequences, as these would also favour palatalization regardless of the morphological context.

[12] An alternative analysis would involve capturing place differences using place-specific faithfulness constraints or stringency relations (de Lacy 2006).

(22) Palatalization in a tautomorphemic /h/+/j/ sequence (see (5d)).

	/ah$_1$j$_2$-a/	*Lar +pal	*Dor +pal	*n+pal	Morph Uniform	*Cor +pal	Uniform -IO	*Lab +pal	Agree[F] -CC
a.	ah$_1$j$_2$a	*!							***
b.	☞ aʃ$_{1,2}$a				*		*		
c.	ahca	*!							

Labials are similar to laryngeals and dorsals in their lack of morphological effects, but the outcome is the opposite – glide strengthening. This is because of the lower ranking of *Lab+pal with respect to all relevant constraints other than Agree[F]-CC, as shown in (23) for the /f/+/j/ sequence.

(23) Glide strengthening in a tautomorphemic /f/+/j/ sequence (see (5a)).

	/af$_1$j$_2$-a/	*Lar +pal	*Dor +pal	*n+pal	Morph Uniform	*Cor +pal	Uniform -IO	*Lab +pal	Agree[F] -CC
a.	af$_1$j$_2$a							*	***!
b.	aʃ$_{1,2}$a				*		*!		
c.	☞ afca							*	

Coronal obstruent + glide sequences exhibit particularly interesting behavior: palatalization applies in heteromorphemic contexts, while glide strengthening applies in tautomorphemic contexts. This is crucially due to *Cor+pal being sandwiched between the two Uniformity-IO constraints, as shown for /s/ + /j/ sequences in (24) and (25).

(24) Palatalization in a heteromorphemic /s/+/j/ sequence (see (4b)).

	/as$_1$-j$_2$a/	*Lar +pal	*Dor +pal	*n+pal	Morph Uniform	*Cor +pal	Uniform -IO	*Lab +pal	Agree[F] -CC
a.	as$_1$j$_2$a					*!			***
b.	☞ aʃ$_{1,2}$a						*		
c.	asca					*!			

(25) Glide strengthening in a tautomorphemic /s/+/j/ sequence (see (5b)).

	/as$_1$j$_2$-a/	*Lar +pal	*Dor +pal	*n+pal	Morph Uniform	*Cor +pal	Uniform -IO	*Lab +pal	Agree[F] -CC
a.	as$_1$j$_2$a					*			***!
b.	aʃ$_{1,2}$a				*!		*		
c.	☞ asca					*			

In contrast, the coronal nasal is palatalized regardless of the morphological context, given the higher ranking of *n+pal (26). This ranking and the resulting behaviour is similar to /h/ and dorsal + /j/ sequences.

(26) Palatalization in a heteromorphemic /n/+/j/ sequence (see (4b)).

	/an₁-j₂a/	*Lar +pal	*Dor +pal	*n+pal	Morph Uniform	*Cor +pal	Uniform -IO	*Lab +pal	Agree[F] -CC
a.	an_1j_2a			*!		*			**
b.	☞ $aɲ_{1,2}a$						*		
c.	anɲa			*!		*			

Leaving the cases of deletion aside, the rankings of constraints in Kirundi palatalization and glide strengthening patterns can be summarized as follows.

(27) A summary of relevant constraint rankings and resulting palatalization (Pal) and glide strengthening (GS) patterns in Kirundi; faithfulness constraints are bolded.

Rankings	*Patterns*
Max-IO, Dep-IO, Lin »	No deletion, insertion, or metathesis in C + /j/
*Dor+pal, *Lar+pal, *n+pal »	Pal of all dorsals, laryngeals, & coronal nasals + /j/
MorphUniform »	
*Cor+pal »	Pal of heteromorphemic coronal + /j/
Uniform »	
*Lab+pal »	GS of tautomorphemic coronal + /j/ & all labial + /j/
Agree[F]-CC	

To conclude this section, the proposed analysis accounts for patterns of alternations in Kirundi C+j data. This analysis clarifies the affinity between palatalization and glide strengthening: both are strategies aimed at repairing the same marked structure (cf. Pater 1999/2004 on NÇ̥). To provide further evidence for the analysis, we will examine related patterns of the C+w sequence avoidance.

3 Kirundi /w/ strengthening

3.1 Data

Glide strengthening in Kirundi is not limited to the palatal /j/, but also involves the labial-velar /w/. The data below are mainly from Broselow & Niyondagara (1990) and Meeussen (1959: 13-15), cross-checked, where possible, with Cox (1969) and Rodegem (1970). The transcription was verified with the same Kirundi consultant referred to in Section 2. Examples include both hetero- and tautomorphemic sequences, as these do not appear to differ in their realizations.

As seen in (28), labial + /w/ sequences are resolved by strengthening the glide to a velar noncontinuant, which agrees in consonantality, sonorancy, voice, and nasality with the preceding consonant (a). The same applies to coronal + /w/ sequences, with the difference that the strengthened element here has a secondary labialization (b). This suggests that what strengthens is the [Dorsal] feature of /w/, while its [Labial] feature remains [-consonantal] and is manifested in the secondary articulation. The lack of secondary labial articulation in (28a) can be explained by a language-specific restriction against sequences of labials and labialized consonants (cf. Broselow & Niyondagara 1990: 78). Continuing with the patterns in (28b), the rhotic also triggers glide strengthening, and optionally deletes. Finally, sequences of dorsals and laryngeals + /w/ do not show strengthening; instead, they are realized as consonants with secondary labialization (c and d).

(28) The realization of heteromorphemic (passive) and tautomorphemic C+w sequences[13]; GS = glide strengthening (with or without secondary labialization), No = no change (in primary place); tone is omitted.

a.	C=labial	p	/ku-koro**p-w-**a/	[gukoro**pk**a][14]	'to be mopped'	GS
		b	/ku-raa**b-w-**a/	[kuraː**bg**a]	'to be looked at'	GS
			/i-n-**bw**a/	[i^{m}**bg**a]	'dog'	GS
		f	/iki-**fw**era/	[igi**fk**eɾa]	'snail'	GS
		m	/ku-ka**m-w-**a/	[guka**mŋ**a]	'to be dried'	GS
			/ku-**mo-w-**a/	[ku**mŋ**a]	'to cut hair'	GS
b.	C=coronal	t	/ku-kubi**t-w-**a/	[gukubi**tk**^{w}a]	'to be beaten'	GS
			/ku-**tw**aara/	[gu**tk**^{w}aːɾa]	'to take/carry'	GS
		d	/i-n-**dw**aare/	[i^{n}**dg**^{w}aːɾe]	'being ill'	GS
		s	/i-**sw**a/	[i**sk**^{w}a]	'termite'	GS
		z	/ku-terer-e**ʣ-w-**a/	[guteɾeɾe**ʣg**^{w}a]	'to be asked for help'	GS
		n	/ku-bo**n-w-**a/	[kubo**nŋ**^{w}a]	'to be seen'	GS
			/imi-**nw**e/	[imi**nŋ**^{w}e]	'hands'	GS
		r	/ku-gu**r-w-**a/	[kugu**ɾg**^{w}a]~[kugu**g**^{w}a]	'to be bought'	GS/ C-Del
			/ku-**rw**aar-a/	[ku**ɾg**^{w}aːra]~[ku**g**^{w}aːra]	'to be ill'	
c.	C=dorsal	k	/ku-tee**k-w-**a/	[guteː**k**^{w}a]	'to be cooked'	No
			/ku-**kw**eeg-a/	[gu**k**^{w}eːga]	to drag'	No
		g	/ku-ra**g-w-**a/	[kuɾa**g**^{w}a]	'to be bequeathed'	No
			/ku-**gu-w-**a/	[ku**g**^{w}a]	'to fall'	No
d.	C=laryngeal	h	/ku-**hw**eer-a/	[gu**h**^{w}eːɾa]	'to die'	No

The diagram in (29) shows how these patterns compare to C+j realizations (setting aside deletion). Glide strengthening is obviously more extensive in C+w sequences compared to C+j sequences, while the corresponding place-changing process – velarization – is absent in the former. Dorsals and laryngeal /h/ show no change, the pattern that is not exhibited by any consonants before /j/. As I will show below, these somewhat different patterns fit well in the analysis proposed for Kirundi C+j sequences. For examples of acoustic realizations of C+w sequences, see Figure A2 in the Appendix.

[13] Omitted from (28) are examples of /ʦ/, /ʧ/, and /ʃ/ + /w/, as these consonants were not discussed in the C+j context. These sequences show the same outcome of strengthening ([k^{w}]) as with other coronals (see Broselow & Niyondagara 1990: 78).

[14] Here and below our acoustic data (Kochetov et al. 2013) showed invariable realization of the glide as a velar stop or nasal, consistent with transcriptions in Meeussen (1959) and Broselow & Niyondagara (1990). See some acoustic examples in Figure A2 in the Appendix; see also Maddieson (2003) on the phonetics of velar glide strengthening in Interlacustrine Bantu languages.

(29) A summary: palatalization (Pal) and glide strengthening (GS) in C+j and C+w sequences.

		C = Lab	C = Cor			C = Dor/Lar
			obs.	/n/	/r/	
C+j	*heteromorphemic*	GS	Pal	Pal	Pal	Pal
	tautomorphemic	GS	GS	Pal	GS	Pal
C+w	*hetero-/tautomorphemic*	GS	GS	GS	GS	No change

3.2 Analysis

As with C+j sequences, we assume that C+w sequences are marked, being prohibited by a highly ranked contextual markedness constraint *C+vel (30). This constraint is also phonetically grounded. With post-consonantal /w/ specifically, Ohala & Lorenz (1977) and Kawasaki (1982) observed that the glide substantially reduces acoustic salience of place contrasts, potentially leading to their confusability. Given some place and manner differences in the Kirundi patterns, the constraint *C+vel is split into more specific constraints, the ranking of which in the language is shown in (31). Among these constraints, the lower ranking of *Dor+vel is likely to be universal, as these appear to be cross-linguistically most compatible with /w/ (Ohala & Lorenz 1977).

(30) *C+vel: avoid consonant + velar segment sequences (*Cw, *Cŋ, *Cɯ, etc.).

(31) Place/manner rankings in Kirundi C+vel sequences.
*Lab+vel, *Cor+vel » *Dor+vel, *Lar+vel

Velar glide strengthening in our analysis results from a higher ranking of Uniformity-IO and a lower ranking of Agree[F]-CC relative to *C+vel, as shown in (32) and (33). For reference, these tableaux contain place-specific *C+j constraints, the ranking of which was established in section 2.2. Specifically, Uniformity-IO rules out candidate (b) which merges two segments, producing a velar nasal or fricative with secondary labial articulation. The other two candidates in (32) violate *Lab+vel, but the no-change candidate (a) also violates the lower ranked Agree[F]-CC ([consonantal] and [nasal]), and thus loses out to the glide strengthening candidate (c). This analysis, of course, presupposes that the latter candidate violates some feature faithfulness constraints; these however, are presumably ranked below Agree[F]-CC, and thus do not affect the outcome. Note that the ranking of *Lab+vel or *Cor+vel constraints above Uniformity-IO would enforce place-changing velarization. This process is not reported in Kirundi, but is found to compete with strengthening in other Bantu languages (see Section 4.1).

(32) Post-consonantal glide strengthening in the /m/+/w/ sequence (see (28a)).

	/am$_1$-w$_2$a/	*Dor +pal	Morph Uniform	*Cor +pal	Uniform -IO	*Lab +vel	*Cor +vel	Agree[F] -CC	*Dor +vel
a.	am$_1$w$_2$a					*		**!	
b.	aŋ$_{1,2}$^{w}a				*!				
c.	☞ am$_1$ŋ$_2$a					*			

(33) Post-consonantal glide strengthening in the /s/+/w/ sequence (see (28b)).

	/as$_1$-w$_2$a/	*Dor +pal	Morph Uniform	*Cor +pal	Uniform -IO	*Lab +vel	*Cor +vel	Agree[F] -CC	*Dor +vel
a.	as$_1$w$_2$a						*	***!	
b.	ax$_{1,2}$^{w}a				*!				
c.	☞ ask^{w}a						*		

A summary of all relevant rankings of constraints responsible for palatalization and both /j/- and /w/-strengthening patterns is given in (34). Overall, this shows that fairly complex patterns of alternations found in Kirundi arise from interactions of the same small set of faithfulness constraints and place/manner-specific contextual markedness constraints. It should be mentioned that the interactions of these processes in Kirundi have not been a subject of formal phonological analysis, although the question of the features involved in Kirundi palatalization did receive some considerable attention in the past (Broselow & Niyondagara 1990; Ntihirageza 1993; cf. Sagey 1990 on the related Kinyarwanda).

(34) A combined summary of relevant constraint rankings and resulting palatalization (Pal) and palatal/velar glide strengthening (GS) patterns in Kirundi; faithfulness constraints are bolded.

<table>
<tr><th>Rankings</th><th>Patterns</th></tr>
<tr><td>Max-IO, Dep-IO, Lin »</td><td>No deletion, insertion, or metathesis in C + /j/ or /w/</td></tr>
<tr><td>*Dor+pal, *Lar+pal, *n+pal »</td><td rowspan="2">Pal. of all dorsals, laryngeals, & coronal nasals + /j/</td></tr>
<tr><td>MorphUniform »</td></tr>
<tr><td>*Cor+pal »</td><td rowspan="2">Pal. of heteromorphemic coronal + /j/</td></tr>
<tr><td>Uniform »</td></tr>
<tr><td>*Lab+pal, *Cor+vel, *Lab+vel »</td><td rowspan="2">GS of tautomorphemic coronal + /j/ & all labial + /j/ or /w/</td></tr>
<tr><td>Agree[F]-CC</td></tr>
<tr><td>*Dor+vel, *Lar+vel</td><td>No change for dorsal & laryngeal + /w/</td></tr>
</table>

4 Discussion

4.1 Interactions of palatalization and glide strengthening: Further evidence

If the analysis proposed for Kirundi is correct, we may expect to find cases of similar interactions of glide strengthening and palatalization in other languages. Although not particularly common, remarkably similar cases have been attested. One of them is Greek, whose many dialects exhibit intricate patterns of palatalization and palatal glide strengthening. The strengthened glide is usually realized as a fricative [ç] or [ʝ] after voiceless or voiced obstruents and /r/ in some dialects (including Standard Greek), and as a stop [c] or [ɟ] in other dialects; after nasals, it is realized as [ɲ] regardless of the dialect (Newton 1972; Baltazani et al. 2016). The diagram in (35) categorizes the dominant patterns of the C+j realization in various Greek dialects based on Newton's (1972) survey (see also Newton 1971). Six general types of patterns (with sample dialects in parentheses) shown in (35) exhibit palatalization of coronal nasal and velar obstruents, and glide strengthening after labials. Most also show glide strengthening after coronal obstruents (less so after sibilants) and the liquids (more so for /r/ than /l/). Sample data from a Type 3 dialect (Kos) are presented in (36). In all these cases the glide is derived from an underlying prevocalic /i/.

(35) General patterns of palatalization (Pal), glide strengthening (GS), and consonant or glide deletion (C-Del, j-Del) in Greek dialects (adapted from Newton 1972: 154-157).

	C = Lab	C= Cor					C = Dor	
	/p f v m/	/t θ ð/	/s z/	/n/	/l/	/r/	/k x/	/ɣ/
Type 1 (Zitsa)	GS	GS	Pal	Pal	Pal	GS	Pal	Pal
Type 2 (Megara)	GS	GS	j-Del	Pal	Pal	GS	Pal	Pal
Type 3 (Kos)	GS	GS	GS	Pal	Pal	GS	Pal	Pal
Type 4 (N. Rhodes)	GS	GS	GS	Pal	GS	GS	Pal	Pal
Type 5 (E. Crete)	GS	GS	GS	Pal	GS	GS	Pal	Pal
Type 6 (Santorini)	GS	Pal	j-Del	Pal	GS	C-Del	Pal	Pal

(36) Sample data: (presumed) realizations of C+j sequences in the Kos dialect (adapted from Newton 1972).[15]

a.	C=labial	p	/ku**pi**-a/	(> pj)	[ku**pc**a]	'oars'	GS
		f	/ra**fi**-a/	(> fj)	[ra**fc**a]	'shelves'	GS
		v	/kara**vi**-a/	(> vj)	[kara**vɟ**a]	'boats'	GS
		m	/ro**me**-os/	(> mj)	[ro**mɲ**os]	'Greek'	GS
b.	C=coronal	t	/ma**ti**-a/	(> tj)	[ma**tc**a]	'eyes'	GS
		θ	/kala**θi**-a/	(> θj)	[kala**θc**a]	'baskets'	GS
		ð	/pe**ðí**-a/	(> ðj)	[pe**ðɟ**a]	'children'	GS
		s	/kra**si**-a/	(> sj)	[kra**sc**a]	'wines'	GS
		z	/vi**zi**-a/	(> zj)	[vi**zɟ**a]	'breasts'	GS
		n	/ɣo**ni**-a/	(> nj)	[ɣo**ɲ**ːa]	'corner'	Pal

[15] As Newton (1972) does not provide the full set of forms for this dialect, some of the forms are adapted from his other dialect examples. Note the correspondences between his and the current IPA notation for palatals: <y k´ g´ n´ l´> = [j c ɟ ɲ ʎ]. It should be noted that Newton renders the common realization of the ɣ+j sequence in all dialects as [j] (<y>), which can be interpreted as ɣ-deletion. An acoustic study by Baltazani & Topintzi (2012), however, shows that the palatal fricative [ʝ] is a more accurate IPA realization of this sound (cf. Baltazani et al. 2016). Given this, the process is classified here as palatalization.

		l	/ski**li**-a/	(> lj)	[skiʎ:a]	‘dogs’	Pal
		r	/xo**ri**-a/	(> rj)	[xo**rɟ**a]	‘villages’	GS
c.	C=dorsal	k	/fi**ki**-a/	(> kj)	[fi**ʧ**a]	‘seaweed’	Pal
		x	/ni**xi**-a/	(> xj)	[ni**ʃ**a]	‘fingernails’	Pal
		ɣ	/tra**ɣi**-a/	(> ɣj)	[traʝa]	‘goats’	Pal

Another example is Udmurt, a Finno-Ugric language spoken in Russia. Kel’makov’s (1996) review of Udmurt dialects reveals at least 3 distinct types with respect to realization of C+j sequences (37). All the types show palatalization of anterior coronal noncontinuants and differ with respect to the presence, absence, or extent of palatal glide strengthening. Southwest dialects, for example, show glide strengthening after labials, velars, and /r/, as illustrated in (38). Coronal non-continuants are palatalized (and geminated), while the sequences of sibilant fricatives and /j/ are resolved by the deletion of the latter (accompanied by consonant gemination).

(37) General patterns of palatalization (Pal), glide strengthening (GS), deletion (Del), and no change (No) in C+j sequences in Udmurt dialects (adapted from Kel’makov 1996: 102-107).

	C = Lab	C = Cor			C = Dor
	/p b m/	/t d n/	/s z ʂ ʐ/	/r/	/k g/
Type 1 (Standard)	No	Pal	No	No	No
Type 2 (Southwest)	GS	Pal	j-Del	GS	GS
Type 3 (Kukmor)	GS	Pal	GS	GS	GS

(38) Sample data: Southwest dialects of Udmurt (adapted from Kel’makov 1996: 102-107).

a.	C=labial	p	/tulɤ**p**-**j**os/	[tulɤ**pc**os]	‘sheepskin coat’	GS
		b	/ʂa**b**-**j**anɤ/	[ʂa**bɟ**anɤ]	‘to scratch’	GS
		m	/e**m**-**j**aɲ/	[e**mɲ**aɲ]	‘to heal’	GS
b.	C=coronal	t	/pur**t**-**j**os/	[pur**c**:os]	‘knives’	Pal
		d	/ku**d**-**j**os/	[ku**ɟ**:os]	‘swamps’	Pal
		s	/pi**s**-**j**anɤ/	[pi**s**:anɤ]	‘to thread a needle’	j-Del
		z	/vu**z**-**j**os/	[vu**z**:os]	‘goods’	j-Del
		n	/puko**n**-**j**os/	[puko**ɲ**:os]	‘chairs’	Pal
		l	/sɨka**l**-**j**os/	[sɨka**ʎ**:os]	‘cows’	Pal
		r	/ʂu**r**-**j**os/	[ʂur**ʎ**os~ʂur**ʥ**os]	‘rivers’	GS
c.	C=dorsal	k	/ɕere**k**-**j**a/	[ɕere**kc**a]	‘(s/he) laughs’	GS
		g	/kure**g**-**j**os/	[kure**gɟ**os]	‘chickens’	GS
		ŋ	/ʂa**ŋ**-**j**os/	[ʂa**ŋɲ**os]	‘vats’	GS

The details of Greek and Udmurt patterns are in many ways different from those of Kirundi, as well as from each other. Nevertheless, they show some striking broad similarities, with glide strengthening applying in most or all contexts where palatalization fails to apply. In fact, with respect to this interaction, these patterns can be categorized as Type 3 and Type 4 (respectively) in the palatalization typology in (1). (Note that the remaining type, Type 2, is represented by the Kirundi heteromorphemic C+j data). Further, both Greek and Udmurt patterns can be easily captured by the set of constraints proposed for Kirundi. Specifically, the ranking of *Dor+pal, *n+pal, and *l+pal above Uniform-IO in the Kos dialect of Greek (39a) would trigger palatalization of dorsals and coronal non-rhotic sonorants, while the ranking of *Cor+pal and *Lab+pal between Uniform-IO and Agree[F]-CC would produce glide strengthening after labials and the remaining coronals (see Baltazani et al. 2016 for a somewhat different formal account of Greek dialect patterns). As in Greek, *Lab+pal in Udmurt (39b) is sandwiched between Uniform-IO and Agree[F]-CC, producing a similar pattern of post-labial glide strengthening. In contrast to Greek, however, the Udmurt grammar places *Cor+pal above Uniform-IO, while *Dor+pal below it, resulting in the palatalization of non-continuant coronals and the patterning of dorsals with labials. Recall that language-particular differences in rankings of *Cor+pal and *Dor+pal are expected by our analysis; at the same time, languages are expected to agree in the lower ranking of *Lab+pal, which is consistent with our data.

(39) Constraint rankings for selected Greek and Udmurt patterns.

a. The Kos dialect of Greek

Max-IO	»	*Dor+pal, *n+pal, *l+pal	»	**Uniform -IO**	»	*Cor+pal	»	*Lab+pal	Agree[F]-CC

b. The Southwest dialect of Udmurt

*Sib-pal	»	Max-IO	»	*Cor+pal	»	**Uniform -IO**	»	*Dor+pal, r-pal	»	*Lab+pal	Agree[F]-CC

The Greek and Udmurt cases of interactions of palatalization and glide strengthening are not isolated. Other examples, albeit with a much more limited extent of strengthening, are provided by Slavic languages. For example, in Russian and Serbian, the palatal glide /j/ strengthens after labials to [l^j] and [ʎ] respectively, while other C+j sequences undergo palatalization (the process known as 'iotation'; e.g. Boyd 1997 on Russian; Morén 2006 on Serbian). In Czech, /m/+/j/ sequences are realized as [mɲ], while sequences of most coronals with /j/ are palatalized (Boyd 1997). While Standard Polish maintains labial + /j/ sequences, the glide has strengthened in northeastern dialects to (alveolo)palatal fricatives and nasals that agree with the consonant in consonantality, sonorancy, voicing, and nasality: /p b f v m/+/j/ → [pɕ bʑ fɕ vʑ mɲ] (Dejna, 1993; Kochetov 1998; Czaplicki 2010; Rubach 2014). Strikingly similar, if not more extensive, patterns of glide strengthening after labials and palatalization elsewhere were also observed in Moldova Romanian (Udler 1976; Bateman 2010), and in the history of various Romance languages and dialects (Ohala 1978; Kawasaki 1982). Korean shows glide strengthening of /j/ to [ɲ] similar to Czech, but only across compound boundaries (Ahn 2008), reflecting the role of morphologically-sensitive faithfulness constraints. Some Bantu languages other than Kirundi have been noted to exhibit palatal glide strengthening after both labials and coronals, with dorsals being subject to palatalization (Ohala 1978; Bateman 2010). In sum, glide strengthening as an alternative to palatalization is more common than previously thought. In most cases, however, it is limited to post-labial contexts, where palatalization is less likely to apply. Therefore, cases like Kirundi, Greek, and Udmurt are particularly revealing.

Our analysis of palatal glide strengthening and place-changing palatalization as competing repair strategies, predicts a similar interaction between velar glide strengthening and place-changing velarization. Kirundi data, however, do not provide evidence for the latter, as C+w sequences are resolved exclusively by glide strengthening (or remain unchanged). The relevant pattern is demonstrated by another Bantu language, Ikalanga, as shown in (40). In this language, the labial stop + /w/ sequences (a) are resolved by velar glide strengthening (to [k^h] or [g]), while the labial sonorant + /w/ sequences (b) are resolved by place-changing velarization (Mathangwane 1996). In addition, the language uses palatalization to resolve C+j sequences, as shown in (c), regardless of the manner of the target consonant. Again, these patterns would naturally fall out from a constraint ranking of manner-specific markedness constraints with respect to Uniformity-IO and Agree[F]-CC, as shown in (41). Given this, the data from Ikalanga provide further support for our analysis of Kirundi and emphasize the relation among the processes of palatalization, velarization, and glide strengthening.

(40) Post-labial velar glide strengthening (a), velarization (b), and palatalization (c) in Ikalanga (adapted from Mathangwane 1996: 179-193; 127-132).

a. Labial obstruent	p	/li**p**-**w**a/	[lip**k**^{h}a]	'get paid'	GS
+ w		/la**p**-**w**a/	[lap**k**^{h}a]	'get cured'	
	b	/n-t̪um**bu**-ana/ (>bw)	[n̪tum**bg**ana]	'small stomach'	GS
b. Labial sonorant	ʋ	/lo**ʋ**-**w**a/	[lo**g**^{w}a]	'be beaten'	Vel
+ w		/lu-zi**ʋo**-ana/ (>ʋw)	[luzi**g**^{w}ana]	'small knowledge'	
	m	/bo**m**-**w**a/	[boŋ^{w}a]	'be smeared'	Vel
		/ʃa**mu**-ana/ (>mw)	[ʃaŋ^{w}ana]	'small lash'	
c. Labial + j	p	/ko**pi**-ana/ (>pj)	[ko**ʦ**^{hw}ana]	'small cup'	Pal
	b	/N-kom**be**-ana/ (>bj)	[ŋkon**ʣ**^{w}ana]	'small water vessel'	Pal
	ʋ	/ze**ʋe**-ana/ (>bj)	[ze**ʣ**^{w}ana]	'small ear'	Pal
	m	/se**me**-ana/ (>mj)	[seɲana]	'small basket'	Pal

(41) Constraint rankings for the Ikalanga Labial + w/j patterns.

*LabSon+vel, *Lab+pal » **Uniform-IO** » *LabObs+vel » Agree[F]-CC

4.2 Other alternatives to palatalization

The focus of this paper has been on palatal glide strengthening as an alternative to palatalization. Our analysis, however, also predicts other resolution strategies, such as deletion, epenthesis, and metathesis (see (2) and Section 2.2). Do we have any evidence for these strategies to compete with palatalization? Kirundi data provided a few examples of consonant deletion involving rhotic + j sequences. Additional cases of consonant deletion are exhibited by Greek dialects (also involving /r/). Glide deletion is also shown by some Greek and Udmurt dialects (with both cases involving sibilant fricatives). In all these cases deletion is restricted to specific manners of articulation. A more general application of the process is presented by English, where /j/ has historically deleted after coronals regardless of their manner (e.g. in General American; in *tune, dune, new, suit, lewd*; Wells 1982: 247) and, in some dialects, after all consonants (e.g. in *beauty,* *few, music, cube, Hugh*; East Anglia English: Trudgill 2008: 191; African-American Vernacular English: Bailey & Thomas 1998).

Another repair strategy, vowel epenthesis, is commonly used in loanword adaptation. For example, English labial or velar + [ju] sequences are adapted in Shona with an epenthetic vowel: [bʱi.ju.ti] 'beauty', [fi.ju.ʧa] 'future', [vʱi.ju] 'view', [ki.ju.va] 'cure'. In contrast, the coronal + [ju] sequences (which are in British English realized as [tju], [dju], and [nju]) are resolved in adaptation through palatalization: [ʧu.bʱu] 'tube', [ʤu.ti] 'duty', and [ɲu.zi] 'news' (Uffmann 2007: 67). Interestingly, English itself uses vowel epenthesis when adapting phonotactically illicit C+j sequences, as for example in [si.ɛ.ɹə] 'Sierra (Nevada) (Spanish [sje.ra] 'mountain range') and Kyoto [ki.ow.ɾow] (Japanese [kjoː.toː]). Less common appears to be consonant epenthesis. An example of this process is provided by Slovenian, where labial + /j/ sequences are synchronically resolved by an insertion of /l/ ([pj], [bj], [mj] → [plj], [blj], [mlj]; Peter Jurgec, p.c.). This process corresponds to post-labial glide strengthening in other Slavic languages.

Finally, the metathesis of consonants and glides has been attested in a number of languages, as for example in Ancient Greek *[morja] > [moira] 'lot' and Kota (Dravidian) [kuːp-j] → [kuːjp] 'blow with breath' (Semiloff-Zelasko 1973). One particularly interesting case is presented by Dhivehi (Indo-Aryan), where metathesis is employed to resolve heteromorphemic sequences of labials and velars + /j/ (42a), while the corresponding sequences with coronals (42b) are resolved by palatalization (Cain 2000; Arsenault 2009). Both processes are accompanied by consonant gemination, which presents a peculiar parallel with Udmurt. The use of gemination in both languages may not be coincidental, as this process may be yet another alternative strategy to repair C+j sequences (see Bethin 1992 on Ukrainian; Kaminskaïa 2002 on Belarusian; Harbert 2007: 74-75, Hall & Hamann 2010 on West Germanic).

(42) Metathesis and palatalization in Dhivehi indefinite noun forms (Cain 2000; Arsenault 2009).

a.	Labial + /j/	/loo**bi-j**ek/	[loː**jb**ːek]	'a love'
	Dorsal + /j/	/bo**ki-j**ek/	[bo**jk**ːek]	'a bulb'
b.	Coronal + /j/	/e**ti-j**ek/	[e**ʧ**ːek]	'a thing'

In sum, palatalization and glide strengthening are only two of several possible ways to resolve the marked C+j structure, and all these strategies are attested in world languages. The table in (43) lists possible strategies to resolve *labial* + /j/ sequences (repeated from (2)), together with schematic examples, the proposed constraint rankings, and sample languages. The table does not reflect, however, an important finding that languages often use more than one strategy to resolve C+j sequences, depending on the morphological context or place/manner of the target consonant.

(43) Possible strategies to resolve C+j sequences

	Strategy	*Schematic examples*	*Ranking*	*Language*
a.	palatalization	pja → ʧa, mja → ɲa	*C+pal » Uniform-IO	e.g. Ikalanga
b.	glide strengthening	pja → pca, mja → mɲa	*C+pal » Uniform-IO, Agree[F]-CC	e.g. Udmurt
c.	deletion	pja → pa, mja → ma	*C+pal » Max-IO	e.g. E. Anglia English
d.	epenthesis	pja → pija, mja → mija	*C+pal » Dep-IO	e.g. Shona
e.	metathesis	apja → ajpa, amja → ajma	*C+pal » Lin-IO	e.g. Dhivehi

A question that remains to be addressed is why some strategies are cross-linguistically more likely than others. Thus, palatalization appears to be a much more common way to resolve C+j sequences than, for example, glide strengthening and metathesis. Another issue concerns the place and manner preferences or implicational relations for specific strategies. While place-changing palatalization tends to avoid labials, palatal glide strengthening targets predominantly labials. In other words, palatalization of labials implies palatalization of coronals and dorsals, while glide strengthening after coronals or dorsals implies glide strengthening after labials. Similar preferences for non-coronal targets appear to be shown by epenthesis, metathesis, and deletion, although more data are needed to confirm this observation. While it is not possible to make strong statements about manner-specific preferences in palatalization (Bateman 2007), coronal nasals appear to be a more likely target of this process, and the least likely target of glide strengthening. Manner of articulation differences also seem to influence the choice of consonant or glide deletion processes. It appears that relative likelihood or specific strategies and their place/manner preferences are based to a large degree on articulatory and perceptual factors, many of which are still to be uncovered.

Another outstanding is the treatment of palatalization and related processes that are not triggered by a glide (e.g. g+i → ʤi). The following section outlines some exploratory ideas on how this can be done within the proposed framework.

4.3 The families of C+pal/vel constraints

Recall that our analysis assumed a fairly general markedness constraint *C+pal (albeit parametrized by the consonant place and manner), prohibiting all sequences of a consonant with a palatal glide, a palatal consonant, or a front vowel. This constraint, however, can be conceived as a cover term for a family of constraints referring to various kinds of palatal segments, as sketched out in (44). One important distinction within this family of constraints is between those with non-syllabic (a) and syllabic triggers (b). The first class includes the constraints most relevant for the current analysis: the more general *C+pal[-syllabic] (avoid C + j, ɲ, ç, c, etc.) in (i) and the more specific *C+pal[-syllabic, -consonantal] (avoid C + j) in (ii). The two constraints are crucially ranked, producing a greater avoidance of C+j sequences compared to sequences with palatal non-syllabic segments in general (iii). The phonetic motivation for this relative markedness relation is the lesser phonetic difficulty of sequences with consonantal palatals compared to those with the palatal glide. First, consonantal gestures are characterized by a greater degree of constriction and a shorter time span compared to the vocalic gestures, including glides (Browman & Goldstein 1992). This results in lesser gestural overlap, and thus milder coarticulatory effects on adjacent consonants and vowels (Recasens 1999). Second, the fricative noise or silence of the stop closure of the strengthened glide temporally delay the CV transitions (see Figure A1 in the Appendix), thus eliminating the particularly perceptually confusing aspect of the C+j sequences. It should be noted that the proposed trigger markedness relation in (a, iii) is parallel to the well-established differences among non-syllabic triggers: high front vowels are the best triggers of palatalization, followed by mid front vowels, and then by low front vowels (i.e. i > e > æ; Bhat 1978, among others). In the current analysis, these differences follow from a crucial ranking of markedness constraints on sequences of consonants and front vowels parametrized by height (44b).

(44) A family of *C+pal constraints
  a. With non-syllabic triggers
    i. *C+pal[–syll]: Avoid sequences of consonants and palatal consonants/glides (i.e.*C + j, ɲ, ç, c).
    ii. *C+pal[–syll, –cons]: Avoid sequences of consonants and palatal glides (i.e.*C + j).
    iii. *C+pal[–syll, –cons] » *C+pal[–syll]
  b. With syllabic triggers
    i. *C+pal[+syll, –bk]: Avoid sequences of consonants and front vowels (i.e.*C + i, e, æ).
    ii. *C+pal[+syll, –bk, –lo]: Avoid sequences of consonants and non-low front vowels (i.e.*C + i, e).
    iii. *C+pal[+syll, –bk, –lo, +hi]: Avoid sequences of consonants and high (non-low) front vowels (i.e.*C + i).
    iv. *C+pal[+syll, –bk, –lo, +hi] » *C+pal[+syll, –bk, –lo] » *C+pal[+syll, –bk]

For the purposes of our analysis of Kirundi patterns, this means that the original constraint C+pal (see (8)) is now split into two, *C+pal[–syll, –cons] and *C+pal[–syll], and each of those is parametrized by place of articulation and, if necessary, by manner. The following tableaux illustrate the revised analysis of heteromorphemic m+j and n+j sequences. As seen in (45), the higher-ranked *Lab+pal[–syll, –cons] assigns a fatal violation to the faithful candidate (a), while sparing the glide-strengthening candidate (c). The lower-ranked *Lab+pal[–syll] assigns violations to both of them. (The palatalized candidate (b) is ruled out by the highly-ranked Uniformity-IO, as in the prior analysis.) As seen in (46), Uniformity-IO is ranked below the segment-specific markedness constraints *n+pal[–syll,–cons] and *n+pal[–syll], and thus lets the latter two constraints determine the outcome. Clearly, the winning candidate [amɲa] is not the most optimal with respect to the *C-pal constraints, yet it presents a markedness improvement over the faithful candidate [amja]. The choice of candidates that do not violate *C-pal (e.g. [amna] or [amma]) is presumably blocked in Kirundi by [Place] faithfulness constraints (not shown here; see footnote 11). A non-palatal segment, however, can be a feasible outcome of glide strengthening in other languages. In the Kalimnos dialect of Greek, for example, the strengthened palatal glide is realized as the non-palatal [s] or [z] after obstruents and /r/ (Newton 1972: 167), instead of the usual [ç/c] and [ʝ/ɟ] in related dialects. Similarly, in the Cyprus dialect the strengthened /j/ is realized as [k] after /r/, while appearing as [c] in all other contexts (Newton 1972: 167; Hall & Hamann 2010).

(45) Post-consonantal glide strengthening in the /m/+/j/ sequence (revised; see (16)).

	/am$_1$-j$_2$a/	Uniform -IO	*Lab+pal [–syll, –cons]	*Lab+pal [–syll]	Agree[F] -CC
a.	am$_1$j$_2$a		*!	*	**
b.	aɲ$_{1,2}$ a	*!			
c.	☞ amɲa			*	

(46) Palatalization in the /n/+/j/ sequence (revised; see (25)).

	/an$_1$-j$_2$a/	*n+pal [–syll,–cons]	*n+pal [–syll]	Uniform -IO	Agree[F] -CC
a.	an$_1$ʝ$_2$a	*!	*		**
b.	☞ aɲ$_{1,2}$ a			*	
c.	anɲa		*!		

Note that the winning candidate (c) in (45) agrees with the preceding segment in all features other than [Place], including the feature [continuant]. Recall, however, that the strengthened fricative + j sequences in Kirundi showed no agreement in the latter feature, prompting us to formulate the Agree[F]-CC constraint accordingly (see (15)). This lack of agreement, however, could be due to preference for non-continuant palatal outputs, resulting from a more refined set of *C+pal[–syll] constraints (e.g. *C+pal[–syll, +cont] » *C+pal[–syll]). Interestingly, the lack of agreement in continuancy (combined with agreement in other features) is attested in the realization of obstruent + j sequences in other languages. In these cases, the strengthened glide is either a fricative [ç ʝ]/[ɕ ʑ] or a stop [c ɟ], regardless of the manner of articulation (stop or fricative) of the preceding segment (e.g. Polish dialects: Dejna, 1993; Standard Greek and dialects: Newton 1972, Baltazani et al. 2016). The realization of these segments in some cases is further complicated by language-particular syllable structure restrictions and phonemic status considerations (see Rubach's 2014 use of the constraint Sonority Sequencing Generalization to account for the palatal outputs in the Kurpian dialect of Polish). Clearly, a more nuanced analysis of the featural composition of the strengthened palatal glide in Kirundi is required.

The refinement of *C+pal constraints in (44) presupposes a similar approach to the originally proposed *C+vel constraint. This would result, specifically, in the distinction between and the crucial ranking of the C+vel[–syll, –cons] and *C+vel[–syll] constraints relevant for our analysis of Kirundi velar glide strengthening (see Section 3.2). The tableau in (47) shows a revised analysis of m+w, with *Lab+vel[–syll, –cons] and *Lab+vel[–syll] showing their preference for the glide strengthening candidate.

(47) Post-consonantal glide strengthening in the /m/+/w/ sequence (revised; see (31); cf. (45)).

	/am$_1$-w$_2$a/	Uniform -IO	*Lab+vel [–syll, –cons]	*Lab+vel [–syll]	Agree[F] -CC
a.	am$_1$w$_2$a		*!	*	**
b.	aŋ$_{1,2}$^{w}a	*!			
c.	☞ am$_1$ŋ$_2$a			*	

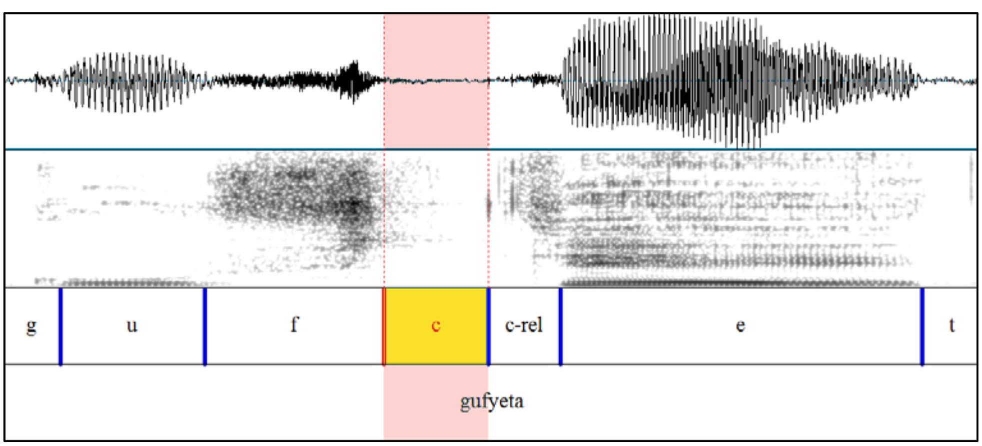
As palatalization in Kirundi is triggered almost exclusively by the palatal glide, our analysis and related predictions have been focused on C+j sequences. Yet, we know that front vowels, and particularly /i/, are as common triggers of palatalization as /j/ (Bhat 1978; Bateman 2007; Kochetov 2011). This is in fact predicted by our formulation of the *C+pal family of constraints in (44). The typology of resolving C+i, C+e, and C+æ sequences, however, is likely to be somewhat different from the C+j sequences. For example, palatalization of a consonant before /i/ rarely results in a merger of the two segments; rather, the consonant palatalizes, while the vowel remains intact. These sequences are also rarely resolved by strengthening (or insertion) of a palatal element (but see Mazovian Polish /pivo/ → [pçivo]~[pɕivo] 'beer'; Dejna, 1993), while being frequently a subject to a phonetically related process of stop assibilation (Hall & Hamann 2006). Another possible way to resolve C + front vowel sequences is to back (or lower) the vowel, as for example after certain consonants in Russian (/i/ → [ɨ]/$C_{[+bk]}$__; Rubach 2000) and Kashaya (/i/ → [u]/d__; Buckley 2000; Collins & Krämer, to appear). Interestingly, the latter work proposes a treatment of the Kashaya 'anti-palatalization' and similar CV interactions in other languages as arising from a constraint interaction mechanism similar to the one proposed here for C+j sequences. Future work should attempt a systematic typological investigation and a formal analysis of C + front vowel sequences.

5 Conclusion

To conclude, this paper argued for a view of palatalization as one of several possible strategies to avoid a marked phonotactic structure (*C+pal). Data from Kirundi provided evidence for this approach, as palatalization in this language closely interacts with palatal glide strengthening, which, in turn, is part of a more general pattern of avoiding consonant + glide sequences. The OT analysis of the Kirundi patterns captured some important aspects of this interaction, making testable predictions about the typology of consonant + glide sequences. The focus on contextual markedness as a trigger of palatalization does not necessarily eliminate the need for a closer study of feature mappings between palatalization triggers and targets. This, in fact, should be the next step to a more complete analysis of segmental alternations in Kirundi. Equally important would be a comprehensive acoustic and articulatory investigation of strengthened glides in the language. Altogether, this phonological and phonetic work is expected to contribute to our better understanding of the underlying mechanisms of consonant and vowel/glide interactions.

Appendix

a.



b.

c.

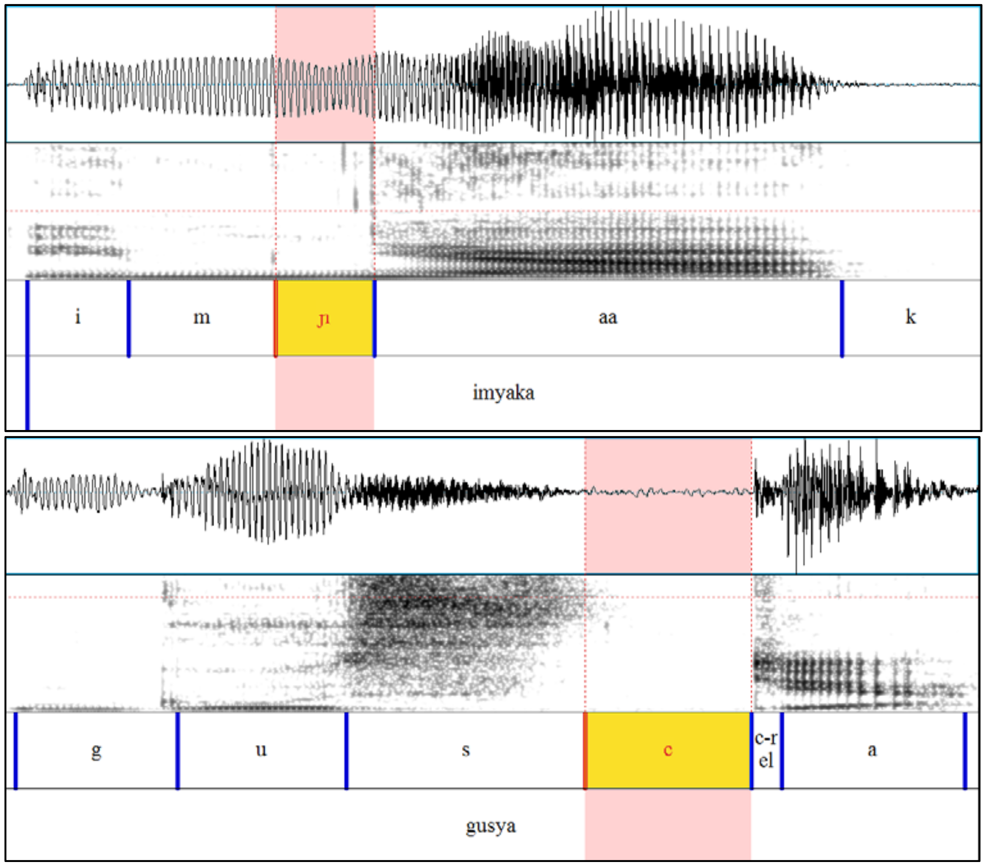
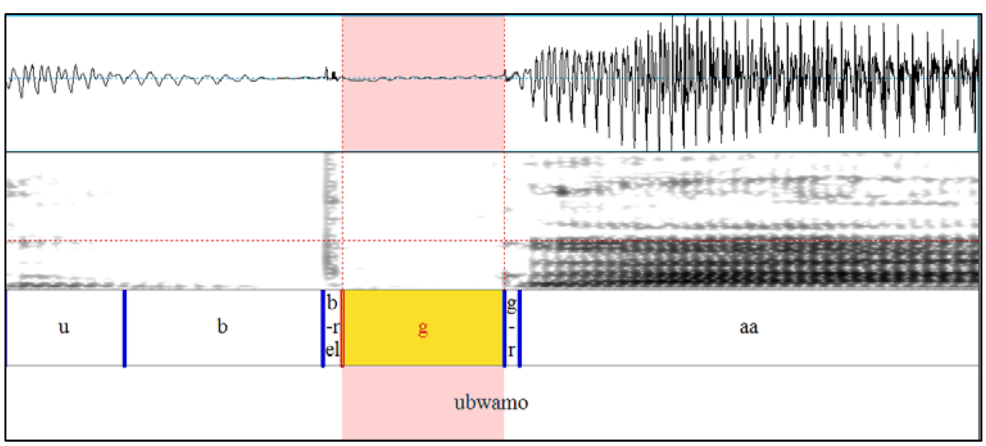


Figure A1. Sample spectrograms from Kochetov et al. (2013) showing glide strengthening in the words (a) *gufyeta* /ku-fjeta/ [gufceta] 'to lick', (b) *imyaka* /imi-aaka/ [imɲaːka] 'years', and (c) *gusya* /ku-se-a/ [gusca] 'to grind'. The closure of the strengthened glide is highlighted; c-rel = the release of [c]. The spectrogram frequency scale is 0-15,000 Hz.

a.



b.

c.

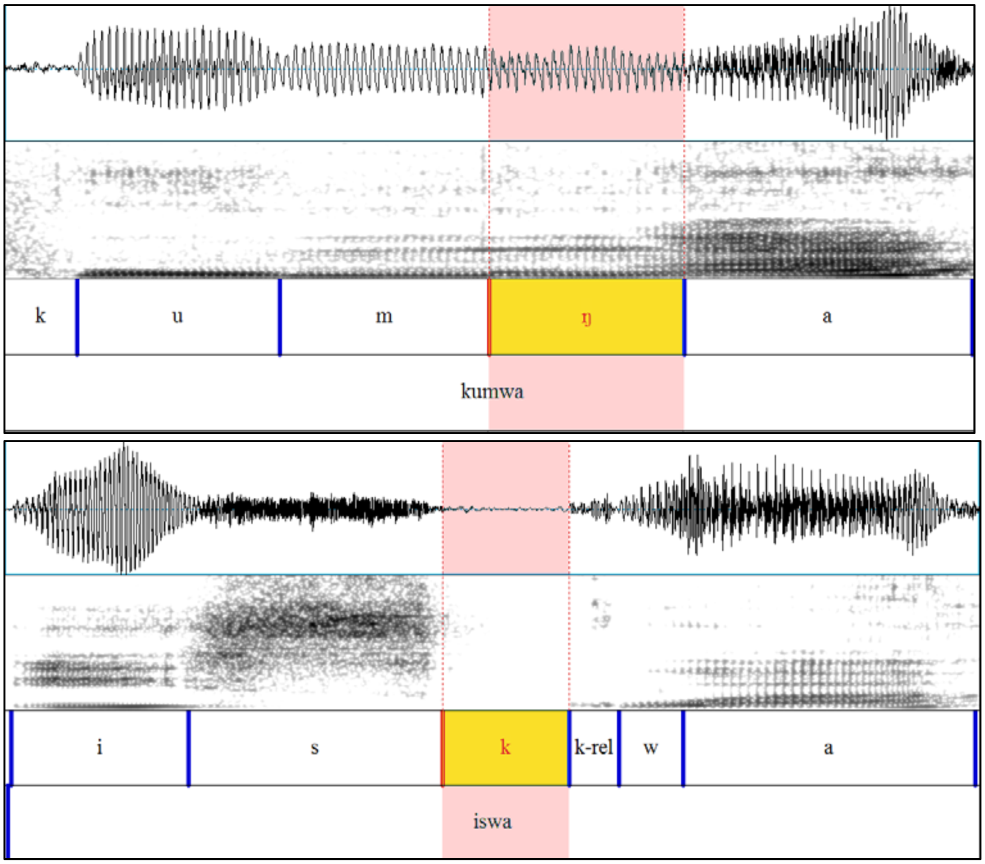


Figure A2. Sample spectrograms from Kochetov et al. (2013) showing glide strengthening in the words (a) *ubwamo* /ubu-aam-o/ [ubgaːmo] 'source', (b) *kumwa* /ku-mo-w-a/ [kumŋa] 'to cut hair', and (c) *iswa* /i-swa/ [iskwa] 'termite'. The closure of the strengthened glide is highlighted; b-rel, g-rel, and k-rel are the stop releases of [b], [g], and [k]. The spectrogram frequency scale is 0-15,000 Hz.

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