*English Language & Literature Teaching*, Vol. *15*, No. 2 Summer 2009

# An Asymmetrical Realization of Nasal-Obstruent Clusters in English*

**Chin-Wan Chung**
(Chonbuk National University)

**Chung, Chin-Wan. (2009). An asymmetrical realization of nasal-obstruent clusters in English. *English Language & Literature Teaching, 15*(2), 51-70.**

This study focuses on the asymmetrical realization of homorganic nasal-obstruent stop clusters in English when they occur word medially and word finally. This uneven realization of NC clusters is not only controlled by the place of articulation of the cluster constituents but also by the agreement of voicing feature specifications of the cluster elements. We propose context-sensitive constraints, which are more specified versions than *NC̥ (Pater, 1996, 1999, 2004). The result of the study reveals that homorganic NC clusters consisting of coronal place feature are faithfully realized word finally while they are constrained word medially. The deletion of voiceless post-nasal coronal stop should be considered a new language specific strategy to avoid *NC̥.

**[homorganic NC clusters/constraints/ranking/optimality theory]**

## I. INTRODUCTION

Consonant clusters can occur in the same syllable or over a syllable or a morpheme boundary. While some consonant clusters are rather free to occur, some other types of clusters have restrictions in different positions in a word.[1] The limitations on the occurrence of clusters depend on the composition of the clusters such as their place and manner. In terms of place restrictions in the syllable coda, Yip (1991, p. 61) argues that restrictions on place specifications may hold for specific syllable positions, particularly codas, or for any consonant clusters (cf. Steriade, 1982; Itô, 1986). However, coronal consonants, unlike other places of articulation, enjoy a special treatment in occurrence,

* This paper was supported by Chonbuk National University in 2009. I am grateful for anonymous reviewers for their helpful comments. Any remaining errors are solely my own.

[1] We observe the occurrence of word medial sonorant clusters is relatively free in comparison with the sonorant sequences at the word final position. See (Chung, 2001; Chung, 2007b) for a more detailed analysis on syllabification and sonorant clusters.

which is also argued for by Yip (1991, p. 61) as in (1)

(1) Freedom of occurrence of coronals, geminates, and homorganic clusters has a common explanation: their lack of place features.

If we consider Yip's arguments on the restrictions on the occurrence of consonant clusters, we can propose that even though there are some restrictions, coronal consonants may occur freely in the syllable positions compared to other places of articulation such as labials and dorsals. It can be also argued that homorganic clusters should show asymmetrical realizations in the syllable coda depending on the place of articulation. Furthermore, if homorganic clusters occur heterosyllabically, they are subject to a less restricted occurrence conditions because the two consonants occur over a syllable boundary, which might be considered a less restricted environment than the syllable coda. Generally, English nasal+obstruent homorganic clusters exhibit similar realizational patterns in the syllable coda for which Yip argues. However, a close observation reveals that nasal+obstruent homorganic clusters in English show rather different realizations than the generalized occurrence patterns proposed by Yip (1991). For example, labial nasal plus obstruent stop homorganic clusters whose realizations should be controlled by the syllable position are differently realized depending on the voicing nature of the post nasal stop consonant. A cluster with a homorganic nasal plus voiceless stop is fully realized as can be seen in 'camp'; in a sequence of a nasal plus a voiced stop in the syllable coda, only the nasal is pronounced in the output as in 'bomb.'

The goal of this paper is to examine homorganic nasal plus stop clusters in English and show how they differently realized in the output when they occur tautosyllabically and heterosyllabically. Based on these observations, we will propose a theoretic analysis, which can provide comprehensive realization patterns of homorganic nasal plus stop clusters in English.

The format of the paper is as follows. Section 2 provides the description of homorganic nasal plus stop clusters in English. Section 3 reviews previous analyses of realization of homorganic clusters. Section 4 introduces constraints and their interaction for the analysis, which is followed by the conclusion and the implications of the analysis.

## II. DATA

In this section, we present tautosyllabic and heterosyllabic homorganic nasal+stop clusters in English. We first introduce such clusters occurring in the syllable coda. The data are mostly taken from Hammond (1999).

(2) Nasal+Stop sequences

| | | | |
|---|---|---|---|
| a. ramp | →[ræmp] | g. mend | → [mɛnd] |
| b. limp | → [lɪmp] | h. bond | → [band] |
| c. jump | → [dʒʌmp] | i. hand | → [hænd] |
| d. lint | → [lɪnt] | j. think | → [θɪŋk] |
| e. font | → [fɔnt] | k. bank | → [bæŋk] |
| f. cant | → [kænt] | l. sink | → [sɪŋk] |

As in (2), among the possible homorganic nasal+stop clusters such as /mp, mb, nt, nd, ŋk, ŋg/, only four of them are realized phonetically while [mb] in 'bomb' and [ŋg] in 'young' do not occur in the output. On the other hand, [mp] and [ŋk] which have the identical cluster constituents with [mb] and [ŋg] in terms of place of articulation appear in the pronunciation. Unlike the asymmetrical realization of homorganic labial and dorsal clusters, coronal homorganic clusters occur in the output without any restriction of the voicing status of the post-nasal obstruent stop, which reflects Yip's argument (1991). But her claim cannot distinguish the realization disparity between [mp]-[ŋk] and *[mb]-*[ŋg]. This also may cause a problem for Pater's suggestion (1996, 1999, 2004) that a cluster consisting of a nasal plus a voiceless obstruent is not favored in many languages, because the data in (2) show the opposite results to those of Pater's claims.

While homorganic labial and dorsal nasal plus obstruent clusters suffer from restricted realization in the syllable coda, both nasal and obstruent stop sequences over syllable boundary are realized without any limitations as shown in (3).

(3) Nasal+Stop sequences: [ɜ] indicates a long schwa.

| | | | |
|---|---|---|---|
| a. sample | →[sǽmpəl] | g. candy | → [kǽndɪ] |
| b. computer | → [kʌmpyútər] | h. gender | → [dʒέndər] |
| c. combine | → [kəmbáyn] | i. donkey | → [dáŋkɪ] |
| d. mambo | → [mámbo] | j. monkey | → [mʌ́ŋkɪ] |
| e. intern | → [íntɜrn] | k. finger | → [fíŋgər] |
| f. mentor | → [mέntər] | l. longer | → [lɔ́ŋgər] |

As observed in (3), all 6 possible homorganic nasal plus obstruent stop clusters are faithfully mapped in the output of the word's medial position. There is no distinction between coronal and peripheral places in terms of restrictions on occurrence. Thus, heterosyllabically, the homorganic nasal plus obstruent stop clusters are allowed to appear without any restrictions, which is different from what we have observed in the data for tautosyllabic homorganic clusters in (2).[2]

In the data presented in (4), homorganic coronal nasal plus voiceless obstruent stop clusters show variational realizations. The homorganic coronal cluster over a syllable boundary has two different realizations. The examples in (4) cannot be explained by the cluster occurrence restrictions that Yip (1991) proposes (cf. Chung, 2007a) because she only deals with the clusters occurring in the syllable coda rather than the word medial position.

(4) Nasal+Stop variational realizations

a. center → [sɛ́ntər]~[ sɛ́nər]
b. fantasy → [fǽntəsi]~[fǽnəsi]
c. internet → [íntərnɛ̀t]~[ínərnɛ̀t]
d. sentence → [sɛ́ntəns]~[sɛ́nəns]
e. pentagon → [pɛ́ntəgan]~[pɛ́nəgan]
f. quantity → [kwántəti]~[kwánəti]

As seen in (4), the second realization of the input indicates that the voiceless post-nasal obstruent stop is deleted in the output. This is not what we expect in the realization of the homorganic clusters because homorganic coronal clusters should occur freely in the syllable without any restrictions compared to labial or dorsal places (Davis, 1991; Yip, 1991). The difference between (3e) and (3f) and the examples in (4) is that they occur in different environments. That is, the post-nasal [t] in (3e) and (3f) is followed by the long schwa [ɜ] and [ɔ], whereas the post-nasal [t] in (4) is followed by the short schwa [ə]. The post-nasal [t] in (4) appears in the syllabically weak position which means that it occurs in the unstressed syllable. This is further supported by the following examples in (5) where the post-nasal [t] appears in the stressed syllable, which is the syllabically prominent position. A segment occurring in such a prominent syllable position does not become the target of deletion.

(5) Nasal+Stop: [t] as the onset of a stressed syllable

intelligent → [ɪntɛ́lədʒənt] *[ɪnɛ́lədʒənt]
centennial → [sɛntɛ́nɪəl] *[sɛnɛ́nɪəl]

[2] It should be noted that the different realization of the identical nasal plus obstrutent stop between the syllable coda and word medial position might be due to positional difference between the root internal and other positions, as pointed out by Pater (1996). He argues that cross-linguistically segments occurring inside the root are more immune to phonological processes than segments in other positions. However, we argue in this paper that the different realization of the identical nasal plus obstruent stop clusters results from the different requirement between tautosyllable and heterosyllable, and the interaction of specified *NC̥ constraints.

syntagma → [sɪntǽgmə] *[sɪnǽgmə]
canteen → [kæntín] *[kænín]

As shown in (5), the [t] in the stressed onset position should appear in the output as shown by the first realization of the input. On the other hand, when [t] is deleted in the output as represented by the second realization of the input, the phonetic realization is unacceptable.

So far we have seen different realizations of the homorganic nasal plus obstruent stop sequences when they occur in the word's final position and in its medial position. The different realizations of the homorganic clusters reveal that there are specific restrictions on the tautosyllabic homorganic clusters in comparison with the heterosyllabic homorganic clusters. The asymmetrical behavior of homorganic clusters in English in part supports what Yip (1991) proposes but her arguments on the realization of clusters should be specified in more detail to explain the diverse patterns of cluster realizations in English.

## III. PREVIOUS ANALYSES

In this section, we introduce three previous analyses that deal with the [g][b]-deletion after a velar nasal [ŋ] and a bilabial nasal [m] within a rule-based approach by Borowsky (1986) and a constraint-based approach by Oh (1998), and the post-nasal [t] deletion by Ladefoged (2001). After reviewing the previous analyses, we will discuss Pater's claim for fixing NC̥ clusters in languages and we will also focus on the possible problems of the previous analyses.

Borowsky (1986, p. 73) proposes a g/b deletion rule which demands the deletion of the voiced obstruents [b] and [g] when they are preceded by a tautosyllabic homorganic nasal. The rule is given in (6).

(6) g/b deletion
g/b → ∅ / N _____ σ]

Borowsky argues that the rule in (6) applies after a 'nasal assimilation rule' which specifies that the archiphoneme N changes into the same place articulation of the following obstruent. If Nasal Assimilation does not apply, the archiphoneme is realized as a coronal nasal by the default rule. Some exemplary derivation is given in (7).

(7) /puNp/ → pump /sɪNg/ → sɪŋg by Nasal Assimilation
/boNb/ → bomb → bom∅ by Nasal Assimilation and [b] deletion

/sɪNg/ → sɪŋg → sɪŋ∅ by Nasal Assimilation and [g] deletion

Borowsky also mentions that g/b deletion rule does not apply to the word internally as in ‘anger, hunger, embryo, umbrella, and thimble.’ In combination with Nasal Assimilation, the g/b deletion rule can explain word final homorganic cluster examples.

While the rule in (6) can provide us with a method to explain word final homorganic clusters in English, it faces some problems. The first problem is that the rule in (6) does not clarify its motivation. This means that the rule does not tell us why [g] and [b] are deleted from the word if they are preceded by the homorganic nasal. If the clusters [mb] and [ŋg] are not finally allowed in the word and the possible repair strategy is deletion rather than insertion, why are [m] and [ŋ] not selected as the deleting segment to fix the unacceptable final clusters? Another problem is that since nasal plus obstruent stop in English form homorganic clusters, how is [nd] exempt from the deletion compared to [mb] and [ŋg]? Thus, the rule in (6) may not explain all the realizations of homorganic cluster examples in English.

Another analysis on cluster simplification by Oh (1998) is couched in Optimality Theory (Prince & Smolensky, 1993, 2004) and Correspondence Theory (McCarthy & Prince, 1995). Since Oh’s analysis is based on the constraints and their interaction, she proposes the following constraints. For a succinct presentation, we present the constraints, which are relevant for the current paper.

(8) Constraints from Oh (1998, pp. 956-958)

a. Peripherality: Parse Peripheral specifications.
b. Coda Son: In (the first segment of) syllable coda, parse segment with sonority.
c. *Complex: Syllables have at most one consonant at the edge.
d. Faithfulness: Pronounce everything as is.

(9) Constraint ranking

Coda Son ≫ Peripherality ≫ Faithfulness ≫ *Complex

The following Table 1 represents how the constraint ranking given in (9) selects the correct phonetic realization of ‘young.’

**TABLE 1**

| /yʌŋg/ | Coda Son | Peripheral | Faith | *Complex |
|---|---|---|---|---|
| ☞ yʌŋ | | * | * | |
| yʌg | *! | * | * | |
| yʌŋg | *! | | | * |

As in Table 1, the given constraint ranking chooses the first candidate as optimal in which the obstruent stop [g] is not realized in the output. This is propelled by the interaction between the high ranking Coda Son and the low ranking *Complex. Ranking Coda Son over *Complex targets the deletion of the less sonorous obstruent [g] rather than [ŋ]. The suboptimal candidates [yʌg] and [yʌŋg] are eliminated due to the violation of the highest ranking Coda Son. The constraint ranking in Table 1, however, cannot explain the actual phonetic forms when we take more examples into account such as mend, send, and hand. The given words are fully pronounced without any deletion as shown by Table 2.

**TABLE 2**

| /mɛnd/ | Coda Son | Peripheral | Faith | *Complex |
|---|---|---|---|---|
| ✂ mɛn | | | * | |
| mɛd | *! | | * | |
| ☞ mɛnd | *! | | | * |

According to the constraint ranking given in (9), the first candidate should be selected as the optimal form, but it is not the actual output form, which is indicated by '✂.' The actual optimal form in Table 2 is the third candidate in which both homorganic coronal nasal plus obstruent stop are realized in the phonetic form. The only way to account for the winning candidate is to rearrange the ranking between Coda Son and *Complex, but reversing the ranking will cause a ranking paradox in the optimality theory, which is not allowed in the machinery of the theory. Accordingly, the constraint-based analysis by Oh (1998) does not provide a tool for the complete account.

For the deletion of [t] in the medial coronal cluster [nt], Ladefoged (2001, pp. 58-59) suggests the following deletion rule. The rule in (10) specifies that the /t/ is lost in words like 'painter' and 'splinter.'

(10) /t/ $\rightarrow \varnothing$ / n._____ ('.' signals a syllable boundary)

Ladefoged argues that the rule in (10) should apply prior to flapping, otherwise the rule does not apply to the resulting form of flapping application such as in [peňər] ('ň' denotes a flapped-n). Even though the deletion rule in (10) can explain some examples of English which represent the medial [t] deletion, there are many other examples where the /t/ does not undergo deletion in the pronunciation as shown by the data in (3e), (3f), and (5). Furthermore, the rule in (10) should be stipulated as an optional rule since it does not obligatorily apply to the data given in (4). Finally, this optional rule also should be justified by the motivation of the post-nasal [t] deletion (cf. Pater 1996, 1999, 2004). Thus, the rule in (10) lacks the necessary conditions for wide range application to homorganic nasal plus obstruent stop clusters in English.

So far we have reviewed previous analyses which are relevant to the final and medial homorganic NC clusters and noticed that the analyses focused on a parochial type of NC clusters rather than considering all possible homorganic NC clusters in English. Thus, they shed light on only a part of homorganic NC clusters in English. In the next section, we will introduce a constraint-based analysis, which can be applied to all the cases of homorganic NC clusters in English.

## IV. ANALYSIS

In this section, we introduce the possible motivation of post-nasal obstruent deletion in the medial and final positions in English, and suggest constraints and their interaction in the selection of the best output forms for the pronunciation.

Before we focus on the English data, we first introduce the important assertion about the realization of NC clusters made by Pater (1996, 1999, 2004). In a series of papers, Pater argues for a general tendency that applies to many languages in the world. He claims that in a sequence of nasal plus consonant, languages prefer to have a nasal plus a voiced consonant to a nasal followed by a voiceless consonant. Thus, while NC (a nasal plus a voiced consonant) clusters are faithfully realized in the output forms, NC̥ (a nasal plus a voiceless consonant) clusters undergo some changes in the output. Pater introduces the three possible supports for the naturally difficult implementation of NC̥.[3] We, however, use only the articulatory justification of it. Huffman (1993, p. 310) argues that there is a difference between NC and NC̥ in terms of raising the velum. The velum is raised gradually for the former sequence and it allows nasal flow reaches very similar to that of plain obstruent during the release phase. On the other hand, a nasal plus voiceless stops calls for an unnaturally fast velar closure, which can be construed as articulatory difficulty. Based on this, Pater proposed the *NC̥ in (11).

(11) *NC̥
No nasal/voiceless obstruent sequences

Because of the marked nature of the *NC̥ constraint, many languages try to avoid a nasal followed by voiceless consonant. This is evinced by the several strategies that languages

[3] Paper (1999) also introduces Ohala and Ohala's (1991, p. 213-cited by Ohala & Ohala, 1993, p. 239) perceptual account for nasal deletion in the nasal plus voiceless stop sequence. With respect to the order of emergence of child' language, NC̥ appeared much later than NC and in the production of NC̥, a nasal was deleted in the pronunciation of a child (Smith, 1973, p. 53). These two factors boil down to the preference of NC to NC̥.

can take in order to eschew the marked cluster in the output forms. The possible strategies and the exemplary languages are given in (12).

(12) Strategies for eluding NC̥ (Pater 1999)

a. Nasal substitution: Indonesian

/mə$N_1$ + $p_2$ilih/ → [mə$m_{1,2}$ilih] 'to choose, to vote'

b. Denasalization: Mandar

/mə$N_1$ + $d_2$undu/ → [mə$n_1$ $d_2$undu] 'to drink'

/mə$N_1$ + $t_2$unu/ → [mə$t_1$ $t_2$unu] 'to drink'

c. Postnasal voicing: Puyo Pungo dialect of Quechua

/sinik + pa / → [sinikpa] 'porcupine's'

/ka$m_1$ + $p_2$a/ → [ka$m_1$ $b_2$a] 'yours'

d. Nasal deletion: Kelantan Malay

/$N_1$ + $T_2$/ → [$T_2$]

e. Vowel insertion: unattested

The examples of the possible strategies languages may employ to avoid NC̥ show that the general target of the phonological processes is $C_1$, which is the coda element of the preceding syllable. This reflects the asymmetrical segment realization depending on the positional faithfulness (Beckmann, 1997, 2004). The asymmetrical segment realization implies that realization priority is given to the syllable onset position while the segments in coda are susceptible to phonological processes.

We may use the *NC̥ constraint in accounting for the realization of homorganic NC clusters in English if we confine the analysis to medial homorganic NC clusters. For final NC cluster realizations, however, the constraint in (11) does not have any effect on the realization of the clusters because the English examples delete voiced labial and dorsal stops after the nasal even though the relevant data satisfy the constraint. What is interesting about the English examples in the coda position is that the homorganic NC̥ clusters are faithfully mapped onto the output which runs against *NC̥.

Applying *NC̥ to the homorganic final clusters in English might be problematic in that the examples presented in (12) show that various phonological processes occur over a syllable or a morpheme boundary. This environment difference might have allowed the English examples to be exempt from the *NC̥ constraint, but the *NC̥ constraint, *per se*, does not specify the exact locus of the cluster such as word internal or edge. Even if we assume the domain of the constraint in (11) is over a syllable boundary, it still causes problems for the medial clusters in English. A possible problem is that in the medial homorganic clusters of English, the /nt/ cluster is optionally realized as [n] in the output, which is not listed as one of the strategies languages use to avoid having NC̥ clusters.

Considering all the cases observed in the realizations of the English NC clusters, we should modify *NC̥ in our analysis.

For a comprehensive constraint-based analysis of the English NC realizations, we first introduce the constraints for the final homorganic clusters.

(13) Constraints for the final NC clusters

a. Max-IO: Every input has its correspondent in the output.

b. Dep-IO: Every output has its correspondent in the input.

c. Relative Linguistic Distance: A coda segment occurring close to a vowel in the input has it correspondent in the output.

d. *NC̥]tauto-σ: No nasal/voiceless obstruent sequences in the same syllable.[4]

e. *NC-Peirpheral]tauto-σ: No peripheral nasal/voiced obstruent sequences in the same syllable.

Max-IO bans any deletion of the input segment in the output while Dep-IO does not allow any insertion in the output. Relative Linguistic Distance is a type of faithfulness constraint that tries to maintain the segmental status of an element occurring right next to the vowel(cf. Chung, 2008). This is based on the deletion patterns of English in the syllable coda in which a coda consonant close to the nucleus is generally realized in the output. For example, in /$VC_1C_2$/, $C_1$ appears in the output while $C_2$ is deleted when $VC_1C_2$ is followed by a form beginning with a consonant, as shown by the following example: 'han$_1$d$_2$shake' → [hæn$_1$ʃek]. *NC̥]tauto-σ requires that the NC̥ sequences not be allowed in the output. Finally, *NC-Peirpheral]tauto-σ specifies that peripheral places such as the labial and the dorsal nasal plus voiced obstruent should not occur in the output.

In the analysis, we rank Dep-IO over Max-IO because only deletion strategy and not

---

[4] An anonymous reviewer pointed out that the NC cluster effect might not be confined to just a sequence of nasal plus stop but it should be extended to a sequence of sonorant plus consonant. In this paper, however, we still argue for the former view. Even though we can easily come up with numerous examples consisting of [r+Consonant] and [l+Consonant] word medially and finally, we cannot find any parallel deletion of word medial [t] that we observed in the examples presented in (4). On the contrary, we have examples such as 'barter' and 'vaulting,' which show the faithful realization of the medial [t] after [l] and the phonetic realization of /t/→[ɾ] after [r]. If there were any generalized effect of sonorant plus consonant sequences word medially and finally, the optional word medial deletion of [t] should be applied to such sonorant plus consonant sequences. Thus, extending to the NC effect to a generalized sonorant plus consonant in English is not tenable. With respect to the deletion of word final [b] and [g] after [m] and [ŋ] respectively, a reviewer also argued that deletion of such voiced stops might be ascribed to relative longer closure duration of [mb] and [ŋg] at the word final position so it would be difficult for [b] and [g] to maintain their voicing feature. Thus, it could be argued that there is no NC effect in English rather it could be the effect of word edge. This idea might provide a phonetic ground for *NC-Peirpheral]tauto-σ, which can justify the motivation of the constraint. So the constraint itself can reflect the word final effect as well.

insertion strategy is employed in order to avoid the peripheral NC sequences in English. Between the two context-sensitive constraints such as *NC̥]tauto-σ and *NC-Peirpheral]tauto-σ, the latter dominates the former since NC̥ sequences are allowed to occur in the final position, regardless of place of articulation of the NC sequences while peripheral NC sequences such as [mb] and [ŋg] are not allowed to appear in the output. This is also explained by Pāṇini's Theorem of constraint ranking in Optimality Theory (Prince & Smolensky, 1993, 2004). Max-IO should dominate *NC̥]tauto-σ in order to secure the faithful realizations of NC̥ clusters in the syllable final position. If the ranking between them is reversed, the input /mp/ should be realized as [m] in order to be an optimal form. RLD constraint should be ranked higher than Max-IO since Max-IO does not specify the faithful occurrence of the two input coda elements but Max-IO generally just requires faithful mapping of input onto the output in the syllable coda. On the other hand, RLD specifically designates the faithful realization of a segment right next to the nucleus. Thus, the ranking of them at least licenses the occurrence of a pre-obstruent nasal in the output. RLD, then, outranks *NC̥]tauto-σ by transitivity. While we can rank some of the constraints, there is no specific ranking among *NC-Peirpheral]tauto-σ, Dep-IO, and RLD.

Based on the constraint interaction, we now present some of the exemplary constraint tables. The following Table 3 represents the realization of input /mb/ → [m] in the output. In the tableau, '.' Indicates a syllable boundary.

**TABLE 3**

| /bamb/ | *NC-Perip] tauto-σ | Dep-IO | RLD | Max-IO | *NC̥] tauto-σ |
|---|---|---|---|---|---|
| a. bamb | *! | | | | |
| b. bam.bə | | *! | | | |
| c. bab | | | *! | * | |
| ☞ d. bam | | | | * | |

The constraint ranking in Table 3 selects (d) as optimal because it only violates the lowest ranking constraint while the candidates (a), (b), and (c) crucially incur the violations of high ranked *NC-Peirp]tauto-σ, Dep-IO, and RLD, respectively. The optimal form avoids the *[mb] cluster in the output by deleting [b] which concomitantly meets the requirement of the high ranked RLD at the same time. The lowest ranking constraint does not play any critical role in Table 3, but it does play a role in the realization of NC̥ clusters when consisting of a peripheral nasal plus a voiceless stop.

The following Table 4 shows the evaluation of the possible candidates of a homorganic input /ŋg/ cluster. The optimal output (d) is also chosen by the same constraint ranking given in Table 3.

**TABLE 4**

| /yʌŋg/ | *NC-Perip] tauto-σ | Dep-IO | RLD | Max-IO | *NC̥] tauto-σ |
|---|---|---|---|---|---|
| a. yʌŋg | *! | | | | |
| b. yʌŋ.gə | | *! | | | |
| c. yʌg | | | *! | * | |
| ☞ d. yʌŋ | | | | * | |

The same constraint ranking can be applied to the final NC̥ sequences where both nasal and obstruent are faithfully mapped onto the output. This is exhibited by the following constraint table.

**TABLE 5**

| /θɪŋk/ | *NC-Perip] tauto-σ | Dep-IO | RLD | Max-IO | *NC̥] tauto-σ |
|---|---|---|---|---|---|
| ☞ a. θɪŋk | | | | | * |
| b. θɪŋ.kə | | *! | | | |
| c. θɪk | | | *! | * | |
| d. θɪŋ | | | | *! | |

Unlike Tables 3 and 4, the high ranking *NC-Perip]tauto-σ in Table 5 does not play a major role. Rather, it is satisfied trivially since all candidates have different phonological constituents that the constraint specifies. Candidates (b), (c), and (d) are suboptimal because they critically violate Dep-IO, RLD, and Max-IO. Candidate (a), which violates the lowest ranking *NC̥]tauto-σ, now emerges as the optimal output. This indicates that when a nasal is followed by a voiceless obstruent, both segments must appear in the output without undergoing any segmental insertion or deletion in order to avoid the marked NC̥ sequences because it is ranked low and its ensuing cost to the evaluation is minimal. The constraint ranking established for the realization of the final homorganic nasal plus obstruent is given in (14).

(14) Constraint ranking for final NC clusters

*NC-Perip]tauto-σ, Dep-IO, RLD ≫ Max-IO ≫ *NC̥]tauto-σ

In order to explain the realization of medial NC clusters, we employ the following constraints, consisting of the three constraints which are adopted from (13) and three new constraints.

(15) Constraints for the medial NC clusters

a. Max-IO: Every input has its correspondent in the output.

b. Dep-IO: Every output has its correspondent in the input.
c. Relative Linguistic Distance: A post-vocalic consonant occurring close to a nucleus in the input has it correspondent in the output.
d. *NC̥-Coronal]hetero-σ: No coronal nasal/voiceless obstruent sequences in the heterosyllable.
e. *NC-Peripheral]hetero-σ: No peripheral nasal/obstruent sequences in the heterosylalble.
f. Max-Onset: A singleton output onset consonant has its input correspondent when not followed by a short neural vowel [ə].

The newly introduced *NC̥-Coronal]hetero-σ in (15d) requires that the [nt] sequences do not occur over a syllable boundary. The constraint given in (15e) bans the clusters over a syllable boundary, which are composed of labial nasal/obstruent and dorsal nasal/ obstruent sequences. Between these two constraints, (15e) outranks (15d) because peripheral nasal/obstruent sequences are faithfully realized without undergoing any segmental insertion or deletion in the output while coronal nasal/voiceless stop sequences can have non-identical realization in the output. This ranking relation secures the identical realization of heterosyllabic peripheral NC clusters in the output.

Max-Onset calls for the faithful realization of an onset element when it is followed by a non-neutral vowel. This indicates that, unlike stressed vowels or stressless long vowels, [ə] is not a strong nucleus which can protect its preceding element. This is highly ranked in this analysis because an onset is not the general target of phonological processes (cf. Beckman, 1997, 2004). The constraint does not show any ranking with Dep-IO and RLD, which are also highly ranked in the analysis. Dep-IO, RLD, and Max-Onset are ranked higher than *NC̥-Cor]hetero-σ even though the high ranking constraints are not in conflict with *NC̥-Cor]hetero-σ.

In the analysis of medial NC clusters, *NC̥-Cor]hetero-σ dominates Max-IO. If the ranking between them is reversed, we will always have an optimal form with the faithful mapping of NC clusters between the input and output. On the other hand, Max-IO outranks *NC-Perip]hetero-σ because peripheral nasal/obstruent clusters over a syllable boundary are faithfully realized even at the cost of violating *NC-Peripheral]hetero-σ.

Based on the constraints in (15) and their ranking relations, we present the following table exhibiting the realization of medial NC clusters.

**TABLE 6**

| /sæmpəl/ | Max-Onset | Dep-IO | RLD | *NC̥-Cor] hetero-σ | Max-IO | *NC-Peri] hetero-σ |
|---|---|---|---|---|---|---|
| ☞ a. sæmpəl | | | | | | * |
| b. sæməl | | | | | *! | |
| c. sæpəl | | | *! | | * | |
| d. sæməpəl | | *! | | | | |

The constraint ranking shown in Table 6 chooses (a) as the optimal candidate, which only violates the lowest ranking *NC-Peri]hetero-σ while satisfying all other constraints. Candidates (b), (c), and (d) are edged out by (a) due to the violation of Max-IO, RLD, and Dep-IO, respectively. The given ranking indicates that medial peripheral NC clusters and /nd/ sequences should have faithful corresponding relations between the input and the output except for the input /nt/ cluster. The following Table shows the evaluation of the medial /nd/ cluster.

**TABLE 7**

| /kændɪ/ | Max-Onset | Dep-IO | RLD | *NÇ̥-Cor]hetero-σ | Max-IO | *NC-Peri]hetero-σ |
|---|---|---|---|---|---|---|
| ☞ a. kændɪ | | | | | | |
| b. kænɪ | *! | | | | * | |
| c. kædɪ | | | *! | | * | |
| d. kænədɪ | | *! | | | | |

The identical output to the input is selected as the best form, which satisfies all the given constraints. Candidate (b) is suboptimal because of its violation of the highly ranked Max-Onset. It incurs a violation of the constraint since the onset [d] is deleted before [ɪ], which is not a short neutral vowel [ə]. The constraint ranking established for medial NC clusters can account for the realization of /nt/ clusters. It is shown by the following table.

**TABLE 8**

| /sɛntər/ | Max-Onset | Dep-IO | RLD | *NÇ̥-Cor]hetero-σ | Max-IO | *NC-Peri]hetero-σ |
|---|---|---|---|---|---|---|
| a. sɛntər | | | | *! | | |
| ☞ b. sɛnər | | | | | * | |
| c. sɛtər | | | *! | | * | |
| d. sɛnətər | | *! | | | | |

The sub-optimal candidate (a), which is identical to the input, is edged out by (b) because it fails to satisfy *NÇ̥-Cor]hetero-σ, which plays a crucial role in Table 8 in the selection of the optimal output. Candidates (c) and (d) are filtered out by the high ranking RLD and Dep-IO. Now candidate (b) emerges as the optimal form. The constraint ranking for medial NC clusters implies that the medial /nt/ cluster is realized as [n] in the output. However, if we consider the data given in (5), which are repeated in (16), the input /nt/ clusters are identically realized in the output.

(16) Nasal+Stop: [t] as the onset of a stressed syllable
   intelligent → [ɪntɛ́lədʒənt] *[ɪnɛ́lədʒənt]
   centennial → [sɛntɛ́nɪəl] *[sɛnɛ́nɪəl]

syntagma → [sɪntǽgmə] *[sɪnǽgmə]
canteen → [kæntín] *[kænín]

The data in (16) are seemingly exceptional to the analysis but the constraint ranking we established for the analysis can account for such data. The crucial role in the selection of the optimal output for the data in (16) is carried out by Max-Onset along with high ranking Dep-IO and RLD. These high ranking constraints block the attempts at avoiding [nt] medial clusters in the output through such means as the deletion of [t] in [nt], the insertion of [ə] between [n] and [t], and the deletion of [n] in [nt]. This is illustrated by the following constraint table.

**TABLE 9**

| /sɪntægmə/ | Max-Onset | Dep-IO | RLD | *NÇ-Cor] hetero-σ | Max-IO | *NC-Peri] hetero-σ |
|---|---|---|---|---|---|---|
| ☞ a. sɪntǽgmə | | | | * | | |
| b. sɪnǽgmə | *! | | | | * | |
| c. sɪtǽgmə | | | *! | | * | |
| d. sɪnətǽgmə | | *! | | | | |

It should be noted that the preservation of the onset element in (16) can be ascribed to the faithful realization of the onset of the stressed syllable, which is argued by Beckman (1997, 2004). However, in this analysis the similar role in the evaluation is implemented by Max-Onset, which subsumes the faithfulness to the stressed syllable. The Max-Onset constraint calls for the faithful realization of onset elements when not followed by the short [ə], which is a reduced stressless vowel. So the onset elements can be faithfully realized if they are followed by a stressed or unstressed vowel but not by a reduced vowel. Considering the range of application of Max-Onset, Max-Onset is more inclusive than faithfulness to the stressed syllable. It is also possible to assume that a vowel lacking an ostensive stress mark might have invisible degree of stress, which protects the vowel from reduction to [ə].

The constraint ranking for the realization of /nt/ to [n] should be able to account for the different realization of the input /nt/ in the output. The different realization of /nt/ is [nt]. The different output realizations of one input can be explained by two ways in the constraint-based theory: the first method is to rerank the relevant constraints and the other to unrank the relevant constraints. This strategy should be carried out on condition that the reranking or unraking of the pertinent constraints in the analysis does not affect the selection of the optimal form from the output candidates of input forms other than /nt/. The only difference between the two strategies is that the former selects the faithful [nt] as optimal while the latter chooses both [n] and [nt] as the optimal outputs. The following two tables show the two pronunciations of the input /nt/. In Table 10, we rerank *NC̥-Cor] hetero-σ and Max-IO whereas we unrank them in Table 11, which is indicated by dotted lines between the constraints.

**TABLE 10**

| /sɛntər/ | Max-Onset | Dep-IO | RLD | Max-IO | *NC̥-Cor] hetero-σ | *NC-Peri] hetero-σ |
|---|---|---|---|---|---|---|
| ☞ a. sɛntər | | | | | * | |
| b. sɛnər | | | | *! | | |
| c. sɛtər | | | *! | | * | |
| d. sɛnətər | | *! | | | | |

**TABLE 11**

| /sɛntər/ | Max-Onset | Dep-IO | RLD | *NC̥-Cor] hetero-σ | Max-IO | *NC-Peri] hetero-σ |
|---|---|---|---|---|---|---|
| ☞ a. sɛntər | | | | * | | |
| ☞ b. sɛnər | | | | | * | |
| c. sɛtər | | | *! | | * | |
| d. sɛnətər | | *! | | | | |

We have seen how medial NC clusters can be accounted for by the relevant constraints and their interaction. The constraint ranking for medial NC clusters is given in (17).

(17) Constraint ranking for medial NC clusters

Max-Onset, Dep-IO, RLD ≫ *NC̥-Cor]hetero-σ ≫ Max-IO ≫ *NC]hetero-σ

*NC̥-Cor]hetero-σ, Max-IO

The medial NC clusters can be explained by one constraint ranking given in (17), and the variant realizations of /nt/ also can be accounted for by ranking modification as allowed for in the Optimality Theory. It is also possible that the constraint rankings in (17) and (14) for medial NC clusters can be combined. The combined constraint still selects an optimal output in both final and medial NC clusters. The constraints used in the analysis of final NC clusters such as *NC-Perip]tauto-σ and *NC̥]tauto-σ will be trivially satisfied in the evaluation of medial NC clusters. On the other hand, Max-Onset, *NC̥-Cor]hetero-σ and *NC]hetero-σ will also be trivially satisfied in the analysis of final NC Clusters. The combined constraint ranking is given in (18).

(18) Combined constraint ranking for final and medial NC clusters

*NC-Perip]tauto-σ, Max-Onset, Dep-IO, RLD ≫ *NC̥-Cor]hetero-σ ≫ Max-IO ≫ *NC̥]tauto-σ, *NC]hetero-σ

In what follows, we will summarize the analysis and provide some implications of the analysis for both linguistics and English education.

## V. CONCLUSION

In this study, we have looked at asymmetrical behavior of nasal plus obstruent sequences in the final and medial positions in the syllable. We argue that the asymmetrical realization of NC clusters in different syllable positions can be accounted for by the relevant constraints and their ranking within the framework of the optimality theory. One constraint ranking given in (18) can select the optimal output in both the final and the medial position in the syllable without mentioning any conditions or exceptions, which we observed in the previous analyses presented in section 3. Thus, the constraint based analysis of the realizations of NC clusters in English can be applied to the different contexts of NC clusters in English, which seemed to be troublesome for a rule-based account. The variant realizations of a medial /nt/ cluster is also explained by reranking or unranking the relevant constraints such as *NC̥-Cor]hetero-σ and Max-IO.

We should note some linguistic implications for the current analysis. First, Pater's *NC̥ constraint should be decomposed into several specific constraints in English. This is because there are asymmetrical realizations of NC clusters in English in the syllable final and medial position. In the syllable final position, post nasal voiced peripheral stops [b, g] are deleted even though the input /mb/ and /ŋg/ satisfy *NC̥ whereas /mp/, /nt/, and /ŋk/, which violate *NC̥ still appear in the output. In the syllable medial position, however, only the coronal nasal of the input /nt/ survives in the output while all other types of NC clusters are faithfully realized in the outputs.

Second, the analysis in this study reveals that the realization of NC clusters in English can add one more strategy for eluding NC clusters to those argued for by Pater (1999), presented in (12). Between nasal and stop sequences of English, nasals occur in the output in the syllable medial and final position. We represent it schematically in (19), in which we generalize several aspects of NC realizations into a schema. We also compare the strategy of English to that of Kelantan Malay (Pater, 1999). For the sake of comparison, we modify Pater's schema.

(19) Strategies for eluding NC: Kelantan Malay and English

a. Kelantan Malay: $/N_1 + C_2/ \rightarrow [C_2]$

b. English: $/N_1 + C_2/ \rightarrow [N_1]$: $C_2$ refer to /b, ŋ/ syllable finally; /t/ syllable medially

Third, an interesting issue that the English examples can suggest is that the faithfulness status between the two different positions is drawn from ‘positional faithfulness’ by Beckmann (1997, 2004): the coda of the stressed syllable and the onset of the unstressed syllable. Beckman distinguishes the difference between privileged and unprivileged positions as in (20).

(20) The two types of linguistic positions

| Privileged positions | Unprivileged positions |
|---|---|
| Root-initial syllable | Non-initial syllable |
| Stressed syllable | Unstressed syllable |
| Syllable onsets | Syllable codas |

However, the two linguistic positions can become complex if two privileged and unprivileged positions are combined so that the codas in stressed syllable sand the onsets in a unstressed syllable are in conflict with respect to the faithful realization. Obviously, the current study shows that the coda of the stressed syllable survives in the output while the onset of the unstressed syllable fails to appear in the output (cf. McCarthy, 2008). We need to research more on such complex cases in other languages regarding positional faithfulness before we propose any generalizations.

The current analysis also has some implications for teaching English pronunciation. Teaching pronunciation of homorganic NC clusters in English should be accompanied by an asymmetrical realization of them because the homorganic NC clusters are only possible in the word medial position in Korean (Chung, 2007a). The learning process of such NC clusters will be facilitated if students are informed of the relevant constraints and their effects on the pronunciation. Learners could better grasp the concept of the relevant constraints if the effects of the constraints are observed in the pronunciation drills. In this way, the students learning English will learn practical aspects and systematic internal constraints of the language.

## REFERENCES

Beckmann, J. (1997). Positional faithfulness, positional neutralization and Shona vowel harmony. *Phonology, 14*(1), 1-46.

Beckmann, J. (2004). Positional faithfulness. In J. McCarthy (Ed.), *Optimality theory: A reader* (pp. 310-342). Malden, MA: Blackwell.

Borowsky, T. (1986). *Topics in the lexical phonology of English*. Unpublished doctoral dissertation. University of Massachusetts, Amherst.

Chung, C.-W. (2001). Syllabification in English and Korean: an optimality-theoretic approach. *English Language & Literature Teaching, 7*(2), 37-54.

Chung, C.-W. (2007a). A constraint-based account of variation in post-nasal /t/ deletion in English. *Studies Modern Grammar, 49*, 149-175.

Chung, C.-W. (2007b). Pronunciation of sonorant clusters in English for Korean speakers: a constraint-based approach. *English Language & Literature Teaching, 13*(3), 23-40.

Chung, C.-W. (2008). Relative positional faithfulness and co-operative effects on phonological processes. *Modern Studies in English Language & Literature, 52*(4), 393-418.

Davis, S. (1991). Coronals and the phonotactics of nonadjacent consonants in English. In C. Paradis & J.-F. Prunet (Eds.), *The special status of coronals: Internal and external evidence* (pp. 49-60). San Diego: Academic Press.

Hammond, M. (1999). *The phonology of English: A prosodic optimality-theoretic approach*. Oxford: Oxford University Press.

Huffman, M. (1993). Phonetic patterns of nasalization and implications for feature specification. In M. Huffman & R. Krakow (Eds.), *Nasals, nasalization, and the velum* (pp. 303-327). San Diego: Academic Press.

Itô, J. (1986). *Syllable theory in prododic phonology*. Unpublished doctoral dissertation. University of Massachusetts, Amherst.

Ladefoged, P. (2001). *A course in phonetics*. Fort Worth, TX: Harcourt College Publishers.

McCarthy, J. J. (2008). *The gradual path to cluster simplification*. Ms., University of Massachusetts, Amherst.

McCarthy, J. J., & Prince, A. S. (1995). Faithfulness and reduplicative identity. In J. N. Beckman, L. W. Dickey & S. Urbanczyk (Eds.), *Papers in optimality theory* (pp. 249-384). Amherst, MA: GLSA.

Oh, M.-R. (1998). An optimal analysis of English coda. *English Language & Literature, 44*(4), 947-962.

Ohala, J. J., & Ohala, M. (1991). Reply to commentators. *Phonetica*, *48*, 271-274.

Ohala, J. J., & Ohala, M. (1993). The phonetics of nasal phonology: Theorems and data. In M. Huffman & R. Krakow (Eds.), *Nasals, nasalization, and the velum* (pp. 225-249). San Diego: Academic Press.

Pater, J. (1996). * NC̥. In K. Kusumoto (Ed.), *Proceedings of NELS 26* (pp. 227-239). Amherst, MA: GLSA.

Pater, J. (1999). Austronesian nasal substitution and other NC̥ effects. In R. Kager, H. Van der Hulst & W. Sonneveld (Eds.), *The phonology-morphology interface* (pp. 310-343). Cambridge: Cambridge University Press.

Pater, J. (2004). Austronesian nasal substitution and other NC̥ effects. In J. McCarthy (Ed.), *Optimality theory: A reader* (pp. 271-289). Malden, MA: Blackwell.

Prince, A. S., & Smolensky, P. (1993). *Optimality theory: Constraint interaction in generative grammar*. Ms., Rutgers University and University of Colorado, Boulder.

Prince, A. S., & Smolensky, P. (2004). *Optimality theory: Constraint interaction in generative grammar.* Malden, MA: Blackwell.

Smith, N. V. (1973). *The acquisition of phonology: A case study*. Cambridge: Cambridge University Press.

Steriade, D. (1982). *Greek prosodies and the nature of syllabification*. Unpublished doctoral dissertation. MIT, Cambridge, Massachusetts.

Yip, M. (1991). Coronals, consonant clusters, and the coda condition. In C. Paradis & J.-F. Prunet (Eds.), *The special status of coronals: Internal and external evidence* (pp. 61-73). San Diego: Academic Press.

**Examples in : English**
**Applicable Languages: English**
**Applicable Levels: College**

Chin-Wan Chung
Department of English
Chonbuk National University
664-14 Duckjin-dong, Jeonju city
Jeollabukdo 561-756, S. Korea
Tel: (063) 270-3205
Fax: (063) 270-3201
Email: atchung@hanmail.net

Received in April, 2009
Reviewed in May, 2009
Revised version received in June, 2009