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An Aspect of NC Cluster Realizations in Bukusu*

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Chung, Chin-Wan. (2020). An aspect of NC cluster realizations in Bukusu. *The Linguistic Association of Korea Journal, 28*(4), 121-145. This study observes various realizations of a nasal plus a consonant (NC) sequence in Bukusu. The newly created Bukusu NCs are composed of a prefix nasal plus a stem-initial consonant, and they are required to have the identical laryngeal, continuant, and place features. If any NCs do not meet these requirements, several sound modifications occur to render NC harmonious with the NC structural requirements. If a post-nasal consonant is a voiceless obstruent, progressive voicing assimilation occurs and then a post-nasal consonant triggers regressive place assimilation. Hardening occurs when a post-nasal consonant has [+voice, +cont]. Post-nasal /l, r, β/ optionally merge with the preceding nasal after becoming hardened and triggering regressive place assimilation if they are followed by a nasal or an NC-initial syllable in a stem. A nasal prefix is deleted if a stem begins with a nasal or a voiceless-initial fricative. Even though different sound change strategies are used in Bukusu, their goal is to make an NC satisfy the requirements of the cluster. In order to provide an analysis, we adopt a constraint-based theoretical framework which allows steps before reaching the final optimal form. This is because some of the sound modifications should occur sequentially. The constraints and their rankings used in the analysis can capture the functional unity that is hidden in sound modification strategies.

Key Words: nasal plus consonant sequences, constraints, ranking, hardening, assimilation, deletion

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1. Introduction

This study delves into several ways of realizing a nasal plus a consonant (henceforth NC) sequences in Bukusu, a language spoken in Kenya. The NC sequences in Bukusu are formed when the prefix /n/ 'the first-singular present tense subject' is concatenated with a consonant-initial imperative morpheme: *ča* 'go-imperative' → ñǰ*a*. The newly formed NC sequence undergoes several modifications to satisfy the conditions that the sequences must meet such as having the same laryngeal, continuant, and place feature specifications. If an NC cluster does not abide by the requirements, sound modifications occur to avoid having the unallowable NC cluster. Concerning the voicing of a post-nasal obstruent, there have been several studies on this topic (Pater, 1996, 1999, 2004). A series of papers by Pater argues that a post-nasal obstruent should be voiced and this requirement levied on the NC cluster can be bypassed by several methods in languages as shown by the examples in (1). The target segments in the input and the sounds that have undergone changes in the output are indicated by bold-faced letters.

(1) a. Nasal substitution in Indonesian

mə$\mathbf{N_1}$-$\mathbf{p_2}$ilih	mə$\mathbf{m_{1,2}}$ilih	'to choose, to vote'

b. Nasal deletion in Kelantan Malay

$\mathbf{N_1}$ T_2	$\boldsymbol{\varnothing_1}$ T_2

c. Post-nasal voicing in Puyu Pungo Quechua

sinik-pa	'porcupine's'	kam-**b**a	'yours'
wasi-ta	'in the jungle'	kakin-**d**a	'the others'

d. Denasalization in Mandar

maN-dundu	mandundu	'to drink'
ma**N**-**t**unu	ma**tt**unu	'to burn'

e. Vowel epenthesis: not attested

As illustrated by the examples in (1), the NC with a voiceless post-nasal consonant is avoided by each different strategy in languages. And this implies that the preceding nasal calls for a voiced consonant which is based on articulatory mechanism argued for by Huffman (1993) and Hayes and Stivers (1995). What is interesting about the examples in (1) is that languages which are independent from each other adopt different modification strategies to avoid the same marked sequence of the NC. If the examples in (1) are accounted for by the related rules such as nasal substitution, nasal deletion, post-nasal voicing, denasalization, and vowel epenthesis, each different rule can explain the data but this could be considered conspiracy of rules to shun the marked segmental sequence (cf. Kager, 1999) because each different independent rule has the same goal to avoid the marked structure without noticing it.

Compared to (1) and other languages like Pulaar (Niang, 1997: 56) where a post-consonant nasal triggers voicing assimilation to a preceding voiceless stop forming a geminate, Bukusu has various types of NC clusters where a post-nasal consonant can be an obstruent stop, a fricative, a liquid, a nasal, and a glide. Since the NC itself tends to have the same voice, [-cont], and place features, several sound modifications occur in the Bukusu NC clusters such as progressive voicing assimilation, regressive place assimilation, hardening of liquids and /β, y/, hardening plus regressive place assimilation with an ensuing merge of an NC, and deletion of a nasal before a nasal and a fricative. Some of the structural change strategies to meet the NC requirements do not occur simultaneously but occur one after another. This implies that a simple input-to-output mapping theoretical framework is not appropriate in analyzing Bukusu examples. Thus, the goal of this study is to observe diverse realizations of NCs in Bukusu to avoid an unwanted NC sequence and provide a procedural constraint-based account through which we can find a functional unity that underlies in various structure change strategies.

This study is structured as follows. Section 2 briefly introduces the basic phonology of Bukusu and presents a set of NC examples with the description of them. Section 3 discusses the former analyses of the NC realizations. Section 4 provides a constraint-based harmonic serialism (McCarthy, 2008, 2010, 2011) account and it is followed by the summary of the study along with its phonological implications in Section 5.

2. Basics of Phonology and the NCs in Bukusu

Before we present the data, we briefly introduce some basics of Bukusu phonology. Bukusu has 5 short vowels and their corresponding long vowels as given in (2).

(2) The vowel inventory (Mutonyi, 2000, p. 145)

i, ii		u, uu
e, ee		o, oo
	a, aa	

In Bukusu, high front and back vowels can form glide /y/ and /w/ each before other vowels and a singleton vowel undergoes lengthening before NC clusters. Bukusu has an open syllable and accordingly an NC sequence between vowels are classified as onset of the second vowel. The consonants of Bukusu can be classified as having four places and five manners of articulation as shown in (3).

(3) The consonant inventory (Mutonyi, 2000, p. 164)

	Labial	Alveolar	Palatal	Velar
Stops	p	t	č	k
	mb	nd	ñǰ	ŋg
Fricatives	f	s		x
	β			
Nasals	m	n	ñ	ŋ
Liquids		l, r		
Glides	w	y		

Based on the short background of Bukusu phonemes and syllable structure, we present the data for various types of NCs. The examples of Bukusu NCs are divided into several groups depending on the process the examples undergo and the initial-segment of a post-nasal stem. The first group of examples consists of the first-singular present tense subject prefix /n/ plus a stem beginning with a voiceless stop. The second group is composed of the prefix /n/ and a stem beginning with a voiced continuant segment such as liquids, a labial fricative, and a palatal glide. The third set of data is structured with the prefix /n/ plus a stem initiating with an alveolar liquid or a voiced labial fricative, which is followed by a syllable beginning with a nasal or an NC sequence within a stem. The fourth data group is composed of the prefix nasal plus a nasal-initiating stem. The final data set has a voiceless-initial fricative stem preceded by the first-singular prefix /n/.

The first set of data is presented in (4) where the NC sequence consists of the prefix /n/ and a stem beginning with a voiceless obstruent which has the [-cont] feature specification. The NC sequence created by morpheme concatenation in (4) undergoes two phonological processes: progressive voicing assimilation and regressive place assimilation. The prefix /n/ triggers progressive voicing assimilation, which can be grounded in the articulation of the NC sequence proposed by Huffman (1993) and Hayes and Stivers

(1995). On the other hand, a stem-initial consonant transmits its place feature to the preceding nasal. Thus, the resulting NC shares the same laryngeal, continuant, and place features as can be observed in the third column. The two assimilation processes in the third column can be verified by referring to the examples in the second column in which a stem is preceded by the third-plural present tense prefix /βa/. The examples in this section come from Mutonyi (1992, 2000) and Odden (2005).

(4) A nasal plus a voiceless stop or an affricate stem-initial segment

imperative	*3pl pres.*	*1sg pres.*	*gloss*
ča	βača	ñǰa	'go'
čexa	βačexa	ñǰexa	'laugh'
teexa	βateexa	ndeexa	'cook'
tiira	βatiira	ndiira	'get ahold of'
piima	βapiima	mbiima	'weigh'
pakala	βapakala	mbakala	'writhe in pain'
kona	βakona	ŋgona	'pass the night'
kula	βakula	ŋgula	'buy'

The second set of examples in (5) consists of the prefix nasal followed by a segment which is voiced and has continuous air stream. As can be observed in (5), a post-nasal voiced continuant undergoes hardening becoming a voiced stop that has the same place of articulation with the stem-initial voiced continuant. The NC in the third column has the same laryngeal, place, and continuant feature specifications, satisfying the conditions required for the Bukusu NCs.

(5) A nasal plus a voiced continuant stem-initial segment

imperative	*3pl pres.*	*1sg pres.*	*gloss*
lola	βalola	ndola	'look'
lasa	βalasa	ndasa	'shoot at'
leβa	βaleβa	ndeβa	'push'
ra	βara	nda	'put'
roβa	βaroβa	ndoβa	'ripen'
rusya	βarusya	ndusya	'vomit'
βakala	βaβakala	mbakala	'spread'
βala	βaβala	mbala	'count'
βasa	βaβasa	mbasa	'forge'

yama	βayuma	ñǰama	'scout'
yaaya	βayaaya	ñǰaaya	'scramble with'
yoola	βayoola	ñǰoola	'scoop'

The third set of examples in (6) is composed of the nasal prefix and the /l, r, β/-initial stem, which are also followed by a nasal-initial or an NC-initial syllable within a stem in (6b). In this type of NC sequence, the stem-initial segments undergoes hardening becoming [d, d, b] respectively and they are optionally deleted in the output (Mutonyi, 2000) as demonstrated by the examples in the third column of (6b). However, we interpret this traditional explanation by adopting the notion called merge between a nasal and a following homorganic obstruent with [-cont] feature when this sequence is followed by a nasal onset or an onset NC sequence within a stem. This optional merge of segments between a nasal and the [d, b] can be evinced by the examples in (6a) where the stem does not begin with the /t, p, k/ in the third column but with corresponding voiced stops [d, b, g] which have undergone progressive voicing assimilation post-nasally. The merge of a nasal and a post-nasal consonant can also be compared to the examples from *lola* 'look' to *βasa* 'forge' in (5) where the post-nasal consonant is not followed by a nasal-initial syllable. In such examples, a merge between a nasal and a consonant does not occur but only a post-nasal consonant hardening occurs instead. An intriguing aspect of this merge needs a further specification because unlike the /l, r, β/-initial stems in (6b), the stems beginning with the /y/ do not undergo optional merge. Thus, it seems that the optional merge between a nasal and a consonant occurs only in the corresponding segments [d, d, b] of the /l, r, β/ having [+voice, +cont, +ant] from /l, β, r, y/. This merge should occur after the [d, d, b] each triggers regressive place assimilation based on the final two examples in (6b).

(6) A nasal plus the /l, r, β/-initial stems

	imperative	*3pl pres.*	*1sg pres.*	*gloss*
a.	tima	βatima	ndima	'run'
	taaña	βataaña	ndaaña	'hack'
	piima	βapiima	mbiima	'weigh'
	kona	βakona	ŋgona	'pass the night'
b.	laanda	βalaanda	naanda	'go around'
	liinda	βaliinda	niinda	'wait'
	loondelela	βaloondeleda	noondelela	'follow'

loma	βaloma	noma	'say'
luma	βaluma	numa	'bite'
laagŋwa	βalaagŋwa	naagŋwa	'be named'
rengexa	βarengexa	neengexa	'place'
roomboora	βaroomboora	noomboora	'show bias'
βaamba	βaβaamba	maamba	'spread'
βuumba	βaβuumba	muumba	'mold'

The fourth set of examples in (7) shows that the prefix nasal is followed by a nasal-initial stem. In this case, the two nasals become geminate consonants and they undergo degemination as can be seen in the examples in the third column (Odden, 2005). Based on the realizations of the third column, it is assumed that the sequence of nasals in the same syllable is not allowed in Bukusu.

(7) A nasal plus a nasal-initial stem

imperative	*3pl pres.*	*1sg pres.*	*gloss*
mala	βamala	mala	'finish'
meela	βameela	meela	'get drunk'
ñaaña	βañaaña	ñaaña	'chew'
ñwa	βañwa	ñwa	'drink'
ŋoola	βaŋoola	ŋoola	'see into the spirit world'

The final set of examples in (8) consists of the alveolar nasal prefix plus a voiceless fricative-initial stem. In such an NC sequence, the prefix nasal is not realized in the output as can be observed in the third column. An interesting aspect of this type of examples is that the stem-initial voiceless fricative does not become a corresponding voiced stop to meet the NC requirement. Insead of such changes, the nasal prefix is deleted. Based on this prefix nasal deletion, we may assume that sound modification is restricted to one feature at a time and this prevents a voiceless fricative from becoming a voiced stop. Thus, the change a voiceless fricative can undergo is to become a voiced fricative or a voiceless stop both of which are still short of satisfying the NC requirements.

(8) A nasal plus a voiceless fricative-initial stem

imperative	*3pl pres.*	*1sg pres.*	*gloss*
fuma	βafuma	fuma	'spread'
fuundixa	βafuundixa	fuundixa	'knot'
xala	βaxala	xala	'cut'
xweesa	βaxweesa	xweesa	'pull'
seesa	βaseesa	seesa	'window'
siimbwa	βasiimbwa	siimbwa	'hahve indigestion'
somya	βasomya	somya	'teach'
sukuwa	βasukuwa	sukuwa	'rub legs'

So far we have presented the various realizations of the NCs where we could witness strategies to satisfy the requirements specifically applied to the sequences. When a stem begins with a segment with the [-cont, -voice] feature specifications, voicing and place assimilation occur and they lead an NC to have identical laryngeal and place features which are mandated in the Bukusu NCs. When a stem begins with the [+cont, +voice], the post-nasal consonant undergoes hardening. However, when the post-nasal /l, r, β/ are followed by a nasal-initial or an NC-initial syllable in a stem, the /l, β, r/ undergo hardening becoming [d, b, d], respectively and they undergo optional merge with the preceding nasal. Finally, when a stem begins either with a nasal-initial or a voiceless fricative-intial stem, the prefix nasal deletion strategy is adopted to avoid the marked NC structure. Based on the data and the strategies applied in the examples in this section, we can assume that a theoretical framework that employs a single input-to-output mapping cannot explain the various realizations of the Bukusu NCs. In the next section, we briefly reviews former studies on the realizations of the Bukusu NCs and discuss their analytic points and problems.

3. Previous Studies

In this section, we briefly discuss previous studies on the realizations of the Bukusu NCs. The two studies solely focus on the Bukusu examples while others deal with different Bantu language examples (Downing, 1990a; Park, 1997) in which the NC realization issue is partially reflected. Thus, in order to provide a comprehensive analysis focused only on the NC sequences in Bukusu, we only introduce two studies in this section. We introduce two former studies which are based on rules by Odden (2005) and CV phonology (Clements and Keyser, 1983) and Feature Geometry (FG: Clements and Hume, 1995) by Mutonyi (2000). The first rule-based approach (Chomsky and Halle, 1968) provided by Odden (2005) presents several rules to explain the examples from (4) to (8).

(9) Rules for the Bukusu NCs
a. Post-nasal voicing: voiceless → voiced / nasal___
Nasal place assimilation: nasal → αplace___[cons, αplace]
b. Post-nasal hardening: voiced continuant → noncontinuant / nasal___
c. l-deletion: l → ∅ / nasal ___V nasal
d. Degemination: C_iC_i → C_i
e. Nasal deletion: nasal → ∅/ ___voiceless continuant

The examples in (4) can be explained by the two rules in (9a) which result in producing the NCs with identical laryngeal and place feature in the outputs of the third column in (4). Each rule in (9a) can be ordered both ways to explain the data in (4). The rule in (9b) can account for the post-nasal hardening examples in (5). The rule in (9c) is responsible for some of the examples in (6b), but the rule is not applicable to other examples from *rengexa* 'place' to *βuumba* 'mold' in (6b). The examples in (7) can be explained by the given rule in (9d) which should be applied after the nasal place assimilation rule. Finally, the examples in (8) can be explained by the nasal deletion rule in (9e).

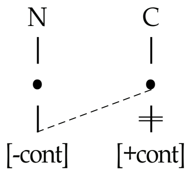
The six different independent rules in (9) can seemingly account for most of the examples from (4) to (8). However, each and every rule in (9) is motivated to satisfy the requirements for the NCs in Bukusu. That is, the NCs in Bukusu should have the same voice, continuant, and place feature specifications. If an NC does not meet these conditions, the input NC undergoes various strategies to avoid having the NC which falls short of satisfying the conditions. All rules in (9) are functionally related but we cannot find the functional unity in the independent rules. This is because each rule is different and it separately applies to produce an output, which is the ultimate purpose of the rule. Thus, it is impossible to find the functional unity of the rules which underlies in each rule.

The second previous analysis is provided by Mutonyi (2000) whose account is framed in CV phonology of Clements and Keyser (1983), which is also based on the precepts of Kahn (1976) and McCarthy (1979, 1981). The CV phonology basically has three different tiers such as syllable tier, skeletal tier, and segmental tier. According to Clements (1986), consonants and vowels are not immediate constituents of syllables but they are mediated by an abstract skeletal tier or timing slots. Since consonants and vowels are mediated by the skeletal slots, it is possible that one segment, either a vowel or a consonant, can be linked to multiple skeletal slots. Based on the CV phonology and the basic concepts of FG, nasal place assimilation examples in (4) can be explained by spreading the place node from the post-nasal consonant to the nasal and post-nasal voicing by which voice feature from the nasal spreads to the following consonant as in (10).

(10) Homorganic nasal assimilation and post-nasal voicing

Mutonyi assumes that the place feature of the nasal prefix is not specified but it gets its place feature from the following consonant as in (10). If the unspecified nasal is followed by a vowel-initial stem, the place feature of the nasal is provided by ‘default coronal assignment’ rule which converts N to [n]. For the post-nasal hardening, Mutonyi provides two feature geometric representations:

(11) Post-nasal hardening



The examples in (5) can be explained by spreading [-cont] feature specification from the nasal to the following [+cont] segment whose feature is now unassociated with the consonant. For the optional consonant deletion examples in (6b), Mutonyi argues that this optional deletion of the post-nasal consonant is due to Meinhof’s Law or Ganda Law which specifies that a post-nasal consonant is deleted when it is followed by a syllable beginning with a nasal or a nasal plus consonant sequence.

For the examples where a nasal is deleted before another nasal or before a voiceless fricative, Mutonyi provides two rules to explain such examples in (7) and (8).

(12) a. Pre-fricative nasal deletion: $\varnothing \Leftarrow$ N C [+cont, -voice]
b. No geminates: $*C_iC_i$

The analysis by Mutonyi (2000) is similar to that of Odden (2005) but with the different theoretical framework. The FG based representations and rules proposed by Mutonyi seem to explain more examples than those of Odden (2005) with respect to the examples in (6b). But the analysis also fails to provide the common reason that is hidden behind those rules and FG representations. That is, all different processes occur in Bukusu in order to avoid NC structures that do not satisfy the requirements. Since this being the case in two former studies, we need to propose an analysis that reflects all the requirements called for the Bukusu NCs. Furthermore, since the relevant phonological processes specifically related and serially ordered, a simple input-to-output mapping cannot provide a satisfactory account. Considering this, we will provide a constraint-based Harmonic Serialism (McCarthy, 2008, 2010, 2011) analysis in the next section.

4. An Alternative Analysis

In this section, we briefly introduce the theoretical background and provide an analysis of the various realizations of the Bukusu NCs. For the analysis, we adopt the theoretical framework called Harmonic Serialism (henceforth HS) proposed by McCarthy (2008, 2010, 2011), which is also developed from the Optimality Theory (Prince and Smolensky, 1993, 2004) and Correspondence Theory (McCarthy and Prince, 1995, 2004). The basic ideas of HS are that it is a hybrid-type of theory in that it employs constraints just like the constraint-based theory but it also allows procedural steps before the final output or optimal form like the classic generative rule-based theory. However, what makes the HS different from the traditional rule-based theory is that HS uses a consistent constraint ranking from the first step to the final step. The HS is grounded on the constraint-based theoretical framework except for the adopting procedural derivation-like steps which are hallmark of the generative phonology. Since the HS allows steps, a sound change cannot proceed from A to C but from A to B and from B to C. This gradual structural change is summarized as "gradualness" as defined in (13).

(13) Gradualness
If β is a member of the set Gen (α), then more than one unfaithful operation is required to transform α into β.

Based on (13), an input can produce outputs that deviate from the input minimally in the first step and among the outputs, a candidate which satisfies best for the given constraint ranking will be selected as optimal in the first step. This is called local optimal form. This optimal form becomes an input of the second step in which Gen generates a number of outputs having only one difference from the input and the local optimal form is chosen by the identical constraint ranking used in the first step. The steps goes on until an input and an output are identical, which is called convergence. This procedural approach can explain the various realizations of the Bukusu NCs which should be analyzed step by step to reach the final form. Based on this, we first provide an analysis for both post-nasal voicing and regressive place assimilation in the next subsection.

4.1. Post-nasal voicing and nasal place assimilation

Post-nasal voicing and regressive nasal place assimilation occur in the examples in (4). In order to explain them, we first present the relevant constraints for the analysis.

(14) a. *NC̥: A nasal plus a voiceless consonant cluster is not allowed.
b. Max-Obst: An input obstruent has its correspondence in the output.
c. Ident-Stem(pl)=Id-St(pl)
Input and output stem correspondents are identical in their place feature specifications.
d. Agree-NC(pl): Agr-NC(pl)
An NC cluster has identical place feature specifications.
e. Anchor-IO(Left): Anch-L
No epenthesis or deletion at the left edge.
f. Ident-Obstruent(voice)=Id-Obst(voi)
Input and output obstruent correspondents are identical in their laryngeal feature.

*NÇ̥ specifies that a post-nasal consonant should be voiced, which is based on articulatory mechanisms proposed by Huffman (1993) and Hayes and Stivers (1995). This is undominated in the analysis and it triggers sound modifications whenever a post-nasal consonant is not voiced. Max-Obst is a faithfulness constraint which calls for the appearance of input obstruents in the output. This constraint does not show any ranking with the markedness *NÇ̥ constraint. Another highest-ranking constraint is Id-St(pl) which does not allow any place change in the stem. Thus, if an NC does not have identical place, it triggers regressive place assimilation, which is grounded on the place markedness hierarchy (Prince and Smolensky, 1993: 181). Agr-NC(pl) requires that any NC cluster have identical place feature specification, which is one of the conditions that the Bukusu NCs should satisfy (cf. Chung, 2015). This constraint is ranked lower than *NÇ̥ in the analysis because priority of application goes to *NÇ̥, which is followed by nasal place assimilation. The ranking order between them is grounded in the HS theoretical components which only allows one change at a time. Since post-nasal voicing and nasal place assimilation cannot occur simultaneously in the HS framework, the constraints should be ranked.

Anch-L does not permit deletion or insertion of a segment at the left edge in the output. It basically protects the nasal prefix which is mostly realized except for a nasal-nasal or a nasal plus a voiceless fricative sequence. This constraint is ranked higher than Agr-NC(pl) because the ranking between them is reversed, an incorrect optimal will be selected. Id-Obst(voi) is lowly-ranked in the analysis because it should be violated in order to satisfy *NÇ̥ if a post-nasal consonant is voiceless. The following constraint tables shows how the constraints and their ranking procedurally select the final optimal form in the examples in (4).

(15) Step 1: nčexa → ñǰexa 'laugh'

nčexa	*NÇ̥	Max-Obst	Id-St(pl)	Anch-L	Agr-NC(pl)	Id-Obst(voi)
nčexa	*!				*	
☞nǰexa					*	*
ñčexa	*!					
nexa		*!				
čexa				*!		

Step 2:

ŋ̌exa	*NÇ	Max-Obst	Id-St(pl)	Anch-L	Agr-NC(pl)	Id-Obst(voi)
ŋ̌exa					*!	
☞ñ̌exa						
ndexa			*!			

Step 3:

ñ̌exa	*NÇ	Max-Obst	Id-St(pl)	Anch-L	Agr-NC(pl)	Id-Obst(voi)
☞ñ̌exa						

At step 1, the second candidate, which undergoes post-nasal voicing, is selected as the local optimal form. The other candidates are edged out by the second candidate. The first and the third candidates are eliminated due to the violation of the undominated *NÇ. The fourth output is suboptimal due to its deletion of an obstruent while the final candidate incurs a violation of Anch-L by deleting the nasal prefix. At step 2, the second form undergoes regressive nasal place assimilation which makes the NC have identical place of articulation and it becomes optimal. At step 3, an output which is identical to the input satisfies all constraints achieving convergence and it is selected as the final optimal form. The constraint indicates that an input undergoes post-nasal voicing and nasal place assimilation later whose application order is reflected in the constraint ranking given in (16).

(16) *NÇ, Max-Obst, Id-St(pl) ≫ Anch-L ≫ Agr-NC(pl) ≫ Id-Obst(voi)

4.2. Post-nasal hardening

Post-nasal hardening occurs only when a stem-intial consonant begins with the feature [+voiced, +cont] such as /l, r, β, y/. Since HS allows only one change at a time and the stem-initial segments in (5) have their corresponding stops, the post-nasal consonants in (5) undergo hardening becoming stops, which satisfy the conditions required for the NCs in Bukusu. For the analysis, we use all the constraints introduced in (14) except for *NÇ and Id-Obst(voi) because the relevant NCs in (5) meet the voicing requirement of the post-nasal consonant. Thus, both constraints do not play an important role in the evaluation. A new constraint we employ is the one that prohibits the occurrence of a post-nasal continuant segment. In order to avoid this marked sequence of structure, hardening of a continuant segment occurs.

(17) *NC[+cont]: An NC cluster consisting of a nasal plus a continuant segment is prohibited.

This markedness constraint is ranked highest in the analysis along with Max-Obst and Id-St(pl). A newly introduced constraint and the ranking interactions we discussed in the previous subsection, we present the following constraint tables.

(18) Step 1: βala → mbala 'count'

nβala	*NC[+cont]	Max-Obst	Id-St(pl)	Anch-L	Agr-NC(pl)
nβala	*!				*
☞nbala					*
ndala			*!		
nala		*!			
βala				*!	

Step 2:

nbala	*NC[+cont]	Max-Obst	Id-St(pl)	Anch-L	Agr-NC(pl)
nbala					*!
☞mbala					

Step 3:

mbala	*NC[+cont]	Max-Obst	Id-St(pl)	Anch-L	Agr-NC(pl)
☞mbala					

As can be observed in (18), a cluster composed of a nasal plus a consonant with the [+cont, +voice] features undergoes hardening and regressive place assimilation is mainly motivated by Agr-NC(pl). Other strategies such as change of place in the stem segment or deletion of one segment in the NC are suppressed by other constraints in the table. The constraint ranking in (19) can explain all the examples in (5).

(19) *NC[+cont], Max-Obst, Id-St(pl) ≫ Anch-L ≫ Agr-NC(pl)

4.3. Post-nasal consonant merge

Post-nasal consonants optionally merge with the preceding nasal when the consonants have [+ant, +cont, +voice] features as can be observed in the data in (6b). Such consonants are very similar to the examples we discussed in 4.2 where post-consonantal segments undergo hardening. Among the /l, r, β, y/ as shown in (5), only /l, r, β/ are the targets of optional merge after they become stops [d, d, b] each if they are followed by a syllable beginning with a nasal or an NC cluster in (6b). In order to explain this case, we should propose a language-specific constraint that reflects the merge of post-nasal consonants with the [+ant, +cont, +voice] features with the preceding nasal. Along with this constraint, we need a constraint which prohibits the deletion of a stem-medial consonant to destruct the environment for an NC merge. We also adopt the constraints used in the previous subsection such as *NC[+cont], Max-Obst, Id-St(pl), Anch-L, and Agr-NC(pl). The three new constraints are provided in (20).

(20) a. $^*NC_{ons}N(C)_{ons}$: An $NC_{[-cont]}$ onset sequence followed by an adjacent N(C) onset is prohibited.
b. Contiguity-Stem=Contig-St
No medial insertion or deletion of a segment in the stem.
c. Uniformity-IO=Uniform
No element of the output has multiple correspondents in the input.

$^*NC_{ons}N(C)_{ons}$ does not allow a sequence of structure where an $NC_{[-cont]}$ onset sequence is followed by an adjacent N(C) onset within a stem. This language specific constraint is ranked lower than Agr-NC(pl) in the analysis because the merge of an NC sequence occurs after a post-nasal consonant, which has undergone hardening, triggers regressive place assimilation, resulting in a homorganic NC cluster. If the ranking between $^*NC_{ons}N(C)_{ons}$ and Agr-NC(pl) is reversed, an incorrect output will be selected as a local optimal form which will be shown in step 2 in (21). Contig-St is a constraint that calls for the faithful realization of stem internal segments. The constraint is not in conflict with $^*NC_{ons}N(C)_{ons}$ so they are equally ranked in the analysis. Uniform is ranked low so that it tolerates the merge between a prefix and a following homorganic consonant with [-cont] to bypass the marked sequence of structure in Bukusu required by $^*NC_{ons}N(C)_{ons}$. The low-ranking nature of this constraint reflects the optional application of merge in Bukusu. The analytic steps in (21) show how a post-nasal consonant is merged with the preceding nasal over a morpheme boundary in Bukusu.

(21) Step 1: nβuumba → muumba 'mold'

$n_1\beta_2$uumba	*NC [+cont]	Max-Obst	Id-St (pl)	Anch-L	Agr-NC(pl)	*NC_{ons} $N(C)_{ons}$	Contig-St	Uniform
$n_1\beta_2$uumba	*!				*			
☞$n_1b_2$uumba					*	*		
$m_1\beta_2$uumba	*!							
$n_1d_2$uumba			*!			*		
$n_1$uumba		*!						
$\beta_2$uumba				*!				

Step 2:

$n_1b_2$uumba	*NC [+cont]	Max-Obst	Id-St (pl)	Anch-L	Agr-NC(pl)	*NC_{ons} $N(C)_{ons}$	Contig-St	Uniform
$n_1b_2$uumba					*!	*		
☞$m_1b_2$uumba						*		
$n_1b_2$uuba					*!		*	

Step 3:

$m_1b_2$uumba	*NC [+cont]	Max-Obst	Id-St (pl)	Anch-L	Agr-NC(pl)	*NC_{ons} $N(C)_{ons}$	Contig-St	Uniform
$m_1b_2$uumba						*!		
☞$m_{1,2}$uumba								*
$m_1b_2$uuba							*!	

Step 4:

muumba	*NC [+cont]	Max-Obst	Id-St (pl)	Anch-L	Agr-NC(pl)	*NC_{ons} $N(C)_{ons}$	Contig-St	Uniform
☞muumba								

The analytic steps in (21) show that the merge between a homorganic NC occurs after hardening triggered by *NC[+cont] and regressive nasal place assimilation enforced by Agr-NC(pl). The local optimal form in step 3 does not violate Max-Obst because the obstruent is fused into the preceding nasal becoming [$m_{1,2}$] to avoid the language specific constraint *$NC_{ons}N(C)_{ons}$ and the optionality of this process is reflected in the low-ranking

Uniform constraint which monitors one to multiple segmental mapping between output and input. The suboptimal third candidate in step 3 is eliminated due to its violation of Contig-St by deleting a stem-medial segment to avoid the marked segmental structure condition required by $*NC_{ons}N(C)_{ons}$. It should be noted that the examples in (6b) would undergo hardening if there were not an adjacent syllable beginning with a nasal or an NC cluster. The constraints and their ranking used on (21) are given in (22).

(22) *NC[+cont], Max-Obst, Id-St(pl) ≫ Anch-L ≫ Agr-NC(pl) ≫ $*NC_{ons}N(C)_{ons}$, Contig-St ≫ Uniform

An interesting aspect of the examples in (6b) is that the merge between a homorganic $NC_{[-cont]}$ before a nasal-initial syllable in the stem is optional. The given constraint in (22) only explains the merge of the NC. The preservation cases of the NC in this specific stem environment can be explained if the $*NC_{ons}N(C)_{ons}$ constraint is ranked lower than Uniform in step 3 in (21). In that case, the first candidate [$m_1b_2$uumba] will be selected as a local optimal form which will eventually be chosen as the ultimate optimal form in step 4. This re-ranking of lower-ranking constraints is generally adopted in the constraint-based analysis to explain optional phenomena.

4.4. Nasal deletion in a nasal-nasal sequence

In Bukusu a nasal-nasal sequence is created when a stem begins with a nasal consonant is prefixed by the first-singular present tense subject morpheme as shown by the examples in (7). Concerning this issue, Mutonyi (2000) and Odden (2005) argue that the prefix undergoes place assimilation triggered by a nasal-initial stem, forming a geminate, which is degeminated in the output. Unlike their claim, we assume in this study that the prefix nasal /n/ is deleted before a nasal-initial stem instead of going through forming a geminate and degemination. This is because the Bukusu language does not allow nasal-nasal sequences either with the identical or non-identical place of articulation. This can be compared to the prohibition of two nasals in the syllable coda as in *hymn-hymnal*, *autumn-autumnal*, and *column-columnist* (Kreidler, 1989: 147-148) in English. Thus, we propose three new constraints and adopt a constraint used in the previous subsections such as Anch-L in order to explain such examples.

(23) a. *Nas-Nas: A nasal-nasal sequence is not allowed.
b. Ident-Stem(nas)=Id-St(nas)
Input nasals in a stem and their correspondents in the output are identical in nasality.
c. Max-Stem(nasal)=Max-St(nas)
Input nasals in the stem must have output correspondents.

*Nas-Nas calls for the prohibition of nasal-nasal sequences in the output. Id-St(nas) prevents the change of a stem nasal in the output to avoid the nasal-nasal sequence. Max-St(nas) requires faithful realizations of any stem nasal segment in the output. These three constraints do not have any ranking among them while they are ranked over Anch-L. The following constraint tables show how the constraints and their interaction can select the final optimal form.

(24) Step 1: nmala → mala 'finish'

nmala	*Nas-Nas	Id-St(nas)	Max-St(nas)	Anch-L
nmala	*!			
☞mala				*
mmala	*!			
nbala		*!		
ndala		*!		
nala			*!	

Step 2:

mala	*Nas-Nas	Id-St(nas)	Max-St(nas)	Anch-L
☞mala				

We can observe that the strategy to avoid the nasal-nasal sequence by changing the stem-initial nasal to an obstruent proves to be futile since the resulting forms violate Id-St(nas). Another option to avoid the marked structure adopted by the final candidate also fails due to its violation of Max-St(nas). The only way to bypass the marked nasal-nasal sequence is to delete the prefix at the cost of violating lower-ranking Anch-L in Bukusu. The constraint ranking we used for explaining the examples in (7) is given in (25).

(25) *Nas-Nas, Id-St(nas), Max-St(nas) ≫ Anch-L

4.5. Nasal deletion in a nasal-voiceless fricative sequence

In Bukusu, a nasal is also deleted when it is followed by a voiceless fricative. Unlike a post-nasal voiced fricative /β/ which undergoes hardening becoming [b], the fricatives [f, s, x] after a nasal do not undergo hardening being realized as [b, d, g] each to have the same place, laryngeal, and continuant feature specifications with the preceding nasal. Instead of hardening of the voiceless fricatives, a pre-fricative nasal undergoes deletion in the output. This indicates that the hardening of voiceless fricatives to voiced stops is forfeited in the HS theoretical framework which allows only a single change at a time: the involved feature changes are [-voice, +cont] to [+voice, -cont]. A post-nasal fricative feature change either to a voiced fricative or to a voiceless stop is controlled by *NÇ and *NC[+cont]. Furthermore, the deletion strategy of the fricatives is suppressed by Max-Obst. Thus, the best option the marked NC cluster can take is to delete the pre-fricative nasal.

In order to explain the examples in (8), we adopt the highest-ranking *NÇ, *NC[+cont], and Max-Obst from the previous subsections along with Anch-L as illustrated by the tables in (26).

(26) Step 1: nfuma → fuma ‘spread’

nfuma	*NÇ	*NC[+cont]	Max-Obst	Anch-L
nfuma	*!	*!		
npuma	*!			
nβuma		*!		
☞fuma				*
numa			*!	

Step 2:

fuma	*NÇ	*NC[+cont]	Max-Obst	Anch-L
☞fuma				

Since the change in a segment is restricted in HS, the first candidate is suboptimal since it violates high-ranking *NÇ and *NC[+cont] once each. The second and the third candidates which undergo one change each in step 1 are also eliminated by violating the undominated *NÇ and *NC[+cont], respectively. The final candidate which deletes the stem-initial fricative in the output is also eliminated by Max-Obst. The fourth candidate which adopts the deletion strategy of the nasal violates Anch-L is emerged as optimal. This local optimal form becomes the input in step 2 and the identical candidate to the input is selected as optimal which satisfies all the constraints achieving convergence. The constraint ranking used in (26) is given in (27).

(27) *NC̥, *NC[+cont], Max-Obst ≫ Anch-L

5. Conclusion and implications

This study has provided an HS account of the variant realizations of NC cluster of Bukusu which occurs depending on the properties of a post-nasal consonant and the specific syllable-initial segment within a stem. The NC formed by a morpheme concatenation is required to have identical laryngeal, place, and continuant features. If one of these conditions is not met in the NC, the cluster undergoes several modifications processes such as post-nasal voicing, nasal place assimilation, post-nasal hardening, post-nasal hardening plus regressive place assimilation with an ensuing optional merge between a nasal and a consonant, and nasal deletion in a nasal-nasal sequence and a nasal plus a voiceless consonant cluster. The constraints rankings we have used in the previous section are as follows.

(28) a. Post-nasal voicing and nasal assimilation
*NC̥, Max-Obst, Id-St(pl) ≫ Anch-L ≫ Agr-NC(pl) ≫ Id-Obst(voi)
b. Post-nasal hardening
*NC[+cont], Max-Obst, Id-St(pl) ≫ Anch-L ≫ Agr-NC(pl)
c. Merge of a nasal and a consonant$_{[-cont]}$
*NC[+cont], Max-Obst, Id-St(pl) ≫ Anch-L ≫ Agr-NC(pl) ≫ *NC$_{ons}$N(C)$_{ons}$, Contig-St ≫ Uniform
d. Nasal deletion in a nasal-nasal sequence
*Nas-Nas, Id-St(nas), Max-St(nas) ≫ Anch-L
e. Nasal deletion in a nasal plus a voiceless fricative
*NC̥, *NC[+cont], Max-Obst ≫ Anch-L
f. Combined constraint ranking
*NC̥[+cont], Id-St(pl/nas), Max-Obst, Max-St(nas) ≫ Anch-L ≫ Agr-NC(pl) ≫ *NC$_{ons}$N(C)$_{ons}$, Contig-St ≫ Uniform ≫ Id-Obst(voi)

Even though there are five different constraint rankings in (26), some constraints are shared by each constraint ranking. This implies it is possible to combine the constraints into one as in (f) in which we also combine similar constraints such as *N$\underset{\circ}{C}$[+cont] and Id-St(pl/nas). The important structural changes are motivated by *N$\underset{\circ}{C}$[+cont] and Agr-NC(pl). The undominated *N$\underset{\circ}{C}$[+cont] prescribes the conditions for a post-nasal consonant while the dominated Agr-NC(pl) requires the identical place feature. The ranking difference between them indicates that the laryngeal and continuant feature of a post-nasal consonant take precedence over the place feature of an NC, which in turn calls for a procedural analysis of the Bukusu NC clusters. Thus, the constraints proposed in this study can explain the NC sequence examples which require to have several identical requirements between the nasal and the following consonant compared to a general constraint proposed by Pater to have identical laryngeal feature specification in the NC.

We can point out some phonological implications from the current study. Firstly, an NC occurring in the same syllabic constituent has really strict requirements as those in Bukusu such as having the same laryngeal, continuant, and place features compared to those of English where an NC across the syllable boundary only require to have identical place feature or optional deletion of a post-nasal coronal voiceless stop (cf. Chung, 2009). Secondly, phonological changes occurring in the Bukusu NCs are limited to one change at a time which is reflected in the prohibition of changing a voiceless fricative to a corresponding voiced stop. Thirdly, it is interesting that a number of different sound modifications occur in one language to achieve the same goal for the wellformed NCs in Bukusu. Fourthly, the sound modifications observed in Bukusu shed light on the segmental changes occurring in the NC sequences in a number of Bantu languages (cf. Downing, 1990a; Park, 1997).

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