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Feature Sharing, Locality, and Serialism in Gradual Harmony*

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Lee, Minkyung. (2018). Feature sharing, locality, and serialism in gradual harmony. *The Linguistic Association of Korea Journal, 26*(4), 83-102. Feature sharing via Share(F) (originating from McCarthy, 2009) well conforms to the phonology of harmony under Optimality Theory (OT) hinged upon Harmonic Serialism (HS-OT) (McCarthy, 2007, 2009). The target language of Kinyarwanda, a Bantu variety, verifies and supports the fact that harmony from feature sharing improves locally and gradually. Three rules interact and progress step by step: nasal assimilation (NA) triggers obligatory consonant aspiration (CA), which, in turn, feeds nasal devoicing (ND) that is optional. Under HS-OT, the Partially Ordered Constraints (POC) model (Pater, 2007; Kimper, 2008) is required for the optional stage of ND as well as the OCP-related consonant phonotactics for the process of CA. In essence, the idea of feature sharing via Share[F] is quite straightforward to the harmony achieved gradually when two consonants are in strict locality. Furthermore, the POC model is well-couched into the architecture of HS-OT.

Key Words: consonant harmony, nasal assimilation, consonant aspiration, nasal devoicing, Share[F], HS-OT

1. Introduction

Optimality Theory (henceforth OT) (Prince & Smolensky, 1993/2004; McCarthy & Prince, 1995) based upon Harmonic Serialism (hereafter HS-OT)

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(McCarthy, 2007, 2008a, 2008b, 2009) provides a new insight to the phonology of harmony. As fully discussed in previous literature (McCarthy, 2007, 2008a, 2008b, 2009; Lee, 2015, 2016), the phonology of harmony well- conforms to the OT grammar with serialism whereby a single change at a time improves harmony locally and gradually. Therefore, in HS-OT, iterative derivations via the Gen-Eval loop obtain multiple local optima from an input to an ultimate output. However, OT with parallelism (henceforth parallel OT) (Prince & Smolensky, 1993/2004; McCarthy & Prince, 1995) permits multiple changes at one time between an input and an output, i.e., the lack of local optimality and gradual harmony improvement.

In Autosegmental Phonology (Goldsmith, 1976a, 1976b), assimilation results from the iterative application of feature spreading rule either leftward or rightward until there is no further harmonic element left or there appears a blocker with an incompatible feature specification. However, in constraint-based OT grammar, a pro-spreading markedness constraint such as Align or Agree is indispensible since there is no direct device or mechanism equivalent to feature spreading rule. As will be dealt with in detail later, in HS-OT, assimilation is attributed to feature sharing by the pivotal role of Share[F] (McCarthy, 2009) instead of feature spreading via Align or Agree under parallel OT.

In the phonology of harmony, assimilation has been viewed as feature agreement between two adjacent segments within a morpheme or across a morpheme boundary. A target sound becomes similar or alike to its conditioning sound. For instance, in nasal assimilation, a nasal target moves its original place of [coronal] to [labial] or [dorsal] place of articulation due to the influence of the following trigger. Likewise, in the target language of Kinyarwanda, an eastern Bantu language, Nasal Assimilation (hereafter NA) shows the same pattern; a nasal target assimilates to the place of the following trigger, thus two locally adjacent segments share the same token of the place of articulation.

Of particular interest here is that voiceless stops, unlike their voiced counterparts, undergo two additional processes of Consonant Aspiration (henceforth CA) and Nasal Devoicing (hereafter ND). Yet, voiced stops get involved in the place of articulation assimilation only. Given the rule-based grammar, NA takes place prior to other phonological processes in rule application order. As observed and described in Kimenyi (1979), NA always precedes CA, which leads to the process of ND. Note here that both NA and CA are obligatory while ND is optional.

Under the architecture of HS-OT (McCarthy, 2007, 2008a, 2008b, 2009), this paper verifies and supports that assimilation results from feature sharing via Share[F] (McCarthy, 2009) by examining and analyzing the target data of Kinyarwanda consonant harmony where three phonological rules interact. To this end, section 2 focuses on the data of consonant harmony phenomena found in Kinyarwanda and their rule interaction. NA is first applied before CA whereby all the voiceless stops are merged or neutralized into [h]. ND is also applied at the final stage of derivation though it is optional. Section 3 starts with introducing Share[F] (McCarthy, 2009), which induces feature sharing between two locally abutting segments along with the basic tenets of HS-OT and further provides a serial OT account for the target data. Here it will be highlighted that a serial derivation via the Gen-Eval loop enables local optimality and gradual harmony improvement in the phonology of harmony. Furthermore, the Partially Ordered Constraints model (Pater, 2007; Kimper, 2008) adopted for optionality as well as consonant phonotactics goes well with the main spirit of HS-OT. Section 4 includes summary and final conclusion of the present paper.

2. Kinyarwanda Consonant Harmony

As well-described in Kimenyi (1979:34), NA is a phonological rule and a morpheme structure rule as well in the sense that a nasal-beginning affix *in-* belongs to the class marker 9/10 and *(-)n-* consists of a morpheme itself. The nasal target always undergoes the place of articulation assimilation in this language. Therefore, it adjusts its original place to that of the following trigger, i.e., a coronal to be a labial or a dorsal. Here notice that, for easy configuration, the data are split into two; one is the example where the trigger is a voiced stop as laid out in (1) and (2) and the other is the case where the trigger is a voiceless one as in (3) below.

Now let us first consider the data set in (1) in which a voiced stop undergoes the place assimilation within a word.

(1) Nasal assimilation[1)]
Within a word

[ibaa*mb*a]	'bitterness'
[kuruu*nd*a]	'to pile'
[ubgee*ŋg*e]	'trick'
[umugaa*ŋg*a][2)]	'doctor'

As italicized in (1), the nasal target assimilates to the place of articulation of the following trigger, thus two locally adjacent segments share the same place of articulation; from the top, the [labial] place, the [coronal] place, and the [dorsal] place of articulation, respectively. In assimilatory direction, the trigger is preceded by its nasal target, i.e., regressive or anticipatory.[3)]

NA in Kinyarwanda is also conditioned by a morpheme structure; the nasal /n/ comes from either the prefix *in-* or *(-)n-* ('I/me') itself. The morphologically-conditioned nasal target also experiences the regressive NA process as clarified in (2), this time, across a morpheme boundary.[4)]

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1) The data adopted here are all excerpted from Kimenyi (1979) and that, for the sake of simplicity, suprasegmental tone marked on a vowel is not shown throughout the paper. Also note that, given the fact that voiceless stops, unlike their voiced counterparts, further undergo the process of CA, which leads to ND as well, they are separately arranged as in (3).
2) Kimenyi (1979:3) represents a long vowel as a sequence of two identical vowels in order to distinguish a short vowel in length. Also note that a geminated vowel or a sequence of two identical vowels is not surface-attested in this language. Therefore, /aa, uu, ee/ are long and /a, u, e/ are short.
3) Here note that no nasal target appears in a suffix as observed in the data set of (2) and (3), which means that the NA process is part of the prefixation rather than the suffixation in this language.
4) As described in Kimenyi (1979:36, 47), in Kinyarwanda, a voiced fricative *β* in /in-βoga/(→ [i*mb*oga]) 'vegetables' in (2a) undergoes consonant strengthening, thus turns into a voiced stop [b] when it is preceded by the consonant that is a homorganic nasal stop. In addition, for ease of articulation, this language allows consonant insertion, thus a velar stop *g* is inserted before a glide *w* as observed in [ňoβergwa](←/n-yoβer-w-a/) 'I fail to know' in (2b).

(2) Nasal assimilation

Over a morpheme boundary

a. With the prefix *in-*

/in-bwa/	[imbga]	'dog'
/in-βoga/	[imboga]	'vegetables'
/in-da/	[inda]	'stomach', 'pregnancy'
/in-doβo/	[indoβo]	'container'
/in-gwe/	[iŋgwe]	'leopard'

b. With the prefix *n-*

/n-pfu-a/	[mpfa][5]	'I die'
/n-wu-ha-a/	[ŋwuha]	'I give it'
/n-yu-uumva/	[ňuumva]	'I hear it'
/n-yoβer-w-a/	[ňoβergwa]	'I fail to know'

As observed in (2a) where the prefix *in-* is attached to the base, the nasal target changes its original place to that of its trigger, thus two locally adjoined consonants share the same [labial]/[coronal]/[dorsal] place of articulation. However, in (2b) where the morpheme *n-* is prefixed either to the base or to another prefix, as in (2a), the same assimilatory pattern is witnessed as well. Here one thing worthy to be noticed is that, when the trigger is a labio-velar glide *w* or a palatal glide *y*, the nasal target turns into a velar nasal [ŋ] as in [ŋ-wuha] 'I give it' or a palatal nasal [ň] as in [ň-uumva] 'to hear that'.

Now let us move onto the target data where, this time, the voiceless stops trigger NA as laid out in (3). Note that the data set in (3) involves two additional phonological processes unlike their voiced counterparts in (1) and (2) in which they undergo NA only.

5) Unlike the data set in (2b) where the trigger of NA is a voiced stop but, in [mpfa] 'I die', the trigger is not a voiced stop but a labiodental affricate /pf/ whereby the nasal target agrees with the place of its host trigger, i.e., labialized. Also note that, since /pf/ is not directly related to the process of CA, it is included here in (2b) away from the data set in (3a) where voiceless stops undergo CA obligatorily.

(3) Further phonological processes

a. Obligatory consonant aspiration[6)]

/in-papuro/	[imhapuro]	'paper'
/ku-n-pima/	[kuumhima]	'to measure/examine me'
/in-taambwe/	[inhaambge]	'step'
/in-tuuro/	[inhuuro]	'wild cat'
/in-ka/	[iŋha]	'cow'
/n-toora/	[nhoora]	'vote for me', 'I vote'
/n-keeka/	[ŋheeka]	'I guess', 'guess me'
/n-kuura/	[ŋhuura]	'I take home', 'take me home'
/n-kora/	[ŋhora]	'I work', 'touch me'
/n-kina/	[ŋhina]	'I play'

b. Optional nasal devoicing

/in-papuro/	[iṃhapuro]	'paper'
/ku-n-pima/	[kuuṃhima]	'to measure/examine me'
/in-taambwe/	[iṇhaambge]	'step'
/in-tuuro/	[iṇhuuro]	'wild cat'
/n-toora/	[ṇhoora]	'vote for me', 'I vote'
/in-ka/	[iŋ̣ha]	'cow'
/n-keeka/	[ŋ̣heeka]	'I guess', 'guess me'
/n-kuura/	[ŋ̣huura]	'I take home', 'take me home'
/n-kora/	[ŋ̣hora]	'I work', 'touch me'
/n-kina/	[ŋ̣hina]	'I play'

Likewise the voiced stops above, the voiceless ones in (3) are sensitive to the NA process as well. Furthermore, interestingly enough, the data in (3) additionally undergo both CA and ND. For instance, in /in-papuro/ 'paper', the target nasal assimilates to the labial place of articulation of the following trigger, which results in the change of /n/→[m]. And the process of CA follows; the

6) Aspiration refers to a plosive pronounced with a strong burst of air as in [p^h, t^h, k^h] with an *h* added. However, a voiceless stop in Kinyarwanda becomes [h] with its laryngeal feature only but all others are delinked given the feature geometric point of view. As Kimenyi (1979:2-3) describes, no aspirated p, t, k exist in the phonemic/phonetic inventory of this language.

voiceless stop is aspirated to become [h]. One step further, as stated in Kimenyi (1979:36), the nasal target is further devoiced, which is not obligatory but optional. Here all nasals are devoiced, thus represented with an underdot in (3). Therefore, given the rule application order, following Kimenyi (1979), two obligatory rules are first applied before the optional rule of ND and NA comes first prior to CA.

One more thing to be considered here is that both CA and ND can be applied on the condition that two locally adjoined segments share the same place of articulation. In other words, those two rules can be applied after the NA process. As argued at length in Kimenyi (1979:36), also as will be discussed later, voiceless stops are all neutralized into [h], which means that they lose their original place right after they transfer their place of articulation to the nasal target.

Thus far, we have examined and discussed the data of Kinyarwanda consonant harmony focusing on some phonological rules and their interaction. Two rules of NA and CA are obligatorily applied and ND is optionally applied. This underlies that the rule application order is divided into two; NA→CA and NA→CA→ND. Therefore, two types of speech are both surface-attested with or without ND.

3. Feature Sharing in Serialism

3.1. HS-OT Mechanism

As briefly discussed above, the major characteristic of HS-OT (McCarthy, 2007, 2008a, 2008b, 2009) is two-fold; locality and gradualness. Optimality is locally achieved and harmony is gradually improved, not found in parallel OT. This means that multiple changes at a time are not permitted and that an iterative derivation from Gen to Eval, looping back and forth, enables local optimality from an input through local optima to an ultimate output, i.e., not direct mapping of an input to an output as in parallel OT. Therefore, via the Gen-Eval loop, the output driven from the previous step of derivation is fed back into the next pass and it stands as an input until the convergent step where no further harmony improvement is possible, that is, all derivations are completed here.

Under the core tenets of HS-OT, a derivational OT, assimilation as feature agreement results from feature sharing between two locally adjoined segments within or across a morpheme boundary. NA and ND favor the same place of articulation and voicing, respectively. Therefore, a markedness constraint that is responsible for feature sharing is required under the HS-OT schema (McCarthy, 2007, 2008a, 2008b, 2009) as adopted in (4).

(4) Share[F] (McCarthy, 2009:8)
Assign one violation mark for every pair of adjacent segments that are not linked to the same token of [F].

As defined in (4), Share[F] enforces every pair of adjacent segments to share the same [F] autosegment. As McCarthy (2009:8) pinpoints, in parallel OT, assimilation as feature spreading from a feature-bearing unit to its neighbors is implemented via the markedness constraint like long-distance Align or local Agree that wrongly predicts surface-unattested languages, i.e., a true pathology (Wilson, 2003, 2004, 2006; McCarthy, 2003, 2009). Therefore, feature spreading via Align or Agree is not sound nor straightforward for the phonology of harmony. In HS-OT, however, harmony as feature sharing is achieved via Share[F] constraint without any pathology involved.

Basically, Share[F] and Ident[F] conflict with one another. Share[F] derives harmony, which, in turn, sacrifices Ident[F]. Given the definition of Share[F] in (4), the following cases in (5) are all germane to the critical violation of Share[F].

(5) Share[nas] violated (McCarthy, 2009:8)

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a. [nas]          b. [nas][nas]        c.
    |                  \   /
   ma                   mã                b a
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As illustrated in (5) where Share[nas] is exemplified, [nas] in (5a) is linked to one but not the other, which violates Share[nas]. The rest is also fatal, too; in (5b), each segment is linked to each different [nas] autosegment, and in (5c), no

[nas] is linked to neither segment. This implies that Share[F] is fully satisfied only when two adjacent segments are linked to the same and a single [nas] autosegment as indicated in (6).

(6) Share[nas] satisfied (McCarthy, 2009:8)

[nas]

mã

Here is the issue to be considered; Share[F] well-matches to the feature privativity instead of feature equipollency.[7] Harmony or assimilation process is not symmetric given the fact that no languages spread [-nasal] but many languages spread [+nasal]. This means that [nasal] is privative. As also argued in previous literature (Steriade, 1993a, 1993b, 1995; Trigo, 1993; Lombardi, 1991; Ladefoged & Maddieson, 1996), [round] is privative as well as [ATR] and [back] whose counterparts are [RTR] (not [-ATR]) and [front] (not [-back]), respectively.

Taken together, it has been shown that HS-OT relies on the main tenets of locality in optimality and gradualness in harmony improvement by allowing a single change at a time through the Gen-Eval loop and that harmony as feature agreement reflects the requirement of feature sharing via the pivotal role of Share[F].

3.2. A Serial OT Account via Share[F]

Returning to the target data in which NA takes place prior to CA and ND, let us first consider how these rules are incorporated into the HS-OT schema equipped with the harmony-triggering Share[F] constraint. In line with McCarthy (2009:8), Share[PL] forces two adjacent segments to be linked to the same and a single [PL] autosegment though the nasal target loses its original

7) Lee (2016) reports that English voicing assimilation may be a possible counterexample to feature privativity in that voicing assimilation in English is sensitive to both [+voice] and [-voice] of the obstruent triggers. For instance, in English inflectional morphology, the feature [-voice] also propagates to the target as evidenced in past tense {-*ed*}, work[t] vs clos[d] or plural {-*s*}, cat[s] vs dog[z], and the like.

place of articulation at the expense of Ident[PL](=No change in [PL]) (McCarthy & Prince, 1995) as in (7).

(7) Harmony-triggering constraint
Share[Place](=Share[PL])
Make two adjacent segments share the same token of [labial], [coronal], and [dorsal] autosegment.

Share[PL] in (7) is used as a cover constraint of Share[labial]/[coronal]/[dorsal] place of articulation as well as Ident[PL], thus harmony in place makes each Ident[PL] sacrificed. Given the crucial role of Share[PL] ranked over Ident[PL], the nasal target changes its place of articulation to that of the host trigger. As the data in (1) specify, within a word, the nasal target and its voiced stop trigger share the same [labial] (as in *-mb-*), [coronal] (as in *-nd-*), and [dorsal] (as in *-ŋg-*) place of articulation due to the demand of Share[PL] posited in (7).

Furthermore, the data set in (2), here as repeated but simplified in (8), where NA obligatorily occurs over a morpheme boundary, Share[PL] gives rise to feature agreement between two locally adjacent segments.

(8) Obligatory nasal assimilation
a. With the prefix *in-*

/in-βoga/	[imboga]	'vegetables'
/in-da/	[inda]	'stomach', 'pregnancy'
/in-gwe/	[iŋgwe]	'leopard'

b. With the prefix *n-*

/n-pfu-a/	[mpfa]	'I die'
/n-wu-ha-a/	[ŋwuha]	'I give it'
/n-yu-uumva/	[ňuumva]	'I hear it'

When the affix *in-* is prefixed to the base as laid out in (8a), the nasal target and the following trigger are linked to the same and a single [PL] autosegment as elaborated in (6) above. The exemplary tableau of the word /in-gwe/ 'leopard' is displayed here in (9).

(9) NA via Share[PL][8)]

Step 1: NA process

/in-gwe/	Share[PL]	Ident[PL]
☞a. iŋ-gwe		1
b. in-gwe	1 W	L

Step 2: Convergence

/iŋ-gwe/	Share[PL]	Ident[PL]
iŋ-gwe		

Under HS-OT, at Step 1, the local output in (9a) holds a single and the same [dorsal] autosegment linked to the adjacent segment, though it causes an additional violation of Ident[PL]. At Step 2, the convergent step where no further harmony improvement is possible, the latest input of Gen and the recent most output of Eval are completely merged together, thus all steps of derivation terminate here.[9)]

For the data in (8b) where the nasal target, the morpheme *n-* itself, is prefixed to the base, under the influence of a labiodental affricate /pf/, the nasal target *n-* changes its original place to the bilabial [m] at Step 1, thus [m-pfu-a] locally wins with the fulfillment of Share[PL]. For the next step, we need more constraint to obtain the local output of [m-pfa](←/m-pfu-a/ from Step 1) though vowel phonology is not our major concern. Note that two vowels are locally adjoined, i.e., vowel hiatus, thus vowel elision is obligatory due to Onset (Ito, 1989; Prince & Smolensky, 1993) demanding that syllables have onsets as clarified in (10).

8) Here I will clarify that this paper follows Prince's (2002) comparative tableaux in which there appears W if the constraint favors the winner and L if it favors the loser. Also the number in the tableau indicates the number of violation incurred by a candidate.

9) Note that all the Share[F] type constraints posited in the present paper stem from McCarthy (2009) and that, throughout the paper, as indicated in (6) above, only candidates where two adjacent segments are linked to the same and a single [PL] autosegment are dealt with in the tableaux. Other cases, as in (5), violate Share[F]. Also, due to space limit, the obligatory process of NA at Step 1 as well as the convergent step is not displayed hereafter and further the constraints not relevant in the current tableaux are not shown, either.

(10) Hiatus resolved[10)]
Step 2

/m-pfu-a/	Onset	Share[PL]	Ident[PL]
☞a. m-pfa			
b. m-pfu-a	1 W		

The local output at Step 1 is fed back into Step 2 via the Gen-Eval loop and thus it stands as an input for the following derivation as shown in (10). The candidate in (10a) fares better since it satisfies Onset, though, Max-Seg(=No segmental deletion) (McCarthy & Prince, 1995), bottom-ranked, thus not displayed here, is readily violated. The most recent output in (10a) is merged onto the latest output of Eval at Step 3, i.e., convergent.

In the meantime, for the case of [ňuumva](←/n-yu-uumva/ 'I hear it') in which a single prefix *n*- undergoes NA, the nasal target obtains the palatal place of its trigger due to the effect of Share[PL]. But, after NA, the trigger, a glide y, is totally eliminated. As stated in Kimenyi (1979:52-53), given the fact that a glide y of the y-beginning affix is readily removed, the sequence of CG[Pal] is intolerant phonotactically in this language. Therefore, we may venture that an OCP-related markedness constraint like *CG[Pal] militates against any sequence of a consonant(=C) and a glide(=G) both matching in [palatal] as posited in (11).

(11) An OCP-related markedness constraint (Goldsmith, 1976a)
*CG[Pal]: No CG sequences agreeing in [palatal]

*CG[Pal] in (11) disallows y-stay after the process of NA at Step 1, thus no sequence of CG[Pal] surfaces. Accordingly, at Step 2, *CG[Pal] ranked over Share[PL] plays a vital role in blocking the surface-unattested competitor like *[ň-yu-uumva] as specified in (12).

10) In Kinyarwanda, when two vowels locally sit side by side, vowel gliding is a possible option to avoid vowel hiatus as well. But, as argued in Kimenyi (1979:12), when a high back vowel /u/ is preceded by a labiodental /pf, f, v/ or a velar /k, g, h/, regressive vowel deletion is favored instead of glide formation. Therefore, a potential output like *[m-pfwa] with a vowel glided fatally violates *Complex(Onset), top-ranked. See Lee (2015) for more details.

(12) With *CG[Pal] >> Share[PL]

Step 2

/ň-yu-uumva/	Onset	*CG[Pal]	Share[PL]	Ident[PL]
☞a. ňu-uumva	1			
b. ňyu-uumva	1	1 W		

Step 3

/ňu-uumva/	Onset	*CG[Pal]	Share[PL]	Ident[PL]
☞c. ňuumva				
d. ňu-uumva	1 W			

Though the derivation of Step 1 is not full-fledged here, NA obligatorily arises, thus an alveolar nasal gets assimilated to be palatalized, which is an input for Step 2 as in (12). Given the crucial order of *CG[Pal] >> Share[PL] under the Partially Ordered Constraints (hereafter POC) model (Kimper, 2008 following Pater, 2007), the candidate in (12a) locally wins.11) The competitor in (12b) is fatally ruled out with the invalid sequence of CG[Pal]. Here note that, given the POC model, *CG[Pal] and Share[PL] are not fixed in their order, i.e., partially ranked, *CG[Pal] >> Share[PL] is responsible for the OCP effect at Step 2 but, with their reverse order, i.e., Share[PL] >> *CG[Pal], feature agreement via NA takes place at Step 1.

Now the output in (12a) gets ready to be an input for Step 3, where, this time, Onset forces a vowel to be deleted at the point of vowel hiatus. Therefore, the local output in (12c) becomes optimal, which is mapped onto the latest output of Eval at Step 4, i.e., convergence.

11) Kimper (2008) strongly claims that the POC model is well-couched into the serial version of OT in that optimality is locally evaluated in each single change via the Gen-Eval loop. The POC model is quite simple; suppose that, in a grammar with the constraints A, B, and C, B and C are not fixed in their order with respect to each other, i.e., partially ordered. This derives two possible total orders of A>>B>>C and A>>C>>B. Note that, given the POC model, there is no requirement that the same total order be selected in each step of derivation (Kimper, 2008:4). Due to this characteristic, the POC model can successfully predict optionality as well as consonant phonotactics under HS-OT.

Compared to the NA process of the voiced stop trigger, the following data set tells us that a voiceless stop takes part in the obligatory processes of NA and CA as well as the optional process of ND. The data set in (3) above is recalled and simplified here as in (13).

(13) Further phonological processes of voiceless stops

a. Obligatory consonant aspiration

/in-papuro/	[imhapuro]	'paper'
/in-taambwe/	[inhaambge]	'step'
/in-ka/	[iŋha]	'cow'
/n-toora/	[nhoora]	'vote for me', 'I vote'
/n-keeka/	[ŋheeka]	'I guess', 'guess me'

b. Optional nasal devoicing

/in-papuro/	[iṃhapuro]	'paper'
/in-taambwe/	[iṇhaambge]	'step'
/in-ka/	[iŋ̣ha]	'cow'
/n-toora/	[ṇhoora]	'vote for me', 'I vote'
/n-keeka/	[ŋ̣heeka]	'I guess', 'guess me'

As discussed earlier, a voiceless obstruent trigger, unlike its voiced counterpart, undergoes further phonological process of aspiration on one hand and incurs ND on the other hand. From the data in (13a), we see that voiceless stops are all aspirated into [h] in syllable onset position, that is, neutralization.[12] Here note again that the nasal target obtains the place of its trigger via NA prior to the process of CA. Therefore, a nasal target itself plays a key role as an indicator to tell what [h] was originally before the CA process occurs.

At Step 1 in which a nasal target experiences NA, i.e., labialized, the local output is yielded again for the following step where the voiceless stop gets neutralized into [h] as elaborated in (14).

12) Unlike the data in (13) where all the voiceless stops are aspirated, any possibility that a voiced stop is wrongly aspirated is entirely banned via the crucial role of *SG[Voi](=No voiced consonants are aspirated.) (Lee, 1998) ranked as high as Onset.

(14) With the obligatory CA
Step 2

/im-papuro/	Onset	Share[PL]	Ident[PL]
☞a. im-ha...		1	1
☜b. im-pa...		L	

For the sake of simplicity, the portion of a word only relevant to harmony is represented in the tableau. At the current stage, i.e., at Step 2, the competitor in (14b) wrongly fares better than the surface-attested form in (14a). Prior to amending this mismatch, as also discussed in (12) above, one question to be asked; why voiceless stops are all merged into [h] after the process of NA? Does the language disfavor any sequences of a nasal and a voiceless stop matching in [PL] phonotactically? Provided that this is a possible answer, as postulated in (15), it is presumed that an OCP-related markedness constraint can remove such redundancy in place of articulation between two adjacent segments matched into [PL].

(15) An OCP-related phonotactic constraint
*NC̣[Place](=*NC̣[PL]) (cf. Kager, 1999:61)
No NC̣ sequences agreeing in [PL]
(N: nasals, C̣: voiceless obstruents)

In fact, *NC̣[PL] sabotages the job of Share[PL] at Step 1 where NA is obligatory since the former disfavors any NC̣ sequences agreeing in [PL] while the latter favors feature agreement in [PL], i.e., they are in conflict. Following Kimper's (2008) POC model under serialism in which two constraints are not fixed in their ranking, that is, partially ordered, the partial ranking of Share[PL] >> *NC̣[PL] derives NA at Step 1, but their reverse order, i.e., *NC̣[PL] >> Share[PL], enforces CA at Step 2 as clarified in (16) where a voiceless stop becomes aspirated.

Under the crucial role of the phonotactic constraint posited in (15), the tableau in (14), not yet complete, is reanalyzed as in (16) where *NC̣[PL] sits over Share(PL) at Step 2.

(16) The change of /p/→[h][13)]

At Step 2

/im-papuro/	Ons	*NÇ[PL]	Share(PL)	Ident(PL)
☞a. im-ha...			1	1
b. im-pa...		1 W	L	L

Since the target nasal has already obtained the place of its host trigger at Step 1 via NA, at Step 2, the trigger becomes aspirated into [h] by abandoning its original place, which makes any articulatory effort reduced. The candidate in (16b), though it is locally optimal at Step 1, is screened out with the fatal violation of *NÇ[PL]. Therefore, the more harmonic change of /p/(as well as /t/ and /k/) to [h] is achieved.[14)] As mentioned earlier, if CA is the last stage of harmonic improvement, (16a) is converged onto the latest output of Eval at Step 3, that is, the whole derivational process is finished here.

However, the process of ND, though it is optional, can be further applied to the result of Step 2 in (16) with the change of /p/→[h]. This time, a nasal target agrees with the [voice] feature of its host, thus it becomes devoiced due to the demand of Share[Voi] as posited in (17).

(17) Share[Voi]

Make two adjacent consonants share the same token of [voice] autosegment.

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13) Compared to (16a), the competitor like *\[...im-ba...\]* still fails to win with the fatal violation of Ident[Voi] partially ranked over Share[Voi] at Step 2. Also see footnote 15.

14) Some might say that *NÇ[PL] and Share[PL] are in conflict due to their different requirements. It is true, indeed. *NÇ[PL], a context-sensitive markedness constraint, goes against Share[PL], i.e., context-free. In fact, the former entirely bans the sequence of nasal-voiceless C sharing the same [PL] feature but the latter favors feature agreement no matter what C is voiced or voiceless. Under the POC model, they are partially ranked, i.e., not fixed, which leads to conflict; at Step 1, Share[PL] induces feature agreement while, at Step 2, *NÇ[PL] blocks it but only affects the sequence of nasal-voiceless C since voiced stops are not relevant to CA in Kinyarwanda. Therefore, the sequence of nasal-voiced C always preserves feature agreement no matter where Share[PL] is ranked, i.e., below or over *NÇ[PL].

Given the fact that ND is not obligatory in this language, the ranking of Share[Voi] and Ident[Voi] is not fixed, i.e., partially ordered. Following the Kimper's (2008) POC model under serialism, the partial order of Share[Voi] and Ident[Voi] is responsible for the presence or absence of ND.

Under the partial order of Share[Voi] >> Ident[Voi] at Step 3, let us take into account the optional ND process at the final stage of harmonic improvement under HS-OT as in (18).[15)]

(18) With nasal devoicing
At Step 3

/im-hapuro/	Ons	*NÇ [PL]	Share (PL)	Share (Voi)	Ident (PL)	Ident (Voi)
☞a. im̥-ha...			1			1
b. im-ha...			1	1 W		L

From Step 2 above, the local output in (16a) is fed back into the process of ND at Step 3 here as indicated in (18). Due to the demand of Share(Voi) partially ranked over Ident(Voi), the local output in (18a) fares better than its competitor in (18b). Therefore, two adjoined segments share the same token of [voice] autosegment. No further harmonic improvement is possible, thus (18a) is mapped onto the latest output of Eval at the convergent step, i.e., Step 4.

As such, consonant harmony in Kinyarwanda has been dealt with via the architecture of HS-OT. A nasal target obligatorily experiences the labial, coronal, and dorsal place of articulation assimilation and further gets devoiced as well. Especially, the latter shows the optional characteristic when two relevant constraints are not fixed, i.e., partially ordered. In addition, voiceless stops further undergo aspiration obligatorily after the stage of NA, which also results in the POC effect, thus they lose their original place and turn into [h] in unison, i.e., neutralized.

15) At this moment, let us briefly consider the absence of ND process. Going back to the tableau in (16) where CA is the final stage of harmonic improvement, if the partial order of Ident[Voi] >> Share[Voi], as italicized below, is embedded into the tableau, the total order is as follows; Onset, *NÇ[PL] >> Share[PL], *Ident[Voi]* >> Ident[PL], *Share[Voi]* but, with their reverse order, ND optionally takes place as verified in (18).

4. Conclusion

Thus far, it has been highlighted that assimilation as feature agreement is attributed to feature sharing via the mechanism of Share[F] under HS-OT where optimality is locally achieved and harmony is gradually improved. In order to confirm and support the fact that feature sharing approach via Share[F] goes well with the phonology of harmony, this paper focuses on some aspects of consonant-related phonological phenomena found in the language of Kinyarwanda; NA feeds CA on one hand and ND is optionally applied on the other hand. Given Kimenyi's (1979) rule-based approach, NA must precede CA, which makes it possible to recover the original place of a voiceless stop via the place of its nasal target. Recall that it leaves its original place onto the preceding nasal target through the NA process; a labial in *[im-h...]*, a coronal in *[in-h...]* and a dorsal in *[iŋ-h...]*.

In addition, for the next stage of CA, the OCP-based phonotactic constraint *NÇ[PL] is ventured and also put over Share[PL] via the POC model under serialism (Pater, 2007; Kimper, 2008). At Step 2, the partial order of *NÇ[PL] >> Share[PL] (as well as the partial order of *CG[Pal] >> Share[PL] for the glide y-deletion after NA) lets all the voiceless stops neutralized into [h]. Note that their reverse order is required at Step 1 where the NA process is obligatorily fulfilled. Therefore, these two obligatory processes of consonant harmony guarantee the iterative steps of NA, CA, and convergence.

In the meanwhile, ND demands one more round of the Gen-Eval loop. The POC model under HS-OT embodies local optimality in optionality. With the additional stage of ND at Step 3 via the partial order of Share[Voi] ranked over Ident(Voi), the serial steps of NA, CA, ND, and convergence are essential. However, for the absence of ND, that is, all the harmony process is completed at the stage of CA, their reverse order is chosen, i.e., Ident(Voi) >> Share(Voi).

As such, as apparently shown from the target data of Kinyarwanda, feature sharing approach via Share[F] is quite suitable for the phonology of harmony where a target sound is locally adjacent to its conditioning sound. Under HS-OT, serial derivations guarantee both locality in optimality and gradualness in harmony improvement and further the POC model where the relevant constraints are partially ordered correctly predicts optionality as well as consonant phonotactics.

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