# Gradual Divergence in MOP and POC: Focus on Burmese Noun Compounding*

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**Lee, Minkyung. (2013). Gradual Divergence in MOP and POC: Focus on Burmese Noun Compounding.** *The Linguistic Association of Korea Journal, 21*(4), 1-25. When two nouns are compounded over a morpheme boundary, two typical phonological phenomena are found in Burmese: counterfeeding opacity and optionality. In a rule-based perspective, vowel weakening is underapplied though the rule description is surface-true since the later application of schwa deletion creates the right environment of vowel reduction too late. Moreover, optional application of voicing extension and deaspiration results in multiple optima. In Harmonic Serialism(HS), a step-wise derivation guarantees gradual harmony improvement via the multiple passes of Gen and Eval loop. For counterfeeding opacity, Markedness-oriented Precedence (MOP) constraint evaluates satisfaction order in a candidate chain, not faithfulness-based violation order. Meanwhile, a different total order on Partially Ordered Constraints(POC) in HS is responsible for free variation. Under the HS's unique property of gradualness, MOP and POC well diagnose and analyze opacity and optionality in Burmese noun compounding.

**Key Words:** harmonic serialism, gradual divergence, MOP, POC, Burmese noun compounding, counterfeeding opacity, optionality

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# 1. Introduction

Optimality Theory (henceforth OT)(McCarthy & Prince 1995, Prince & Smolensky 2004), starting with the parallel version of OT, succeeds to the most recent version of OT called Harmonic Serialism (hereafter HS, McCarthy 2007, 2008a, b, 2009) based upon gradualness. Unlike parallel OT, serial OT, so-called a derivational OT, stands on its unique property of gradualism. In HS, multiple steps of an intermediate derivation are embedded between the input and the ultimate output through the multiple passes of Gen-Eval loop. As each derivation progresses step by step, harmony is gradually improved. Accordingly, optimality in HS is realized in a local pattern, but not globally at once. Therefore, in serial OT, the input cannot map onto the final output in a single step.

Given these two core principles of gradualness and harmonic improvement in HS, as clearly evidenced in previous literature (Lee 2007, 2011a, b, c), the opaque case of non-surface-apparent or non-surface-true (the terminology due to McCarthy 1999) is successfully dealt with. In addition, optionality in phonology causing multiple variants is also straightforwardly accounted for within the HS architecture.[1)]

Targeting the data of Burmese noun compounds and examining what phonological changes are found in word formation process of noun compounding, this paper demonstrates how serial OT diagnoses and analyzes the phonology operating in Burmese morphology.[2)] When two words are adjacent across a morpheme boundary, i.e., they are compounded, two interesting phonological phenomena are observed: underapplication opacity through the rule ordering paradox and optionality (or free variation, Kager 1999) resulting in multiple variants. The presence or absence of rule application incurs variability.

To this end, section 2 introduces the primary cores of serialism-oriented OT

1) Note that serial OT is not an alternative to parallel OT. As argued in McCarthy (2008b:504), it is a variant implementation of OT's basic ideas, just like parallel OT. However, unlike parallel OT, serial OT relies on the entirely different architecture of gradualness whereby it achieves local optimality and gradual harmonic improvement.

2) Given Campbell (1991:241), Burmese, a Burmic branch of the Tibeto-Burmese family, is the official language of the Republic of Burma spoken by about 30 million people.

model and discusses how it accomplishes gradualness and harmonic improvement. Under gradualism, the necessity of Precedence (henceforth Prec) constraint based upon markedness satisfaction order in a candidate chain, not on faithfulness violation order (McCarthy 2007), and its key role in opacity will be highlighted. Furthermore, in line with Kimper (2008), Partially Ordered Constraints (hereafter POC, Anttila 1997) will be adopted within HS for optionality. Section 3 investigates and discusses the major phonological phenomena observed in Burmese noun compounding process. In Burmese noun compounding, the presence or absence of a schwa vowel, whether or not it is underlying or derived, plays an important factor to affect other phonological changes. In section 4, focusing on two typical phonological changes of counterfeeding opacity and optionality, a serial OT account will be provided. Gradual divergence of harmony from the input to the ultimate output is guaranteed in opacity via MOP while optionality via POC under HS. Section 5 summarizes and concludes the paper.

## 2. Gradualness and Harmonic Improvement in HS

Under parallel OT pursuing globalism (McCarthy & Prince 1995, Prince & Smolensky 2004), phonological changes take place at once as exemplified in the /pap/→[pa.bə] mapping in which both Dep(=No insertion) and Id(voi)(=Featural identity in voice) are violated simultaneously. However, serial OT (McCarthy 2007, 2008a, b, 2009) underlies two core principles of gradualism and harmonic improvement. Therefore, phonological changes arise step-by-step through the multiple passes of Gen and Eval loop as illustrated in (1). The data come from McCarthy (2007:63).

(1) HS's serial derivations

Step 1: /pap/→ [pa.pə]

| /pap/ | No-coda | Dep | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|---|
| a. pap | W1 | L | L | |
| ☞b. pa.pə | | 1 | 1 | |

Step 2: /pa.pə/→[pa.bə]

| /pa.pə/ | No-coda | Dep | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|---|
| c. pa.pə | | | W1 | L |
| ☞d. pa.bə | | | | 1 |

Step 3: Convergence

| /pa.bə/ | No-coda | Dep | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|---|
| pa.bə | | | | |

Under the gradualness requirement in HS, the input /pap/ maps into [pa.pə] at Step 1, which is the locally chosen optimal output (not an ultimate output), but again fed back into the following Gen. This time, the local optimum /pa.pə/ becomes [pa.bə] at Step 2, which is yielded again as a new input for the next path of derivation. However, no further harmonic improvement is made, and thus /pa.bə/ is convergent to the most recent output of Eval at Step 3. Therefore, the whole HS's derivation terminates here. Note that the global mapping of /pap/ to [pa.bə] in a single step is not valid in HS due to gradualness in harmonic improvement.

Gradualness in HS affects the generation of valid candidate chains as laid out in (2).

(2) Valid chains for input /pap/ (McCarthy 2007:63)

a. <pap> Faithful parse
b. <pap, pa.pə> *Dep
c. <pap. pa> *Max
d. <pap, pa.pə, pa.bə> *Dep → *Id(voi)

Each candidate chain in (2) is valid since it violates a single faithfulness constraint at a time. Given the ranking in (1), the candidate chain in (2d)

becomes optimal. Therefore, the potential chain like *<pap, pabə> is fatally ruled out with more than one faithfulness violation in a chain, i.e., Dep and Id(voi) violations at once. Compared to this, the chain in (2d) fully satisfies gradualness in harmonic improvement.

From the candidate chains in (2), we see the intermediate stages of derivation in a chain where the violation order of a faithfulness constraint is recorded. In HS, regarding opacity, Prec constraint evaluates the violation order of faithfulness constraints in a chain as introduced in (3).

(3) Prec constraint (McCarthy 2006:25)
Prec(A, B):
Let A′ and B′ stand for forms that add violations of the faithfulness constraints A and B, respectively. To any chain of the form <X, B′, Y>, if X does not contain A′, assign a violation mark, and to any chain of the form <X, B′, Y>, if Y contains A′, assign a violation mark.

As defined in (3), constraint A violation must precede B violation in order as in (4b). Note that, as in (4a), only A violation is not the case of Prec violation. A violation cannot follow B violation and B violation cannot precede A violation as in (4d). Otherwise, Prec is violated twice in total. In addition, as shown in (4c), if there appears B violation in a chain, surely A violation must preexists. Otherwise, Prec is still violated.

(4) The evaluation of Prec violation

| | Prec(A, B) |
|---|---|
| a. A violation only | ∨ |
| b. A→B violation | ∨ |
| c. B violation only | * |
| d. B→A violation | ** |

As argued in McCarthy (2007), Prec constraint should obey the Metaconstraint introduced in (5) and accordingly, the ranking of Prec(A, B) in hierarchy is determined.

(5) Metaconstraint on the ranking of Prec constraint (McCarthy 2007:99)
B >> Prec(A, B)

Here we see that Prec constraint cannot sit over the constituent B of Prec(A, B). However, as argued in previous literature (Lee 2008, 2009), Prec constraint based on faithfulness violation order under Metaconstraint cannot predict opacity satisfactorily and straightforwardly.[3)]

Alternatively, in line with Lee (2008, 2009), MOP (originally proposed by Lee 2006) with markedness satisfaction order will be employed here, instead. MOP better conforms to the spirit of Metaconstraint and further gets rid of the side-effect of faithfulness-based Prec constraint.

For free variation in HS, following Kimper (2008:3), POC (Anttila 1997) will be employed.[4)] Given the POC model, a grammar consists of constraints and their rankings but the rankings are not complete as shown in (6).

(6) Partially Ordered Constraints (POC)
a. Constraints: A, B, C
b. Partially ordered rankings: A >> B, A >> C
c. Two possible total orders based on partially ordered constraints:
A >> B >> C, A >> C >> B

Given the constraints A, B, C in (6a), if we assume that there are two partial orders of constraint A ranked over B and over C as in (6b), we obtain two possible total orders as arranged in (6c). Therefore, the possibility of multiple total orders on POC derives variability.

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3) Due to space limit, this paper cannot touch upon the contradiction of Metaconstraint with faithfulness-based Prec here. As strongly argued in Lee (2008, 2009), counterbleeding opacity of /-ti/ suffixation in Modern Hebrew(Levi 2000) and counterfeeding opacity in Bedouin Arabic are not correctly predicted by faithfulness-based Prec under Metaconstraint. Also see Lee (2011) supporting markedness-oriented Prec for opacity in Turkish allomorph selection.

4) Including POC, Stochastic OT(Boersma 1997) and Floating Constraints (Nagy & Reynolds 1997) commonly claim that variability results from multiple available rankings of a language's constraint hierarchy. Kimper(2008), following Pater(2007), adopts POC within HS to deal with optional variation found in Bengali minor phrase.

Taken together, HS-oriented OT model permits a step-wise and iterative derivation via the multiple passes of Gen and Eval loop and thus harmonic improvement is always local and gradual. For opacity in serialism, MOP with markedness satisfaction order in a chain necessitates. For the emergence of optionality, each variant results from each different total order on partially ordered constraints.

## 3. Phonological Changes of Burmese Noun Compounding

This section examines the data of Burmese noun compounds and further discusses what phonological changes take place when two words are adjacent over a morpheme boundary, i.e., compounded. Let us consider the preliminary data as laid out in (7).

(7) Noun compounds in Burmese (Okell 1969)[5)6)]

| | |
|---|---|
| a. pàñ (flower) + əyauñ (color) | pàñyauñ (pink) |
| b. əhmù (leader) + əmaʔ (minister) | hmùmaʔ (ministers)[7)] |
| c. bəma (Burmese) + əká (dance) | bəmaga(Burmese dance) |

5) Given Cornyn (1944:7), in Burmese, stops, affricates, and sibilant consonants take place in five places of articulation in three orders as below:

| | Labial stop | Alveolar stop | Normal sibilant | Palatal affricate | Velar stop |
|---|---|---|---|---|---|
| Plain | p | t | s | c | k |
| Aspirated | ph | th | sh | ch | kh |
| Voiced | b | d | z | j | g |

6) In this paper, following Cornrie(1987), Okell's [ă], a toneless weak vowel, is represented by [ə]. Other notations are shown as below (Okell 1969:8):
hC: an aspirated consonant (=[$C^h$] in IPA) (cf. In footnote (5), Cornyn(1944) uses Ch for aspirated obstruents, instead.)
Ch: a dental sound (For example, *dh* is a voiced dental fricative like *th* in English *there*.)
Vñ : a nasalized vowel

7) Given Cornyn (1944:8), nasals in Burmese occur in three positions with the division of plain vs. preaspirated as below:

| | labial | alveolar | velar |
|---|---|---|---|
| plain | m | n | ŋ |
| preaspirated | hm | hn | hŋ |

d. eiñ (house) + əthiʔ (new) eiñdhiʔ (new house)
e. əhpou (male) + əthañ (sound) hpoudhañ (male voice)
f. əyauñ (color) + souñ (be complete) yauñzouñ (in color)
g. əywe (age) + tu (be the same) ywedu (co-eval)
h. əyweʔ (leaf) + əhaùñ (old) yweʔhaùñ (old leaf)
i. ətheʔ (breath) + əpyìñ (heavy) theʔpyìn (sigh)
j. htwi (spitting) + hkənè (suffix) htwigənè (expressing disgust)
k. məneʔhpyañ (tomorrow) + əhka (time) məneʔhpyañga (tomorrow)

The data above tell us that weak vowel deletion (WV-del) takes place and thus a noun-initial [ə] is deleted in compounds. In [W1+W2] compounds, the schwa vowel, either in W1 or W2, disappears as long as it stands in the initial position. However, as shown in (7c), if there is a preceding consonant, the weak vowel remains intact.

Another interesting change witnessed here is that the first consonant of W2 tends to be voiced. In (7c-g), (7j), and (7k), the voiceless consonants become voiced, while those in (7h-i) remain voiceless. Here there is a general tendency that a consonant in between two voiced sounds surfaces as voiced sounds.[8] However, as shown in (7h-i), there appears a glottal stop when the consonant fails to be voiced. This is due to the voiceless nature of the glottal stop.

Now let us take a look at a more complicated set of data. Consider the examples as laid out in (8).

(8) Other phonological changes in Burmese noun compounds
a. hniʔ (two) + lá (month) hnəlá (two months)
b. meìñmá (woman) + (ə)wuʔ (clothing) meìñməwuʔ (woman's clothing)
c. làñmá (main road) + to (honorific) làñmədo (main road)
d. nà (ear) + caʔ (clamp) nəjaʔ (earphone)

8) As observed in Okell (1969:15), there are lexical exceptions to this rule as shown below:
hna (nose) + (ə)hkaùñ (hollow) hnəhkaùñ (nostril)
nwà (ox) + (ə)htì (male) nəhtì (bull)
This seems to be related to the nature of the toneless weak vowel [ə]. Here the general pattern noticeable is that the aspirated sounds are not voiced after [ə]. This is left open to further research.

| | |
|---|---|
| e. pà (cheek) + saʔ (join) | pəzaʔ, bəzaʔ (mouth) |
| f. sà (eat) + pwè (gathering) | səbwè, zəbwè (table) |
| g. hkà (waist) + paʔ (go around) | hkəbaʔ, kəbaʔ, gəbaʔ (belt) |
| h. hsañ (hair) + (ə)piñ (thread) | hsəbiñ, səbiñ, zəbiñ (hair) |
| i. kàñ (bank) + (ə)pà (vicinity) | kəbà, gəbà (bank cliff) |

Compared to the data in (7) where vowel weakening (V-Weak) does not take place, one thing to be clearly noted in (8) is that the last vowel of W1 is reduced. Though there is no known generalization about the vowel reduction in Burmese noun compounds, as Lee (2013) argues, it is presumed that vowel reduction occurs only when W2 is monosyllabic. Note that W2 are all monosyllabic words except in (8b), (8h), and (8i) which have optional [ə] sounds as indicated by the parentheses. Following Okell's (1969: 243- 244) claim that some [ə]'s are underlying while others are simply prefixes, we can deduce that [ə] may imply a derivative prefix in Burmese. Therefore, if we interpret that the parenthesis means the prefix, we may as well argue that the forms without [ə] are the inputs for compounding. Then we can generalize that the monosyllabicity of W2 is the necessary condition for vowel reduction.

Burmese has four diphthongs, /ei/, /au/, /ai/, and /ou/, which are not reduced as witnessed in (7e-f). As argued in Lee (2013), given the assumption that the diphthongs are the sequence of [+syllabic] and [-syllabic] sound, we see why the diphthongs do not undergo vowel reduction.[9] However, the final vowels in (7a-c) and (7h-i), the data repeated here in (9) but simplified, fail to undergo vowel reduction. Of particular interest in this regard is that there already exists another [ə] either in the penultimate position of W1 or in the first position of W2.

(9) With the lack of vowel reduction

| | |
|---|---|
| a. pàñ (flower) + əyauñ (color) | pàñyauñ (pink) |
| b. əhmù (leader) + əmaʔ (minister) | hmùmaʔ (ministers) |
| c. əyweʔ (leaf) + əhaùñ (old) | yweʔhaùñ (old leaf) |

9) Though this paper follows Okell's(1969) transcription, surely the two segments are not both vowels. In this paper, following Cornyn(1944:8-9), a diphthong is represented as the sequence of a vowel and a glide.

Here note that vowel reduction results in the sequence of two weak vowels. Therefore, the avoidance of vowel reduction is due to the OCP effect as posited in (10).

(10) Vowel OCP (Goldsmith 1979)
On the syllabic level, no two toneless vowels can come together.[10)]

The OCP in (10) is responsible for the presence or absence of vowel reduction in the data in (7). Therefore, the OCP principle should be obeyed in word formation process of Burmese morphology as proved in (11).

(11) The OCP effect
/əhmù (leader) + əmaʔ (minister)(7b)/ → [hmùmaʔ (ministers)]

| a. UR: | əhmù + əmaʔ | b. UR: | əhmù + əmaʔ |
|---|---|---|---|
| V-Weak: | (blocked by OCP) | WV-del: | hmù + ma |
| WV-del: | hmù + ma | V-Weak: | hmə + ma |
| PR: | [hmùma] | PR: | *[hməma] |

As clarified in (11b), with the reversed order of the rule application, i.e., WV-del feeds V-Weak, we obtain the wrong result. Once a weak vowel is deleted, the OCP cannot prevent V-Weak. This implies that there should be a crucial ordering between these two rules. Unlike in (11b), the reversed order of feeding, i.e., counterfeeding, should be enforced to get the correct result as in (11a). Therefore, due to the vital role of the OCP, V-Weak should precede WV-del in the counterfeeding rule relation as elaborated in (12).

(12) Counterfeeding rule order between V-Weak and WV-del

/pàñ (flower) + əyauñ (color)(7a)/

| V-Weak: | ---------- |
|---|---|
| WV-del: | pàñ + yauñ |
| PR: | [pàñyauñ] |

10) There is one exception recorded in Okell(1969) to the vowel OCP proposed here. /kəlà (India) + (ə)hsin (looks)/ is realized as [kələhsin] (Indian looking).

Unlike in (12), if WV-del is applied prior to V-Weak, then it could create the right environment for the application of V-Weak. Then the surface form wrongly becomes *[pənyauñ], thus V-weak should precede WV-del in counterfeeding rule relation.

Once a vowel is weakened, then the following coda consonant, if any, is eliminated as shown in (8a) and (8h-i), here repeated in (13).

(13) Final consonant deletion (C-del)

| | |
|---|---|
| a. hniʔ (two) + lá (month) | hnəlá (two months) |
| b. kàñ (bank) + (ə)pà (vicinity) | kəbà, gəbà (bank cliff) |
| c. hsañ (hair) + (ə)piñ (thread) | hsəbiñ, səbiñ, zəbiñ (hair) |

Here interestingly enough, the data in (8e-i) (also repeated in (13b-c)) show the optional variation of voicing in the pre-[ə] position. Given the variability of the voicing in these examples, we can safely assume that [+voice] feature is extended to the preceding consonant across [ə]. As clarified in (7e) and (7j-k), here repeated but simplified in (14b), the [+voice] feature from the first consonant of W2 fails to spread to the preceding voiceless consonant across a full vowel. Therefore, we see that, as indicated in (14a), the condition that a consonant is voiced before ə[+voice] is indispensable.

(14) Obstruent voicing (Ob-voi) and voicing extension (V-ext)

| | |
|---|---|
| a. With Ob-voi and V-ext | |
| pà (cheek) + saʔ (join) | pəzaʔ, bəzaʔ (mouth) |
| sà (eat) + pwè (gathering) | səbwè, zəbwè (table) |
| b. Without Ob-voi and V-ext | |
| əhpou (male) + əthañ (sound) | hpoudhañ (male voice) |
| htwi (spitting) + hkənè (suffix) | htwigənè (expressing disgust) |

Note that V-ext is optional since the surface form is acceptable without V-ext as the variability of pronunciation in (14a) indicates.

Finally, regarding the three-way variation shown in (8g-h), here repeated in (15), what remains unresolved is the presence of plain voiceless stops before the ə[+voice] sequence.

(15) Three-way variation

| | |
|---|---|
| a. hkà (waist) + paʔ (go around) | hkəbaʔ, kəbaʔ, gəbaʔ (belt) |
| b. hsañ (hair) + (ə)piñ (thread) | hsəbiñ, səbiñ, zəbiñ (hair) |

To deal with the data in (15), we may assume that there is yet another optional change of an aspirated stop into a plain stop before a weak vowel (called Deasp(iration)). In other words, [Spread Glottis] loses its value before a schwa vowel, though it is optional. Then in [hkəbaʔ] in (15a), if V-ext is applied, the output form is [gəbaʔ], but if Deasp is applied the result is [kəbaʔ] as elaborated in (16).

(16) Optional rule application

| | /hkà + paʔ (8g)/ |
|---|---|
| V-Weak: | hkə + paʔ |
| WV-del: | ---------- |
| C-del: | ---------- |
| Ob-voice: | hkə + baʔ |
| (V-ext)(opt): | (gə + baʔ) |
| (Deasp)(opt): | (kə + baʔ) |
| PR: | [hkəbaʔ], [gəbaʔ], [kəbaʔ] |

Thus far, it has been shown that V-Weak counterfeeds WV-del in rule relation and that V-Weak feeds C-del and Ob-voi feeds V-ext as well. Moreover, V-Weak feeds V-ext and Deasp but V-ext and Deasp are optional, resulting in multiple variants.

## 4. Serialism-oriented OT Account

Now employing the latest version of OT (McCarthy & Prince 1995, Prince & Smolensky 2004) called HS (McCarthy 2008a, b, 2009), let us consider how serial OT captures the phonological characteristics of Burmese word formation process of noun compounding.

Given the data observations where phonological changes found in Burmese

noun compounds are closely related to the presence or absence of a toneless weak vowel, we see that the word-initial schwa is deleted when two words are adjacent in compounding context. This means that the constraint posited in (17a) is top-ranked in hierarchy. Moreover, when W1 and W2 are adjacent over a morpheme boundary, the vowel of W1 is obligatorily weakened under the condition that W2 is monosyllabic. The constraint in (17b) compels a tonal vowel to be reduced, realized as a schwa. This implies that Max and Ident constraints are bottom-ranked and thus readily violated, respectively.

(17) Top-ranked constraints
  a. $^{*}$#ə]$_{\text{Noun Compound}}$ (=*#ə]$_{NC}$):
     No word-initial schwa in noun compound.
  b. *V′+ $\sigma$ ]$_{NC}$ (=(Red)uce)(Kager 1999:406):
     Avoid a tonal vowel before a monosyllable in noun compound.

One step further, the OCP constraint in (18) prohibits the sequence of two schwa vowels. As argued earlier, V-Weak is entirely barred due to the key role of OCP, thus V-Weak is underapplied in the counterfeeding rule relation with WV-del.

(18) Vowel OCP (Goldsmith 1979):
     Avoid a toneless schwa sequence.

*VC$_{vl}$V in (19a) militates against any discrepancy of voicing when an intervocalic consonant does not agree in [voice] with its neighboring sounds. Furthermore, as posited in (19b), following McCarthy (2009), the [voice] feature of a voiced obstruent spreads to the adjacent obstruent, which induces the agreement to the [voice] value of a trigger.

(19) More constraints
  a. *VC$_{\text{voiceless}}$V (=*VC$_{vl}$V):
     Avoid an intervocalic voiceless consonant.
  b. Share(voice) (=Sh(voi)):
     Assign a violation mark for every pair of adjacent obstruents not linked to the same token of [voice].

Given the fact that Burmese has a strong tendency to disfavor a word-final [əC] sequence in noun compounds, we need a specific markedness constraint as posited in (20a). On the other hand, the specific sequential constraint in (20b) filters out any candidate with a weak vowel preceded by an aspirated obstruent.

(20) The specific sequential constraints
a. *əC#]$_{NC}$: No word-final əC sequence in noun compound.
b. *[SG]ə]$_{\sigma}$ (=*[SG]): No SG before tautosyllabic /ə/.

With the constraints postulated so far, now let us consider how serial OT achieves the gradual divergence from the input step-by-step through the multiple intermediate derivations via Gen and Eval loop as the tableaux in (21) illustrates.

(21) Gradualness in harmonic improvement in HS
Step 1: /nà+caʔ/ → [nə+caʔ]

| /nà+caʔ/ | Red | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|
| a. na+caʔ | W1 | 1 | |
| ☞b. nə+caʔ | | 1 | |

Step 2: /nə+caʔ/ → [nə+jaʔ]

| /nə+caʔ/ | Red | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|
| c. nə+caʔ | | W1 | L |
| ☞d. nə+jaʔ | | | 1 |

Step 3: Convergence[11)]

| /nə+jaʔ/ | Red | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|
| nə+jaʔ | | | |

At Step 1, the input is mapped onto the candidate in (21b) with more

11) Throughout the paper, the convergent step of an HS derivation is abbreviated since the latest input to Gen is identical to the most recent output of Eval, thus no further harmonic improvement is possible. Also, for easy configuration in a tableau, the constraints not relevant in the evaluation are omitted.

harmonic improvement and thus the latter is chosen as a local optimum. (21a) fares worse with no vowel reduction. Here note that, in HS, a serial derivation achieves local optimality on the course of derivation. Therefore, serial OT does not allow multiple changes from the input in a single step. In other words, passing through each step of derivation, harmonic improvement should be gradually increased until no further harmonic improvement is possible. At Step 2, the local optimum in (21b) is fed back into Gen again as a new input and now mapped onto (21d). At Step 3, this newly chosen local optimum is recalled to Gen but it is identical to the most recent output of Eval, i.e., they are convergent, and thus the whole step-wise derivations are complete here.

The tableaux in (22) tell us that a diphthong is not reduced to be a schwa though it is followed by a monosyllable.

(22) Step 1: with word-initial /ə/ deletion[12)]

| /əhpou+əthañ/ | *#ə]$_{NC}$ | Red | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|---|
| a. əhpou+əthañ | W2 | | | |
| b. əhpou+thañ | W1 | 1 | 1 | |
| ☞c. hpou+thañ | | 1 | 1 | |

Step 2: with intervocalic voicing[13)]

| /hpou+thañ/ | *#ə]$_{NC}$ | Red | *VC$_{vl}$V | Id(voi) |
|---|---|---|---|---|
| d. hpou+thañ | | 1 | W1 | L |
| ☞e. hpou+dhañ | | 1 | | 1 |

At Step 1, the locally chosen output (22c) is mapped into (22e) at Step 2

12) Don't be confused that, in (22c) at Step 1, schwa deletion in both W1 and W2 fully obeys the HS's gradualness requirement with a single basic faithfulness violation, Max-Seg(=No deletion). See McCarthy (2007:61-62, 2008b:501) for the revised version of 'a single modification at a time'.

13) The potential candidate like *[hpə+dhañ] is fatally filtered out under the assumption that Parse(Diph)(=Realize a diphthong on the surface.) is top-ranked over Reduce in hierarchy. Therefore, no diphthongs are reduced in Burmese. One step further, *[hbou+dhañ] is not valid, either under the top-ranked constraint like *VoicedAspObs (=No voiced aspirated obstruents) since voiced aspirated obstruents are not found in Burmese phonemic inventory. Also see footnote 5.

with better harmonic improvement. Therefore, (22e) finally surfaces as the ultimate output at the following convergent step where there is no further harmonic improvement.

Now let us move onto the data of (8e) to (8i) involving optionality. To incorporate these into the current HS analysis, as fully discussed earlier, this paper employs the POC model (Anttila 1997) in line with Kimper(2008)(an original proposal by Pater 2007). POC in HS imposes a different total order on partially ordered constraints at Eval and thus optionality in HS is predicted as local and gradual.

Given POC in HS, optionality in (13b)(=8i) results from a different total order with partially ordered constraints as proved in (23) and (24).

(23) Optionality via POC: Sh(voi) >> Id(voi)

Step 1

| /kàñ+pà/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Sh (voi) | Id (voi) |
|---|---|---|---|---|---|
| a. kàñ+pà | W1 | L | 1 | | |
| ☞b. kəñ+pà | | 1 | 1 | | |

Step 2

| /kəñ+pà/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Sh (voi) | Id (voi) |
|---|---|---|---|---|---|
| c. kəñ+pà | | W1 | L | | |
| ☞d. kə+pà | | | 1 | | |

Step 3

| /kə+pà/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Sh (voi) | Id (voi) |
|---|---|---|---|---|---|
| e. kə+pà | | | W1 | L | L |
| ☞f. kə+bà | | | | 1 | 1 |

Step 4

| /kə+bà/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Sh (voi) | Id (voi) |
|---|---|---|---|---|---|
| g. kə+bà | | | | W1 | L |
| ☞h. gə+bà | | | | | 1 |

The evaluation tableaux above tell us that the partially ordered ranking of Sh(voi)>>Id(voi) crucially operates at Step 4 and that each local optimum is yielded to Gen again with gradual harmony improvement. The whole derivation terminates at the convergent step where the locally chosen output in (23h) is identical to the latest output of Eval.

For the other optional variant in (13b), this time, POC in HS imposes a partial order of Id(voi) ranked over Sh(voi) as indicated in (24).

(24) The other optional variant by POC: Id(voi) >> Sh(voi)
Step 4: Convergence

| /kə+bà/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Id (voi) | Sh (voi) |
|---|---|---|---|---|---|
| ☞a. kə+bà | | | | | 1 |
| b. gə+bà | | | | W1 | L |

From Step 1 to Step 3, the partially ordered ranking of Id(voi)>>Sh(voi) does not play a crucial role in the evaluation. Thus, local optimality up to Step 3 is the same as (23) though the total order with a different partial order between Id(voi) and Sh(voi) operates. At Step 4, we see the crucial role of POC. At the following convergent step, the local output in (24a) is merged into the latest output of Eval. Here note again that an invariant total order, this time, with the partial order of Id(voi)>>Sh(voi), works during the whole derivational processes. As such, POC in HS conforms to the HS's basic spirits and further successfully predicts variability.

For the data in (15) where three optional variants emerge, we see that POC in HS still plays a pivotal role in Burmese noun compounding. For three-way optionality in (15b)(=8h), the partial ranking of *[SG] posited in (20b) and Max(SG) along with that of Id(voi) and Sh(voi) leads to optionality as evidenced in (25).

(25) With POC: Max(SG) >> Id(voi) >> Sh(voi) >> *[SG]

Step 1

| /hsañ+piñ/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Max (SG) | Id (voi) | Sh (voi) | *[SG] |
|---|---|---|---|---|---|---|---|
| a. hsañ+piñ | W1 | L | | | | | 1 |
| ☞b. hsəñ+piñ | | 1 | | | | | 1 |

Step 2

| /hsəñ+piñ/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Max (SG) | Id (voi) | Sh (voi) | *[SG] |
|---|---|---|---|---|---|---|---|
| c. hsəñ+piñ | | W1 | L | | | | 1 |
| ☞d. hsə+piñ | | | 1 | | | | 1 |

Step 3

| /hsə+piñ/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | Max (SG) | Id (voi) | Sh (voi) | *[SG] |
|---|---|---|---|---|---|---|---|
| e. hsə+piñ | | | W1 | | L | L | 1 |
| ☞f. hsə+biñ | | | | | 1 | 1 | 1 |

The tableaux in (25) are self-explanatory. Max(SG) ranked over *[SG] militates against any deletion of [SG] from the input. Therefore, given the step-wise derivation through the multiple passes of Gen-Eval, the local output in (25f) is given birth again as the ultimate output at the convergent point.

For the remaining variants which do not hold [SG], here we see that Max(SG) is bottom-ranked, though not shown in the tableaux here, and that, as clarified in (23) and (24), the partially ordered ranking of Id(voi) and Sh(voi) predicts more optional variants as shown in (26) and (27).[14)]

14) Due to space limit, the full-fledged HS derivations are not displayed throughout the paper. Note that, from Step 1 to Step 3, local optimality is the same as the tableaux from (25) through to (27) though they rely on the different total order with the partially ordered constraints. This implies that the role of POC starts to play at Step 4 in (26) and (27). Therefore, the derivational processes up to Step 3 are all omitted in (26) and (27).

(26) With POC: *[SG] >> Sh(voi) >> Id(voi) >> Max(SG)

Step 4:

| /hsə+biñ/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | *[SG] | Sh (voi) | Id (voi) |
|---|---|---|---|---|---|---|
| a. hsə+biñ | | | | W1 | 1 | |
| ☞b. sə+biñ | | | | | 1 | |

Step 5:

| /sə+biñ/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | *[SG] | Sh (voi) | Id (voi) |
|---|---|---|---|---|---|---|
| c. sə+biñ | | | | | W1 | L |
| ☞d. zə+biñ | | | | | | 1 |

Under the demand of gradualness in HS and with the partial order of *[SG]>>Sh(voi)>>Id(voi)>>Max(SG), the local output at Step 3 stands as a new input for the following derivation of Step 4 where (26b) is more harmonic than (26a). At Step 5, (26d) fares better with more harmonic improvement and then it is merged into the latest output of Eval at the following convergent step.

Compared to the tableaux in (26), this time, with the partial order of Id(voi)>>Sh(voi), another optional variant surfaces as verified in (27).

(27) With POC: *[SG] >> Id(voi) >> Sh(voi) >> Max(SG)

Step 4

| /hsə+biñ/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | *[SG] | Id (voi) | Sh (voi) |
|---|---|---|---|---|---|---|
| a. hsə+biñ | | | | W1 | | 1 |
| ☞b. sə+biñ | | | | | | 1 |

Step 5: Convergence

| /sə+biñ/ | Red | *əC#]$_{NC}$ | *VC$_{vl}$V | *[SG] | Id (voi) | Sh (voi) |
|---|---|---|---|---|---|---|
| ☞c. sə+biñ | | | | | | 1 |
| d. zə+biñ | | | | | W1 | L |

Due to the bottom-ranked Max(SG), the emergence of [SG] is intolerant, thus

(27b) is superior with more harmonic improvement. The local output in (27b) is convergent to the latest output of Eval in (27c).

In short, it has been highlighted that serial OT achieves gradual harmonic improvement and further, with the cooperation of the POC model in HS, it can successfully account for the case of local optionality found in Burmese noun compounding.

Finally, let us take into account for the counterfeeding rule relation between V-Weak and WV-del. As fully discussed earlier, the feeding order between the two rules gives rise to the surface-unattested result. Therefore, V-Weak must precede WV-del though the former is underapplied.

Given the gradualness-oriented HS, unlike in McCarthy (2007), we need to posit the Prec constraint based upon the satisfaction order of markedness constraints in a chain, so-called MOP, to deal with the underapplication opacity as posited in (28).[15)]

(28) Prec(Red, $^{*}$#ə]$_{NC}$)[16)]

a. Give a violation mark if the satisfaction of Red does not precede that of $^{*}$#ə]$_{NC.}$

b. Give two violation marks if the satisfaction order is entirely opposite; the satisfaction of $^{*}$#ə]$_{NC}$ cannot precede that of Reduce and the satisfaction of Reduce cannot follow that of $^{*}$#ə]$_{NC.}$

The satisfaction order of markedness constraints in Prec must be preserved to deal with counterfeeding opacity. Therefore, the satisfaction of Reduce must precede that of schwa deletion in a chain.

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15) This paper does not delve into the problematic status of the Prec constraint based on faithfulness violation order under Metaconstraint (McCarthy 2007:99). See Lee (2009) for this issue. In this paper, MOP better supports the basic spirit of Metaconstraint and further plays a key role as a determiner in opacity. Refer to Lee (2006, 2011) for details.

16) As argued in McCarthy (2007:109), under the HS's gradualness, multiple divergence from the input cannot take place at once. For instance, in Bedouin Arabic's counterfeeding opacity where low vowel raising counterfeeds vowel epenthesis, the chain like *<gabr, gibur> is not valid because it violates both Id(low) and Dep at the same time and in a single step. Likewise, in MOP, the potential chain like *<pàñ+əyauñ, pəñ+yauñ> is illegal since two markedness constraints are satisfied at once in a chain.

The ranking of the Prec posited in (28) conforms to the Metaconstraint as laid out in (29).

(29) MOP on Metaconstraint (Lee 2009:106)
$M_B$ >> Prec($M_A$, $M_B$) >> $M_A$
(M=markedness constraint)

Under the MOP on Metaconstarint in (29), the tableau in (30) predicts the underapplication opacity successfully and satisfactorily.[17)]

(30) Counterfeeding opacity

| /pàñ+əyauñ/ | *#ə]$_{NC}$ | PREC | RED | *əC#]$_{NC}$ |
|---|---|---|---|---|
| a. pàñ+əyauñ<br>< > | W1 | | | |
| ☞b.<pàñ+əyauñ, pàñ+yauñ><br><*#ə]$_{NC}$> | | 1 | 1 | |
| c.<pàñ+əyauñ, pàñ+yauñ, pəñ+yauñ><br><*#ə]$_{NC}$, Red> | | W2 | L | W1 |

The candidate chain in (30c) with feeding order fatally violates Prec, thus ruled out. Note that markedness satisfaction order in a chain is entirely opposite, resulting in the Prec violation twice in total. Therefore, (30b) wins with the one-time Prec violation since no prior satisfaction of Red does not exist in a chain.[18)]

17) Compared to the tableaux so far, the tableau in (30) shows a bit different format in which gradual divergence from the input is represented by a candidate chain. This enables Prec to play its role as a determiner on chains involving the history of markedness satisfaction. The tableaux either showing a step-wise derivation or its accumulation in a chain well reflect the HS's basic tenets of gradualness and harmonic improvement.

18) Note that, in parallel OT, intermediate derivational stages are also allowed via Sympathy(McCarthy 1999), OO-correspondence (Kenstowicz 1996, Benua 1997), Local Conjunction (Smolensky 1995) and Stratal OT (Rubach 1997, Kiparsky 2000, Ito & Mester 2003). However, as argued in McCarthy(2007), they are all inadequate as a theory of

As such, counterfeeding opacity is well predicted by the Prec based upon markedness satisfaction order that is better conforms to the basic spirit of Metaconstraint (McCarthy 2007). Therefore, MOP in HS is essential and responsible for opacity as well.

## 5. Conclusion

This paper has shown that a gradualness-oriented OT model provides a successful analysis from non-surface-true opacity to optionality(or free variation) found in Burmese noun compounding. OT with serialism, unlike OT with parallelism, requires that harmonic improvement be local and gradual, thus, the mapping of the input to the ultimate output does not come from the one-time process but from the multiple intermediate derivations via Gen and Eval loop.

When two words are adjacent and compounded over a morpheme boundary in Burmese, there appear two typical phonological phenomena: counterfeeding opacity and optionality. Vowel reduction counterfeeds schwa deletion, thus the former is underapplied though the rule description is surface-true. In addition, the presence or absence of the application of voicing extension or deaspiration leads to optionality. Given the HS's core principles of gradualness and harmonic improvement, for opacity, markedness-oriented Prec in accordance with Metaconstraint successfully predicts the opaque optimal output. Markedness satisfaction order, instead of faithfulness violation order, is evaluated in a candidate chain. Meanwhile, for optionality, a different POC is chosen for each different variant but serial harmony is achieved within the same total order on the course of the entire derivation.

As such, as clearly evidenced in Burmese noun compounding, serial OT can be successfully extended to the residual issues of phonology such as opacity and optionality that remain challengeable to parallel OT in globalism. MOP and POC well conform to the basic spirits of HS architecture and further guarantee gradual divergence in HS.

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opacity. See McCarthy (2007) for details.

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