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NC Effects in olumarama phonology

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Abstract
A nasal consonant (NC) sequence, in most languages, will trigger a range of repair mechanisms because it is considered marked phonetically. Rule based theoretical models that account for *NC effects focus on how phonological rules condition morphological structures. This means that linguistic incursion in the role played by syllable phonotactics in the simultaneity of some processes is given minimal prominence. In this regard, Optimality Theory offers a better model because it licenses the multiplicity of the phonological processes through its principle of global constraint interaction. Studies of *NC effects have shown that there are similarities and differences in how languages resolve NC sequences. This paper argues that through constraint interaction, phonological processes used to resolve NC patterns in Olumarama can be adequately described. The analysis of data from Olumarama confirms that the language has its own rich set of constraints that determines repair mechanisms for the marked NC sequence.

Keywords: onset, cluster, constraint, markedness, faithfulness

Introduction

*NC Effects is the summative term for the whole process of repairing nasal consonant sequence that is considered phonologically marked in most languages (Hyman, 2003) [5]. Most languages have restrictions on the occurrence of a nasal consonant cluster with each language employing its own repair mechanisms through the application of various phonological processes (Hyman, 2003; de Lacy, 2007; Pater, 1999, 2001; Nandelenga, 2013, 2014) [5, 1, 19, 20, 13, 14]. Among Bantu languages, the phonological process of voice assimilation changes voiceless consonants to voiced [ND], deletion targets either the nasal to form the output consonant structure [T] or the obstruents to remain with the structure [D] while a nasal glide sequence remains unchanged. Hyman (2001: 154) [4] similarly uses these abbreviations and others to express the following:

Abbreviations and their meaning (Hyman, 2001: 154) [4] (1)

N = nasal consonant	S = voiceless fricative
C = oral obstruent	Z = voiced fricative
T = voiceless stop	TS = voiceless affricate
D = voiced stop	DZ = voiced affricate

A study of various *NC effects typology shows that a sequence of a nasal followed by a voiceless consonant is phonologically marked and is repaired through the process of post-nasal voicing. In Kuria (Odden, 2013) [15], a nasal approximant sequence undergoes the process of post-nasal voicing to surface as a voiced stop as shown in the following example:

Kuria Post-nasal Hardening (Odden, 2013: 9) [15] (2)

Input	Gloss	Output	Gloss
i) /oko-r̲émérǎ/	'to farm for'	[okoó-n̲-d̲émerá]	'to farm for me'
ii) /oko-j̲έsέrǎ/	'to pluck for'	[okoó-ɲ̲-g̲έsεrá]	'to pluck for me'
iii) /uku-β̲úúrjá/	'to ask'	[ukuú-m̲-b̲uurjá]	'to ask me'

The voiced segments [b d g] in (2) are as a result of post-nasal voicing from the voiceless consonants [r, j, β] which are preceded by the nasals [n, ɲ, m] respectively. ND only occurs when T is a voiceless stop but in the case where it is a voiceless fricative then the phonological process of deletion takes place. In deletion, the nasal is deleted leaving the obstruent intact. Odden (2005) [16] and Nandelenga (2013, 2014) [13, 14] describe the phonological process of deletion in Olubukusu (a Bantu language in Kenya) where output forms from underlying structures lack the nasal prefix while the fricative surfaces meaning that the process deletes the nasal but leaves the fricative intact. The process of post-nasal hardening changes weak obstruents into prenasalized stops shown in the following example.

Lubukusu typology of *NC effects (Nandelenga, 2014: 46) [14] (3)

	Input	Output	Gloss	Repair mechanism
(a)	/N-texa/	[nde:xa]	'I boil'	Place assimilation & post-nasal voicing.
(b)	/N-fuka/	[fuka]	'I cook'	Nasal deletion.
(c)	/N- βala/	[mba.la]	'I count'	Place assimilation & post-nasal hardening.
(d)	/N-lima/	[ndi.ma]	'I cultivate'	Place assimilation & post-nasal hardening.
(e)	/N- nala/	[n̩ .na.la]	'I get used'	Formation of syllabic nasals.

This paper, therefore, investigates how the language treats nasal consonant onset clusters in terms of the repair mechanisms that it employs. The role played by the language's syllable structure in determining phonological processes is also examined. Lastly, this paper examines the markedness and faithfulness constraints that are relevant in examining Olumarama data. This paper adopts an Optimality Theory (OT) account as its premise of language particular ranking of universal constraints can account for the phonological processes in NC sequences in Olumarama.

Table 1: Olumarama Syllable Structure

	Bilabial	Labio-dental	Alveolar	Palato-alveolar	Palatal	Velar
Stops	p		t		c	k
Fricatives	β	f	s	ʃ		x
Nasals	m		n		ɲ	ŋ
Liquids			l, r			
Glides					j	w
Affricates			ʦ			
Pre-nasal	^{m}b		^{n}d, ^{n}z		^{ɲ}ɟ	^{ŋ}g

Olumarama is among the eighteen dialects of Luhya (Kanyoro, 1983) [7]. The few studies that have been carried out in Olumarama have focused on the language's phonemic inventory and some aspects of its morphophonology (Ebarb & Marlo, 2015) [2]. Since consonants and by extension, the syllable structure, are at the centre of *NC effects, the following table is a representation of the phonemic inventory of Olumarama consonants.

Olumarama Consonants (Kanyoro, 1983) [7] (4)
Due to lack of any study carried out on Olumarama syllable structure, a study of the language's syllable structure will compare with studies in other Luhya dialects. Olumarama, like the other Luhya dialects, has the basic (CCV, CV, V) syllable structures (Oluoch, 2003; Nandelenga, 2013; Ondondo, 2013) [17, 13, 18]. The Olumarama syllable structures are described in the following examples.

The CV(V) Syllable Structure (5)

	Input	Output		Gloss
(i)	/βa/	[βa]	CV	'be!'
(ii)	/lay-a/	[la.ya]	CV.CV	'praise'
(iii)	/e-li-i-ra/	[e.li:.ra]	V.CVV.CV	'name'

In the Consonant Vowel (long vowel) CV (V) Syllable Structure in (5), consonants occupy the onset position while the vowels fill the nucleus. The nucleus can be occupied by either the short vowel as shown in (i) and (ii) resulting in the syllable structure CV or the long vowel in (iii) leading to the CV (V) syllable structure. The CV (V) syllable structure can occur in word initial, word medial and word final positions.

The CCV (V) Syllable Structure (6)

Input	Output	Gloss
(i) /sjo:.m-a/	[sjo:.ma] CCVV.CV	'threaten'
(ii) /o-.βu-.sj-e/	[o.βu.sje] V.CV.CCV	'flour'
(iii) /βwa:.n-a/	[βwa:.na] CCVV.CV	'light'
(iv) /swa:.k-a/	[swa:.ka] CCVV.CV	'hit'

The Olumarama Consonant Vowel (long vowel) CCV (V) syllable structure as shown in (6) has a consonant-glide cluster, the only one permitted in Olumarama onsets. The glides are the labio-velar glide [w] and the palatal glide [j]. As shown in examples in (6 (i, iii, iv)) the root vowel lengthens when preceded by a consonant-glide sequence. The vowel sequence in (6 (ii)) also undergoes glide formation though the root vowel does not lengthen. This syllable structure is found in all word positions. Onsetless syllables occur in both word initial and word medial positions as shown in the following data:

The V (V) Syllable Structure (7)

Input	Output	Gloss
(i) /a.βo/	[a.βo] V.CV	'them'
(ii) /i.ri:.r-a/	[i.ri:.ra] V.CV:.CV]	'snore'
(iii) /o-.mu-.a.n-i./	[o.mu.a.ni] V.CV.V.CV	'giver'
(iv) /a:.^{m}bi/	[a:.^{m}bi] VV.CV	'near'

The Vowel (long vowel) V (V) syllable structure in Olumarama as shown in (7) has no onset. It is evident that the words have onsetless syllables, vowels occupying the position of syllable nucleus. The nucleus can either be occupied by a single vowel resulting in the V syllable structures in (i, ii, iii) or by a long vowel as shown in (iv) leading to the formation of the V (V) syllable structure. Similarly, this syllable type can be found in word initial (i, ii, iv) and word final (iii) positions.

3. NC Effects in Olumarama

This section examines the phonological processes that repair marked structures and the markedness and faithfulness constraints that are relevant in examining Olumarama data. The viability of Optimality Theory is also tested based on its premise of language particular ranking of universal constraints which should be able to account for the phonological processes triggered by NC sequences in Olumarama.

An onset nasal consonant sequence occurs when a nasal and a consonant combine at the beginning of a stem (Odden, 2013) [15]. This cluster is prohibited in most Niger-Congo languages (Hyman, 2003) [5] and therefore, various processes generally referred to as the *NC effects are set in motion to repair this condition. Repair mechanisms such as post-nasal hardening, place assimilation, deletion and post-nasal voicing are some of the phonological processes that repair the ill formed structures. From the data, the only nasal consonant sequence allowed is the nasal glide sequence as shown in the following example.

Nasal Glide Sequence in Olumarama (8)

Input	Output	Gloss
(i)/o-mu- + ana/	[o.mwa:.na]	'a child'
(ii)/si- + ɛnene/	[sjɛ:.ɲe.ne]	'I alone'

From the data in (8) it is evident that a sequence of a nasal followed by a glide is acceptable in the language. The relevant constraints in the construction of a tableau include *NC, CODA, DEP-IO and UNIFORMITY as represented in the following tableau.

/o-m_1u_2-ana/ ⟶ [o.m_1w_2a:.na] 'a child' (9)

Table 2

/o-m$_1$u$_2$-ana/	*NÇ	*Coda	DEP IO	Unif Io
a) ☞[o.m$_1$w$_2$a:.na]				*
b) [o.m$_1$t$_2$a:.na]	*!			
c) [om$_1$.w$_2$a:.na]		*!		
d) [o.m$_1$i.w $_2$a:.na			*!	

From tableau (9) the two glides used are the labio-velar glide [w], and the palatal glide [j]. The two glides can follow nasals without any need for repair. Any other NC sequence, such as NT sequence as shown in (b) will undergo repair to conform to the phonotactics of the language.

3.1 Nasal + Voiceless Stops

Olumarama has four voiceless stops; the labial stop [p], the alveolar stop [t], the palatal stop [c] and the velar stop [k]. As the following data show, a combination of a nasal and a voiceless stop is prohibited in the language and this is repaired through the phonological processes of voice and place assimilation. The nasal will share the same place of articulation as the voiceless stop while the stop acquires the voiced feature of the nasal as shown in the following data.

Formation of Voiced Prenasalized Bilabial Stops (10)

Input	Output	Gloss
(i)/e<u>N</u>-<u>p</u>epet-a/	[e-^{m}<u>b</u>epet-a]	'I juggle'
(ii)/e<u>N</u>-<u>t</u>o:l-a/	[e-^{n}<u>d</u>o:l-a]	'I pick'
(iii)/e<u>N</u>-<u>c</u>a:k-a/	[e-^{ɲ}<u>ɟ</u>a:k-a]	'I start'
(iv)/e<u>N</u>-<u>k</u>o:ɲ-a/	[e-^{ŋ}<u>g</u>o:ɲ-a]	'I taste'

In the data (10), both place and voice assimilation occurs when a nasal prefix is followed by a voiceless stop. This shows the general rule that nasals tend to assimilate their place feature from that of the following consonant. Concurrently, the voiceless bilabial also assimilates the voice feature [+voice] of the nasal with the resulting nasal cluster being voiced prenasalized stops.

The optimal surface output of the nasal plus voiceless stop sequence can be described in OT terms through the interaction of various faithfulness and markedness constraints that can account for the structural and featural changes. In articulatory phonetics, the *NÇ constraint leads to post-nasal voicing. As a sound changes from a nasal into an obstruent, there is almost complete cutting off of air; however, the raising of the velum is slow to the extent that some air escapes to the nasal cavity leading to the voicing (Kager, 1999:61) [6]. Since no optimal output can emerge intact with a nasal plus a voiceless stop sequence, the constraint *NÇ is undominated in the Olumarama constraint hierarchy. The constraint *CODA requires that syllables must not end in coda consonants and since Olumarama has open syllables only, this constraint is also undominated and its violation by a candidate is fatal.

The coalescence of input segments violates the correspondence constraint UNIFORMITY-IO which states that no element in the input should have multiple correspondents in the output thus an anti-coalescence constraint (Kager, 1999) [6]. Since the violation of this constraint is necessary for the well-formedness of the onset sequence in Olumarama, the constraint is lowly ranked. This constraint will, therefore, rank below both the *NÇ and *CODA constraints that are undominated. The three constraints will yield the following constraint hierarchy: *NÇ, *CODA >> UNIFORMITY-IO, and this is represented in the following tableau.

/e<u>N</u>$_1$ + <u>t</u>$_2$oo.la/ ⟶ [e.^{n}<u>d</u>$_{1,\,2}$oo.la] 'I pick' (11)

Table 3

/eN$_1$-t$_2$oo.la/	*Nç	*coda	Unif-io
a) ☞[e.^{n}d$_{1,2}$oo.la]			*
b) [e.n$_1$t$_2$oo.la]	*!		
c) [en$_1$.t$_2$oo.la]		*!	

Candidate (11 (a)) is the optimal candidate since it undergoes coalescence to avoid a nasal consonant sequence. Candidate (b) fails to resolve *NÇ by retaining a sequence of a nasal and the voiceless stop while candidate (c) ends in a coda consonant thereby incurring a fatal violation.

The optimal output sequence is voiced meaning that the voiceless stop has acquired the voicing feature [+voice] from the nasal. The constraint IDENT-IO$_{VOICE}$ that ensures values of voice in the input are preserved in the output is, however, lowly ranked in the language since its violation enables voice assimilation in the output of the optimal candidate to occur. The voiceless stop is supposed to retain the value [-Nasal] in its output, however, the oral sound acquires the plus [+Nasal] feature of the nasal leading to lack of correspondence between input and output for the value [nasal]. The constraint IDENT-IO$_{NASAL}$ is, therefore, also violated though it is ranked lowly in Olumarama as attested in the optimal output.

The constraint that encourages the retention of input vowels for ease of articulation is the constraint MAX-IO$_{VOWEL}$ which is manifested in the output of the optimal candidate in Olumarama and it ranks above IDENT-IO and UNIFORMITY-IO constraints. The interaction of these constraints in evaluating the outputs of a nasal-voiceless stop interaction can be represented as follows in the constraint hierarchy: *NÇ, *CODA >> MAX-IO$_{VOWEL}$ >> IDENT-IO$_{NASAL}$, IDENT-IO$_{VOICE}$, UNIFORMITY-IO as shown in the following tableau.

/e<u>N</u>$_1$ + <u>t</u>$_2$oo.la/ ⟶ [e.^{n}<u>d</u>$_{1,2}$oo.la] 'I pick' (12)

Table 4

/eN$_1$-t$_2$oo.la/	*NÇ	*Coda	Max Io$_v$	Ident I-o$_{nas}$	Identi-o$_{voi}$	Unifio
a)☞[e.^{n}d$_{1,2}$oo.la]				*	*	*
b) [e.n$_1$t$_2$oo.la]	*!					
c) [en$_1$.t$_2$oo.la]		*!				
d) [^{n}d$_{1,2}$oo.la]			*!	*	*	*

Candidate (12 (a)) is the optimal candidate since the violation of the low ranked constraints is necessary for the repair processes of voice and place assimilation to occur. Candidate (d) could have been wrongly declared as the optimal candidate but it violates the anti-vowel deletion constraint MAX-IO$_V$. This shows that the preservation of vowel inputs in the output is important for the identification of the correct optimal output.

The function GEN can also produce [e.too.la] deleting the nasal and [e.ni.too.la] inserting another vowel to avoid the marked sequence. The two are sub-optimal candidates, however, this does not accurately represent the language and, therefore, the constraints that rule them out must be identified. In this case the constraint that rules [e.t$_2$oo.la] out is the faithfulness anti-deletion constraint [MAX-IO]. This is because the nasal segment /n/ is deleted in the output structure. On the other hand, the anti-insertion constraint [DEP-IO] rules out the last candidate [e.n$_1$i.t$_2$oo.la] due to the insertion of the epenthetic segment /i/. The optimal candidate does not violate these constraints meaning that for the candidate to emerge as the winner, the constraints should rank above the IDENT-IO family of constraints. With the above observation, the constraint hierarchy for a nasal plus voiceless stop sequence can be proposed as: *NÇ̥, *CODA >> MAX-IO$_V$ >> MAX-IO, DEP-IO >> IDENT-IO$_{NAS}$, IDENT-IO$_{VOI}$ as shown in the following tableau.

/e<u>N</u>$_1$ + <u>t</u>$_2$oo.la/ ⟶ [e.^{n}<u>d</u>$_{1,2}$oo.la] 'I pick' (13)

Table 5

	*NÇ̥	*Coda	Max Io$_v$	Max I-o	Dep I-o	Ident I-o$_{nas}$	Ident I-o$_{voi}$
a)☞[e.^{n}d$_{1,2}$oo.la]						*	*
b) [e.n$_1$t$_2$oo.la]	*!						
c) [en$_1$.t$_2$oo.la]		*!					
d) [nd$_{1,2}$oo.la]			*!			*	*
e) [e.t$_2$oo.la]				*!			
f) [e.n$_1$i.t$_2$oo.la]					*!		

From the tableau in (13), it was significant that the constraints MAX-IO and DEP-IO be ranked above the IDENT-IO family of constraint because failure to do so would have led to the candidates (e) and (f) being declared as the optimal candidates yet their output is not the attested form in Olumarama language.

3.2 Nasal + Voiceless Fricative

A sequence of a nasal and a voiceless fricative is phonologically marked in the language and crosslinguistically. It is repaired through the phonological process of deletion. The nasal is deleted leaving the following voiceless fricative intact as shown in the data below.

Nasal + Voiceless Fricative (14)

Input	Output	Gloss
(i) /e<u>N</u>-<u>f</u>iɲa/	[e.<u>f</u>i.ɲa]	'I press'
(ii) /e<u>N</u>-saɟa/	[e.<u>s</u>a.ɟa]	'I pray'
(iii) /e<u>N</u>-ʃina/	[e.<u>ʃ</u>i.na]	'I dance'
(iv) /e<u>N</u>-xaɟa/	[e.<u>x</u>a.ɟa]	'I refuse'

The data in (14) show that the deletion of a nasal prefix occurs whenever it precedes a voiceless labio-dental fricative (i), voiceless alveolar fricative (ii), voiceless palato-alveolar fricative (iii) and the voiceless velar fricative (iv). Pater (2001) [20] notes that nasals are weaker than obstruents as they largely assimilate to the place of articulation of the obstruents rather than the reverse. This implies that in the case of deletion in Olumarama, the nasal is more likely to be deleted rather than the fricative since it is weaker. Similarly, weak sounds are more likely to be deleted than strong sounds. Based on the strength hierarchy which is the inversion of the sonority hierarchy (Goldsmith, 2011) nasals are weaker than fricatives and, therefore, more prone to sound loss. In addition, the production of fricatives is known to produce turbulence as air squeezes out (Ladefoged, 2006) [10] meaning that a lot of air is required in the oral cavity to create the necessary turbulence for the production of the sound.

In OT terms, just like Nandelenga (2013) [13] observes in Lubukusu, the markedness constraint *NÇ̥ that forbids a nasal plus a voiceless consonant sequence is still undominated. As stated earlier, segments occurring in the syllable initial positions need to be preserved. This can be taken care of by introducing an undominated constraint MAX-IO$_{ROOT}$ that preserves the root syllable initial. Olumarama only allows open syllables implying that the constraint *CODA is undominated.

The anti-deletion constraint MAX-IO$_V$, which ensures the vowel in the input is preserved for easier articulation and perception, will rank highly. From the above description, the constraint hierarchy will be as follows: *NÇ̥, MAX-IO$_{ROOT,}$ *CODA >> MAX-IO$_V$ as represented in the following tableau.

/e<u>N</u>$_1$ + <u>s</u>$_2$aja/ ⟶ [e.<u>s</u>$_2$a.ja] 'I pray' (15)

Table 6

/eN$_1$-s$_2$aja/	*NÇ̥	Max IO$_{ROOT}$	*Coda	Max IO$_V$
☞[e.s$_2$a.ja]				
[e.n$_1$s$_2$a.ja]	*!			
[e.n$_1$a.ja]		*!		
[en$_1$.s$_2$a.ja]			*!	
[s$_2$a.ja]				*!

From the tableau (15), (a) is the optimal candidate as it satisfies all the constraints in the constraint hierarchy. The onset sequence for candidate (b) is a nasal plus fricative cluster while candidate (c) deletes the root initial fricative incurring a fatal violation. Candidate (d) has a syllable coda in the output while candidate (e) has deleted vowels present in the input.

3.3 Nasal + Voiced Fricative

A sequence of a nasal followed by a voiced fricative in Olumarama is repaired through nasal place assimilation and post-nasal hardening. The articulation of a nasal + voiced fricative cluster will require a lowered velum for an uninterrupted airflow for the articulation of the nasal and great turbulence in the oral cavity for the articulation of the fricative. This kind of articulation is phonetically demanding, the reason why it is subject to repair. In post-nasal hardening, the weak continuant fricative is hardened into a voiced pre-nasalized stop [^{m}b]. This is based on the strength scale, where the weak continuant fricative ranks just slightly above the nasal sounds. This facilitates the post-nasal hardening of the fricative into a stop. Nasal place assimilation also takes place as the voiced bilabial prenasalized stop is articulated in the oral cavity resulting in a voiced pre-nasalized bilabial sound. The following data shows the output when a nasal is prefixed before a voiced fricative at the syllable onset position.

(16) Formation of Voiced Bilabial Prenasalized Stops

Input	Output	Gloss
(i)/e<u>N</u>-<u>β</u>iira/	[e-<u>^{m}b</u>iir-a]	'I tell'
(ii)/e<u>N</u>-<u>β</u>oola/	[e-<u>^{m}b</u>ool-a]	'I say'

The data in (16) suggest that post-nasal hardening occurs, as the voiced bilabial fricative [β] surfaces as the voiced prenasalized bilabial stop [^{m}b]. Olumarama lacks voiced plosives hence the voiced bilabial interacts with the nasal to form the voiced pre-nasalized bilabial stop [mb]. The nasal on the other hand assimilates to the place of articulation of the bilabial meaning that the resultant segment is articulated at the bilabial place.

If the no nasal + voiced fricative sequence was to be violated, the resultant output will have the segments [m] and [β] following each other. This would be in violation of the Sonority Sequencing Principle (SSP) which advocates for a rising sonority to the nucleus followed by a drop. The output that has the sequence of segments [m] and [β] following each other violates the SSP since there is no rise in sonority towards the nucleus. The constraint that will disqualify such candidates in favour of coalescence is the undominated constraint SSP. The undominated constraint *CODA will also be relevant.

As discussed earlier, the anti-vowel deletion constraint MAX-IO$_V$ will help ensure that candidates with pure forms of output from a nasal voiced fricative sequence in Olumarama are ranked higher than those without. IDENT-IO$_{NASAL}$ is a lowly ranked constraint since the nasal feature in the input is not represented in the output by the optimal candidate.

Another distinction can be made between the fricative input [β] and how it maps to the prenasalized bilabial plosive output [^{m}b]. A unique feature of fricatives is that during their articulation there is a continuous flow of air along the oral cavity, giving the sounds a feature [+continuant]. This structural change can be described using the constraint IDENT-IO$_{CONTINUANT}$ which is ranked lowly because it is violated by the optimal candidate. The anti-coalescence constraint, UNIFORMITY-IO is also relevant but it is lowly ranked since it is violated by the optimal candidate.

The following will, therefore, be the constraint hierarchy for the nasal plus voiced fricative sequence: SSP, *CODA >> MAX-IO$_V$ >> IDENT-IO$_{NASAL,}$ IDENT-IO$_{CONT.,}$ UNIFORMITY-IO as shown in the following tableau.

/e$\underline{N}_1$ + $\underline{\beta}_2$ii.xa/ ⟶ [e.$^m\underline{b}_{1,2}$ii.xa] 'I keep' (17)

Table 7

/eN$_1$- β$_2$ii.xa/	SSP	*CODA	Max IO$_V$	Ident I-O$_{NAS}$	Ident I-O$_{CON}$	Unif I-O
a) ☞[e.^{m}b$_{1,2}$ii.xa]				*	*	*
b) [e.m$_1$b$_2$ii.xa]	*!					
c) [em$_1$.b$_2$ii.xa]		*!				
d) [^{m}b$_{1,2}$ii.xa]			*!	*	*	*

From tableau (17), candidate (a) is the optimal candidate since its violations are necessary for the process of post-nasal hardening to take place. Candidate (b) has a nasal + voiced fricative sequence. Candidate (c) fails to coalesce leaving the nasal to act as a syllable coda, while candidate (d) violates MAX-IO$_V$ by beginning the output with a consonant.

More sub-optimal candidates such as /e.mi.bi.xa/ and /e.bi.xa/ can also be generated. The anti-insertion constraint DEP-IO rules the first candidate out and it will rank slightly above the constraint UNIFORMITY-IO to prevent the candidate /e.mi.bi.xa/ from being declared the optimal candidate. Candidate /e.bi.xa/ is ruled out by the anti-deletion constraint MAX-IO which will also be ranked above the UNIFORMITY-IO. Based on the new constraints, the following can be considered as the constraint hierarchy: SSP, *CODA >> MAX-IO$_V$ >> DEP-IO, MAX-IO >> IDENT-IO$_{VOICE}$, IDENT-IO$_{CONT.,}$ UNIFORMITY-IO as represented in the following tableau.

/e$\underline{N}_1$ + $\underline{\beta}_2$ii.xa/ ⟶ [e.$^m\underline{b}_{1,2}$ii.xa] 'I keep' (18)

Table 8

/ eN$_1$- β$_2$ixa/	SSP	*Coda	Max I-o$_V$	Max I-o	Dep I-o	Ident I-o$_{nas}$	Ident I-o$_{con}$	Unif Io
a) ☞[e.^{m}b$_{1,2}$ii.xa]						*	*	*
b) [e.m$_1$b$_2$ii.xa]	*!							
c) [em$_1$.b$_2$ii.xa]		*!						
d) [^{m}b$_{1,2}$ii.xa]			*!			*	*	*
e) [e.b$_2$ii.xa]				*!				
f) [e.m$_1$i.b$_2$ii.xa]					*!			

Candidate (a) remains as the optimal candidate since the violations incurred are of lowly ranked constraints compared to the other candidates.

3.4 Nasal + Liquids

Phonetically, both the liquids and the nasal are sonorants and they, therefore, share the feature [+sonorant]. It would, therefore, be in violation of the Obligatory Contour Principle (henceforth OCP) for them to co-occur in an onset without any repair (McCarthy, 1986) [11]. The OCP principle states that adjacent sounds should not be identical (Myers, 2004) [12]. If the two sounds are mapped into the output without any repair, they will share the feature [+sonorant] thereby violating the OCP.

In addition, in the production of the sonorants, there is no strict restriction of airflow to inhibit spontaneous vibration of the vocal cords. The vibration requires intense supply of air to both the oral cavity where the lateral is articulated and the nasal cavity where the nasal is produced. These articulations are supposed to occur almost concurrently meaning that there will be no ease of articulation as opposed to the articulation of a single prenasalized sound.

Similarly, an onset sequence of a nasal followed by a trill is resolved through the deletion of the nasal leaving only the trill intact as shown in the following data.

Nasal Trill Sequence (18)

Input	Output	Gloss
(i) /e$\underline{N}$- + $\underline{r}$ul-a/	[e-$\underline{r}$ul-a]	'I leave'
(ii)/e$\underline{N}$- + $\underline{r}$em-a/	[e-rem-a]	'I cut'

The data in (18) shows that the nasal prefix is deleted in a nasal + trill sequence. The process of nasal deletion used in resolving this banned sequence of a nasal plus a trill is the same as that of a nasal-voiceless fricative sequence. This means that some constraints used in describing the optimal output from a nasal + voiceless fricative sequence can also be used here.

The constraint *NC̥, MAX-IO$_V$ and *CODA are relevant in describing the nasal trill interaction. The following will be the constraint hierarchy: *NC̥, *CODA >> MAX-IO as represented in the following tableau.

/e$\underline{N}_1$ + $\underline{r}_2$u.la/ ⟶ [e.$\underline{r}_2$u.la] 'I leave' (19)

Table 9

/eN_1- r_2u.la/	*NÇ	*CODA	Max IO_V
a) ☞[e.r_2u.la]			
b) [e_1.nr_2u.la]	*!		
c) [e_1n.r_2u.la]		*!	
d) [r_2u.la]			*!

From tableau (19), (a) emerges as the optimal candidate by deleting the nasal prefix and, therefore, preserves all the input segments in the output. The other candidates are disqualified because they violate constraints of a higher rank.

The suboptimal /e.ni.ru.la/, /e.ⁿdu.la/, and /e.nu.la/ can be generated for evaluation. Constraints that disqualify them will have to be identified. The anti-insertion constraint DEP-IO disqualifies /e.ni.ru.la/ while the output /e.ndu.la/ that erroneously undergoes place and voice assimilation is ruled out by the undominated constraint $IDENT_{[CONT,VOI]}$. The output /e.nu.la/ is disqualified by the anti-root morpheme deletion constraint $MAX\text{-}IO_{ROOT}$. The newly proposed constraint hierarchy will be as follows: *NÇ, *CODA, $IDENT_{[CONT,VOI]}$ >> MAX-IO, DEP-IO as represented in the following tableau.

/eN_1 + r_2u.la/ ⟶ [e.r_2u.la] 'I leave' (20)

Table 10

/eN_1- $r_2$ula/	*NÇ	*CODA	IDENT [CONT,VOI]	MAX IO_{ROOT}	MAX IO_V	DEP IO
a) ☞[e_1.r_2u.la]						
b) [e_1.nr_2u.la]	*!					
c) [e_1.n_2u.la]				*!		
d) [e_1n.r_2u.la]		*!				
e) [r_2u.la]					*!	
f) [e_1.ni.r_2u.la]						*!
g) [e_1.nd_2u.la]			**!			

Candidate (a) in (20) is retained as the optimal candidate since it preserves all the input segments in the output. It can thus be concluded that in Olumarama a nasal plus a trill sequence is repaired through the deletion of the nasal.

An onset sequence of a nasal + lateral is prohibited and will, therefore, undergo repair through the phonological processes of post-nasal hardening and nasal place assimilation. The process of post-nasal hardening hardens the weak lateral [l] into a prenasalized stop [ⁿd] that has a higher rank on the strength scale. In nasal place assimilation, the nasal assimilates its place of articulation to the following consonant. Therefore, in the output the nasal will share the same place of articulation as the liquid as both will be articulated at the alveolar ridge. The output cluster is therefore a voiced prenasalized alveolar stop. The data below illustrates these interactions.

Formation of Voiced Prenasalized Alveolar Stop (21)

Input	Output	Gloss
(i) /eN- + las-a/	[e-ⁿdas-a]	'I throw'
(ii) /eN- + loβ-a/	[e-ⁿdoβ-a]	'I refuse'
(iii) /eN- + lex-a/	[e-ⁿdex-a]	'I leave'
(iv) /eN- + lol-a/	[e-ⁿdol-a]	'I see'
(v) /eN- + loor-a/	[e-ⁿdo:r-a]	'I dream'
(vi) /eN- + lip-a/	[e-ⁿdip-a]	'I pay'

From the data in (21), an onset sequence of a nasal plus a lateral is marked and, therefore, resolved through post-nasal hardening and nasal place assimilation. This occurs only if the second stem syllable starts with any sound but a nasal. The stop output [nd] from the lateral input [l] is as a result of the post-nasal hardening of the weak lateral. The nasal on its part as earlier stated undergoes nasal place assimilation to share the same place of articulation as the liquid.

A constraint hierarchy to account for the optimal output and evaluate other candidates need to be constructed. The constraint that checks against the nasal + lateral sequence hence lack of post-nasal hardening and place assimilation is the undominated *NÇ constraint. The feature [+sonorant] in the input does not surface in the output of the optimal candidate. This is a violation of the featural constraint $IDENT\text{-}IO_{SON}$. The optimal candidate violates this constraint meaning that the constraint is lowly ranked. The constraint $IDENT\text{-}IO_{NASAL}$ is also relevant in this constraint hierarchy since the segments identified for the feature [+nasal] in the input should also show the same feature in the output. The optimal candidate violates this constraint meaning that a repair of the nasal + lateral sequence does not need to be faithful to the [+nasal] feature. This categorizes $IDENT\text{-}IO_{NASAL}$ as a low ranked constraint.

The undominated constraint *CODA disqualifies outputs that fail to coalesce the nasal prefix with the lateral. UNIFORMITY-IO constraint which checks against coalescence is also violated by the optimal candidate. This constraint, therefore, will rank low in the constraint hierarchy. For ease of articulation, Olumarama syllabifies into an onsetless syllable. Therefore, the constraint at work in the onsetless syllable $MAX\text{-}IO_{VOWEL}$ will rank above the UNIFORMITY-IO constraint. The above constraints can be ranked as follows in the constraint hierarchy; *NÇ, *CODA >> $MAX\text{-}IO_V$ >> $IDENT\text{-}IO_{NASAL}$, $IDENT\text{-}IO_{SON}$, UNIFORMITY-IO as shown in the following tableau.

/eN_1 l_2o.βa/ ⟶ [e.ⁿ$d_{1,\,2o.\beta a}$] 'I refuse' (22)

Table 11

/eN_1- $l_2$oba/	*NÇ	*Coda	Max IO_V	Ident IO_{NAS}	Ident IO_{SON}	Unif IO
a) ☞[e.ⁿ$d_{1,2}$o.βa]				*	*	*
b) [e.$n_1$$l_2$o.βa]	*!					
c) [en_1.l_2o.βa]		*!				
d) [l_2o.βa]			*!			

From the tableau in (22), candidate (a) is the optimal candidate with the least serious violations that the language nevertheless allows for the correct manifestation of a nasal + lateral interaction.

The function GEN generates an infinite number of candidates such as /e.lo.βa/, and /e.ni.lo.βa/. The output /e.lo.βa/ can be ruled out through the addition of anti-deletion constraint MAX-IO. The constraint will rank just above UNIFORMITY-IO and IDENT group of constraints in order to align with the languages preference for preservation of input segments over the preservation of input features.

The candidate /e.ni.lo.βa/ violates the anti-insertion constraint DEP-IO. This constraint just ranks above UNIFORMITY-IO and the IDENT group of constraints to prevent the candidate from also being declared optimal. The constraint hierarchy for a nasal + lateral sequence is: *NÇ, *CODA >> MAX-IO$_{VOWEL}$ >> MAX-IO, DEP-IO >> IDENT-IO$_{NASAL}$, IDENT-IO$_{SON}$, UNIFORMITY-IO as represented in the following tableau.

/e$\underline{N}_1$ + l_2o.ba/ ⟶ [e.$^{n}\underline{d}_{1,2}$o.ba] ‘I refuse’ (23)

Table 12

/eN_1- l_2o.ba/	*NÇ	*Coda	Max IO$_V$	Max IO	Dep IO	Ident IO$_{NAS}$	Ident IO$_{SON}$	Unif IO
a) ☞[e.$^{n}d_{1,2}$o.ba]						*	*	*
b) [e.n_1l_2o.ba]	*!							
c) [en_1.l_2o.b		*!						
d) [l_2o.ba]			*!	*				
e) [e.l_2o.ba]				*!				
f) [e.n_1i.l_2o.ba					*!			

Candidate (a) in (23) still remains the optimal candidate with the least serious violations among the different outputs. Were it not for the deletion of the vowel hence violation of the constraint MAX-IO$_{VOWEL}$ candidate (d) would also have emerged as an inaccurate optimal candidate. This explains why non-violation of the anti-vowel deletion constraint in Olumarama is important.

3.5 Nasal + Affricate

A sequence of a nasal and a voiceless affricate is phonologically marked in Olumarama and it is repaired through the processes of voice and place assimilation. The nasal undergoes place assimilation as it is articulated at the alveolar ridge. At the same time the affricate assimilates to the voice feature of the nasal to become the voiced prenasalized alveolar fricative [nz] as shown in the following data.

Formation of Voiced Prenasalized Alveolar Fricative (24)

Input	Output	Gloss
(i) /e$\underline{N}$- + $\underline{ʦ}$i + -a/	[e-$^{n}\underline{z}$i-a]	‘I go’
(ii) /e$\underline{N}$- + $\underline{ʦ}$u:n + -a/	[e-$\underline{^{n}z}$u:n-a]	‘I prick’

The data (24) (i, ii) show that voice and place assimilation occurs in Olumarama whenever a nasal is followed by the voiceless affricate [ʦ]. The nasal [n] assimilates to the place of articulation of the following affricate [ʦ] while the affricate acquires the voiced feature of the nasal resulting in the formation of the voiced prenasalized alveolar fricative [^{n}z].

In articulatory phonetics, the articulation of the affricate involves the raising of the velum to prevent air from escaping to the nasal cavity. However, there is considerable gap as one articulates first the stop, then the fricative meaning that the velum considerably lowers in the preparation for the production of the fricative. It is at this point that some air escapes through the velum and with the vibrating vocal cords, this leads to nasalization.

OT constraints such as *NÇ, *CODA and UNIFORMITY can account for the voice and place assimilation that occurs whenever a nasal prefix is followed by an affricate. To prevent nasalized stops in the output, an inaccurate manifestation of a nasal + affricate sequence in Olumarama, the specific constraint that ensures it is a prenasalized fricative that appears in the stem of the optimal output is the markedness *DEP-IO $_{[STEM]}$ FRC is used. The constraints will form the following constraint hierarchy: *NÇ, *CODA >> *DEP-IO $_{[STEM]}$FRC >> UNIFORMITY-IO, as represented in the following tableau.

/e$\underline{N}_1$ + $\underline{ʦ}_2$e.xa/ ⟶ [e.$^{n}\underline{z}_{1,2}$ e.xa] ‘I laugh’ (25)

Table 13

/eN_1 – $ʦ_2$e.xa/	*NÇ	*Coda	*Dep-IO $_{[STEM]}$ FRC	Unif IO
a) ☞[e.$^{n}z_{1,2}$e.xa]				*
b) [e.$n_1t_2$se.xa]	*!			
c) [en_1.$t_2$se.xa]		*!		
d) [e.$^{n}d_{1,2}$ e.xa]			*!	

From the tableau (25), candidate (a) is the optimal candidate as its violation of the anti-coalescence constraint is necessary for the repair processes of voice and place assimilation to take place. Candidate (b) has a nasal voiceless affricate sequence that is banned in the language while candidate (c) has a coda consonant which is disallowed in the language. Candidate (d) wrongly resolves the sequence in its output.

Voice assimilation changes the affricate from voiceless to voiced thus violating the constraint IDENT-IO$_{VOICE.}$ The constraint is low ranked since its violation is necessary in order to avoid a nasal voiceless affricate sequence in the language. The feature value of the affricate [-Nasal] is also lost as it assimilates to the nasal feature meaning that the constraint IDENT-IO$_{NASAL}$ is lowly ranked as its violation is necessary for the repair of the nasal affricate sequence.

The constraint MAX-IO$_{VOWEL}$ ensures retention of input vowels which is important for ease of articulation and preservation of the input form in the output. The interaction of the constraints will result in the following constraint hierarchy: *NÇ, *CODA >> MAX-IO$_{VOWEL}$ >> IDENT-IO$_{NASAL}$, IDENT-IO$_{VOICE}$, UNIFORMITY-IO as shown in the following tableau.

/e$\underline{N}_1$ + $\underline{ʦ}_2$e.xa/ ⟶ [e.$^{n}\underline{z}_{1,\,2}$e.xa] ‘I laugh’ (26)

Table 14

/eN_1 - $ʦ_2$e.xa/	*NÇ	*CODA	MAX IO$_V$	IDENT IO$_{NAS}$	IDENT IO$_{VOI}$	UNIF IO
a) ☞[e.$^{n}z_{1,2}$e.xa]				*	*	*
b) [e.$n_1ʦ_2$e.xa]	*!					
c) [en_1.$ʦ_2$e.xa]		*!				
d) [$ʦ_2$e.xa]			*!			
e) [$^{n}z_{1,2}$e.xa]			*!	*	*	*

In the tableau (26), candidate (a) is still the optimal candidate since it violates lowly ranked constraints compared to the other candidates. Candidate (d) and (e) fail to preserve all vowels present in the input while candidate (d) also failing to preserve the [nasal] and [voice] features present in the input. It is thus evident that a sequence of a nasal and a voiceless affricate in Olumarama is best resolved through the processes of voice and place assimilation.

3.6 Nasal + Nasal Sequence

A sequence of a nasal prefix and another nasal is disallowed in Olumarama and must be repaired through the phonological process of deletion where the nasal prefix is deleted while the initial nasal of the root is left intact. The nasal + nasal sequences are shown in the following data.

Nasal + Nasal sequence (27)

Input	Output	Gloss
(i) /eN- + nak-a/	[e-nak-a]	'I kick'
(ii) /eN- + mal-a/	[e-mal-a]	'I finish'
(iii) /eN- + ɲool-a/	[e-ɲool-a]	'I find'
(iv) /eN- + ŋool-a/	[e-ŋool-a]	'I scribble'

The data (27) shows that a sequence of nasal prefix and a root nasal (i-iv) results in the deletion of the nasal prefix while the initial nasal of the root is left intact.

Optimality theory constraints can account for the various nasal + nasal interactions that lead to the deletion of the prefix nasal. The markedness constraint *NN bans nasal + nasal sequence in Olumarama, therefore, it is undominated. All the input segments, particularly the first nasal, are not preserved in the output meaning that the constraint MAX-IO ranks low in the constraint hierarchy. The vowels in the input should be retained in the output meaning that the constraint MAX-IO$_V$ will rank highly in the constraint hierarchy. The constraint *CODA is undominated since Olumarama only allows open syllables while DEP-IO also ranks highly as insertion of segments will lead to sub-optimal outputs. The following will be the expected constraint hierarchy: *NN, *CODA >>MAX-IO$_V$ >>DEP-IO>>MAX-IO as represented in the following tableau.

/eN$_1$- + n$_2$a.ka/ ⟶ [e$_1$.n$_2$a.ka] 'I kick' (28)

Table 15

/eN$_1$-+ n$_2$a.ka /	***NN**	***CODA**	**MAX IO$_V$**	**DEP IO**	**MAX IO**
a) ☞[e$_1$.n$_2$a.ka]					*
b) [e$_1$.nn$_2$a.ka]	*!			*	
c) [e$_1$n.n$_2$a.ka]		*!		*	
d) [n$_2$a.ka]			*!		*

From the tableau (28) candidate (a) is the optimal candidate because it preserves the input segments in the output thus it violates the low ranked anti-deletion constraint MAX-IO$_V$. Candidate (b) fails to delete the underlying nasal in the nasal prefix while candidate (c) has a coda consonant which is disallowed in Olumarama. Candidate (d) on the other hand fails to preserve the vowel segment thus violating the anti-deletion constraint. It is evident that a sequence of onset nasals is disallowed in Olumarama and it is resolved through the deletion of the nasal in the prefix.

4.0 Conclusion

A nasal + consonant sequence is disallowed in Olumarama unless the consonant is a glide. Nasal consonant sequences are repaired through the application of phonological processes such as voice assimilation, place assimilation, post-nasal hardening and deletion of the nasal stop. Unlike nasal lateral sequence that is repaired through the process of nasal place assimilation and post nasal hardening, a nasal trill sequence in Olumarama mostly undergoes the process of deletion. All these repairs are driven by the undominated markedness constraints that demand structural change on the marked inputs for surface well-formed ness.

Due to the fact that markedness constraints largely dominate faithfulness constraints there is a considerable change in the lexical structure of words upon the application of a phonological process. However, the need to preserve lexical identity is greater during the application of some phonological processes meaning that certain input structures are preserved in the output. Various OT constraints interact in a constraint hierarchy to account for the optimal candidate. There is no duplication of rules to account for the different repair processes but mere recourse to constraint interaction of Olumarama specific constraint hierarchy.

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