A Contrast-based Analysis of Consonant Cluster Simplification in English*

Seok-keun Kang (Wonkwang University)**
Mira Oh (Chonnam National University)***

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The purpose of this paper is to reconsider Consonant Cluster Simplification in English. We first provide a brief review of previous syllable-based analyses of the phenomenon, showing that they are empirically inadequate. Then considering CCS within a framework of the cue-based theory (Steriade, 2000), we claim that it can be given a natural and unified account in terms of the perceptual salience of the involved consonants. We claim that the quality and quantity of the internal and external cues determine CCS: Consonants with perceptually salient phonetic cues resist deletion, while consonants lacking salient cues are relatively prone to deletion.

Key words: Consonant Cluster Simplification, constraints, cue-based, internal cue, external cue, perceptual

1. Introduction

Syllables have been invoked as predicates in the statement of segmental constraints. Thus the context like 'in the coda' plays a crucial role in constraints and rules alike. For example, Consonant Cluster Simplification in English (henceforth CCS in English) has been attributed to the idea that codas license a limited set of segments. Many phonological processes like assimilation and neutralization which have been treated in syllabic terms, however, can be reconstructed on a phonetic basis. Steriade (1999, 2000) argues that languages tend to license segmental contrasts where they are

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*** The second author is a corresponding author.

maximally perceptible. In the same vein, segmental deletion can also be accounted for by the cue-based theory (Côte, 2000).

The goals of this study are twofold. First, we critically review the previous syllable-based analyses of CCS in English. Second, we argue for the cue-based theory with respect to CCS in English. It is argued that the standard generative approach to CCS in English, which relies on the syllable and the Principle of Sonority Sequencing, is empirically inadequate, and an alternative contrast-based approach employing perceptual factors is developed. We will show that the likelihood that a consonant deletes correlates with the quality and quantity of the auditory cues associated to it in a given context. The approach is implemented in Optimality Theory (Prince & Smolensky, 1993; McCarthy & Prince, 1995).

2. Previous Analyses on Consonant Cluster Simplification in English

Examples in (1) illustrate CCS in English.

(1) [n]-[gn] : sign-signature, resign-resignation
[m]-[gm] : paradigm-paradigmatic, phlegm-phlegmatic
[m]-[mn] : column-columnar, hymn-hymnal
[ŋ]-[ŋg] : long-longer, young-younger
[m]-[mb] : bomb-bombard, dumb-dumbo
[m]-[lm] : calm-calmative

Previous analyses have dealt with CCS in English in terms of Sonority Sequencing Principle, which can be stated as a markedness constraint in (2).

(2) Son-Seq (Clements, 1990)
Complex onsets rise in sonority, and complex codas fall in sonority.

Avoidance of final clusters of rising sonority is cross-linguistically common. A close examination of the data in (1), however, reveals that the Son-Seq constraint cannot fully explain CCS in English. For instance, although codas like [mb] and [ŋg] satisfy the Son-Seq constraint, they do not surface.

Three kinds of previous analyses will be reviewed in this section. One of the previous approaches to the phonotactic description of English is based on sonority scale (Selkirk, 1984; Rice, 1992). Selkirk (1984) offers a theory of phonotactics in terms of sonority indices and conditions upon them. Her account using the specification of a minimum sonority difference alone, however, is untenable (Borrowsky, 1986). For instance, her analysis would not allow such examples as 'month, tuft, act,' contrary to the fact. Furthermore, the exact value of the minimum sonority difference is not given in Selkirk (1984).

Another approach to CCS in English is rule-based. For example, Borowsky (1986) provides three phonological rules given in (3).

(3) a. Voiced obstruent deletion

[-son, +voiced] -> ∅ / [+nas] ______$]_\sigma$

b. n-deletion

n -> ∅ / m ______]

c. g-deletion

g -> ∅ / ______[+nas]]

The rules in (3), however, lack explanatory adequacy since they cannot account for why CCS in English occurs only in the ill-formed coda sequences.

The other approach is a constraint-based analysis within the Optimality Theory framework. For example, Oh (1998, p. 957) deals with CCS in English by employing the constraints given in (4).

(4) a. Peripherality: Parse peripheral specifications.

b. Coda Son: In syllable codas, parse only segments with sonority.

c. Max-IO: Every segment of the input has an identified correspondent in the output.

d. *Complex: Syllables have at most one consonant at an edge.

Tableau (5), for example, illustrates how these constraints are ranked to produce the optimal output for 'long'.[1]

1) Here it is assumed that the input form of 'long' is /lɔŋg/. For a different view, see Borowsky (1986).

(5)

long	Coda Son	Max-IO	Peripherality	*Complex
☞a. lo[ŋ]		*	*	
b. lo[ŋg]	*!			*
c. lo[g]	*!	*	*	

In (5), candidate (a) is correctly selected as optimal because it is the only candidate that passes the top-ranked constraint, Coda Son. Oh's analysis, however, has at least two shortcomings. First, her analysis does not reflect that CCS in English is motivated by the Son-Seq constraint. Furthermore, it would make a wrong prediction in cases where the relevant coda consonants are alveolars, as illustrated in (6).

(6)

find	Coda Son	Max-IO	Peripherality	*Complex
☜a. fi[n]		*		
☞b. fi[nd]	*!			*
c. fi[d]	*!	*		

In the tableau above, "☜" indicates a wrongly predicted candidate. Given the constraint Coda Son in (4b), candidate (6a) would be incorrectly selected as optimal. Likewise, Oh's (1998) analysis cannot account for the asymmetry between coronal stops and peripheral stops with respect to CCS in English; [nd] clusters are allowed in coda position, while peripheral voiced stop and nasal clusters are not. In the next section, we will examine another constraint-based analysis and argue for a contrast-based analysis for CCS in English.

3. The Phonetic Bases of Consonant Cluster Simplification in English

In this section, we will consider an alternative analysis of CCS in English within the framework of OT. After discussing the shortcomings of that analysis, we will argue that CCS in English results from multiple dynamicallly interacting factors within the contrast-based framework (Steriade, 2000; Côte, 2000).

3.1. An Alternative OT Analysis for Consonant Cluster Simplification in English

Let us examine the examples in (7) and (8).

(7) /g/ -> ø % [+nasal]____]$_\sigma$

a.	paradigm	paradigmatic
	phlegm	phlegmatic
	syntagm	syntagmatic
b.	sign	signature
	malign	malignant
c.	long	longer
	strong	stronger

(8) /b/ -> ø / [+nasal]____]$_\sigma$

iamb	iambic
bomb	bombard
crumb	crumble

As shown in (7) and (8), both labial and velar voiced stops delete when they occur with nasals in coda. In order to account for this, we need a constraint preventing voiced stops and nasals from co-occurring in coda. Note, however, that not all voiced stops are subject to deletion when adjacent to coda nasals; contrary to /b/ and /g/, /d/ does not delete, as exemplified in (9) below:

(9) no deletion of /d/ after a nasal

hand	handy
fiend	fiendish

The examples in (7)-(9) clearly show that what should be ruled out in coda is a sequence of nasal and [-coronal] voiced stops. To capture the fact, we can propose the constraint in (10).

(10) *Nasal-b/g]$_\sigma$: Nasals and noncoronal voiced stops cannot co-occur in coda.

$*$Nasal-b/g$]_\sigma$ is undominated, so when the input contains both a [-coronal] voiced stop and a nasal in coda, one of the consonants should be deleted to satisfy the constraint. Deletion of a segment, of course, incurs a violation of constraint Max-IO, which requires that every segment in the input have a correspondent in the output. In the case at hand, however, the ranking $*$Nasal-b/g$]_\sigma$ $\gg$ Max-IO favors deletion over perfect faithfulness. Now a question arises: Why is it /b/ or /g/, not a nasal consonant, that is deleted? The answer may come from the requirement of sonority on consonant clusters. Cross-linguistically, low-sonority onsets are preferred, but preferred codas are those that are high in sonority (Hooper, 1976; Zec, 1988; Clements, 1990; Steriade, 1982, 1988; McCarthy & Prince, 1986). Within OT, the preference for high-sonority codas can be formalized as a family of constraints of the general type $*$Coda/X, where X is a variable that ranges over each step of the segmental sonority scale. The individual $*$Coda/X constraints are in a universally fixed ranking determined by the sonority scale, with the highest rank given to the constraint against the least sonorous coda (cf. Prince & Smolensky 1993). The $*$Coda/X subhierarchy assumed here is as follows:

(11) $*$Coda/stop $\gg$ $*$Coda/nasal

Note that when there is only one nasal or stop consonant in coda, it does surface. Coda consonants in 'man' and 'cab', for example, do not delete, indicating that the faithfulness constraint Max-IO should be ranked above $*$Coda/X constraints. As a result, $*$Nasal-b/g$]_\sigma$ outranks $*$Coda/X constraints by transitivity. That is, the desired ranking is as follows:

(12) $*$Nasal-b/g$]_\sigma$ $\gg$ Max-IO $\gg$ $*$Coda/stop $\gg$ $*$Coda/nasal

The following tableaux, for example, show how the constraint hierarchy above works to produce the correct outputs in 'paradigm', 'bomb', 'long' and 'sign', respectively:2)

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2) /g/ deletion in (13a) triggers lengthening of the preceding vowel, while neither /b/ deletion in (13b) nor /g/ deletion in (13c) does, which will not be discussed in this paper.

(13) a.

paradigm	Son-Seq	*Nasal-b/g]$_\sigma$	Max-IO	*Coda/stop	*Coda/nasal
☞a. paradi[m]			*		*
b. paradi[g]			*	*!	
c. paradi[gm]	*!	*!		*	*

b.

bomb	Son-Seq	*Nasal-b/g]$_\sigma$	Max-IO	*Coda/stop	*Coda/nasal
☞a. bo[m]			*		*
b. bo[b]			*	*!	
c. bo[mb]		*!		*	*

c.

long	Son-Seq	*Nasal-b/g]$_\sigma$	Max-IO	*Coda/stop	*Coda/nasal
☞a. lo[ŋ]			*		*
b. lo[ŋg]		*!		*	*
c. lo[g]			*	*!	

d.

sign	Son-Seq	*Nasal-b/g]$_\sigma$	Max-IO	*Coda/stop	*Coda/nasal
☞a. si[n]			*		*
b. si[gn]	*!	*!		*	*
c. si[g]			*	*!	

In (13a), candidate (c) violates the top-ranked constraint *Nasal-b/g]$_\sigma$, so it is excluded from consideration immediately, because the other candidates pass it. Candidates (a) and (b) are not distinguished by Max-IO, and so *Coda/stop, the next constraint down the hierarchy, becomes relevant. Candidate (a) obeys the constraint, but candidate (b) does not. Hence, candidate (a) is selected as optimal. Constraint *Coda/nasal has no bearing on the outcome. In (13a), due to the ranking *Nasal-b/g]$_\sigma$ ≫ Max-IO, consonant deletion is preferred over input-output faithfulness. In addition, since *Coda/stop outranks *Coda/nasal, it is /g/, not /m/, that should be deleted to satisfy the higher-ranked constraint, *Nasal-b/g]$_\sigma$. Tableaux in (13b-d) can also be accounted for in the same way.

Let us now consider how the constraint hierarchy proposed above can deal with the cases where the coronal voiced stop /d/ appears with the nasal /n/ in coda position. In this case, constraint *Nasal-b/g]$_\sigma$ is irrelevant, since the involved stop consonant is /d/, neither /b/ nor /g/. Rather it is the constraint Max-IO that plays a crucial role in choosing the optimal outputs. To illustrate, consider the following tableau:

(14)

find	*Nasal-b/g]σ	Max-IO	*Coda/stop	*Coda/nasal
☞a. fi[nd]			*	*
b. fi[n]		*!		*
c. fi[d]		*!	*	

Note that none of the candidates in (14) have /b/ or /g/ in coda, so they are not subject to *Nasal-b/g]$_σ$. Since Max-IO, which militates against deletion of input segments, is ranked higher than *Coda/X constraints, candidate (a), which is most faithful to the input, is selected as optimal. So far, we have argued that the different behaviors between coronal stops and non-coronal stops with respect to deletion can be treated straightforwardly with the constraint hierarchy given in (12).

At this point, we need to address some questions regarding the independent motivation for *Nasal-b/g]$_σ$, which plays a crucial role in the present analysis. The constraint functions to delete non-coronal voiced stops adjacent to a nasal in coda. Then a couple of questions still remain. First, why do only non-coronal stops delete? Second, why does this constraint refer to voiced stops excluding voiceless stops? Hayes and Stivers (1995) explain the prevalence of obstruent voicing only in postnasal position through computational vocal tract modeling. Given the widespread pattern of voicing in obstruents adjacent to nasals, the *Nasal-b/g]$_σ$ constraint cannot be supported. In the next subsection, we will show that the real motivation derives from the lack of contrast of these non-coronal voiced stops in this position.

3.2. A Contrast-based Analysis

3.2.1. A Sequence of an Obstruent and a Sonorant

We have shown that the previous constraint-based analyses within the OT framework conceive of CCS in English in terms of relatively arbitrary and language-specific constraints. In this subsection, however, we will argue that CCS in English should be treated as a deletion process which occurs when enough contrast is not given to a segment in a particular position. Our analysis is also couched within the OT framework, but it provides a set of highly general phonetically-based constraints which, through ranking, interact to produce the elaborate particularity of CCS in English. We believe that we better understand phonology proper once we learn to extract the phonetics out of it.

Most of the previous analyses on CCS in English have been made in terms of the minimal syllabic domain, coda. We, however, argue that, in the sequence of VC1C2, C1 deletes because it is perceptually weaker than C2. In other words, consonant deletion is motivated by the principle of perceptual salience; it applies when a consonant lacks perceptual salience and becomes more easily confusable with nothing, that is, when the cues that permit a listener to detect its presence are diminished (Côte, 2000, p. 135). Deletion removes such deficient segments. The identification of consonants relies on a number of acoustic cues, which can be grouped into two categories: internal cues produced during the closure part of the consonant, and contextual cues that originate from neighboring segments. Steriade (1999, 2000) maintains that languages tend to license segmental contrasts where they are maximally perceptible. Sibilant-stop initials should be preferred to other obstruent clusters since sibilants, unlike stops, have internal cues, the frication noise. Sequences like [sta] are expected to be as bad as [kta] in terms of sonority sequencing, but they are favored in terms of perceptual recovery of individual oral constrictions.

Returning to our discussion on CCS in English, segments of low sonority like stops are harder to be perceived because the perceptibility of a low-sonority segment depends not on its own internal acoustic properties but on the external cues present on adjacent high-sonority segments. Thus in a sequence of a stop and a nasal, stops are suboptimally cued and do not surface. Then the dominance *Coda/stop over *Coda/nasal in (11) naturally falls out from the cue-based theory. Examples given in (1) are repeated in (15) for expository purpose.

(15) [n]-[gn] : sign-signature, resign-resignation
[m]-[gm] : paradigm-pardigmatic, phlegm-phlegmatic
[m]-[mn] : column-columnar, hymn-hymnal
[ŋ]-[ŋg] : long-longer, young-younger
[m]-[mb] : bomb-bombard, dumb-dumbo
[m]-[lm] : calm-calmative

The alternations between [n]-[gn], [m]-[gm], [ŋ]-[ŋg], and [m]-[mb] can be accounted for in a straightforward way by the cue-based analysis. Sonorants always survive in the sequence of a nasal and a stop. Nasals have their internal cues like a prominent low frequency F1, referred to as the nasal formant, but voiced stops show very weak low F1 and show so much variation (Olive et al., 1993). In subsection 3.1, such alternations as [n]-[gn] and [m]-[gm] have been mainly motivated by Son-Seq in (2) coupled with the dominance of ∗Coda/stop over ∗Coda/nasal. On the other hand, the alternations of [ŋ]-[ŋg] and [m]-[mb] have been accounted for by the dominance of ∗Coda/stop over ∗Coda/nasal although the [ŋg] and [mb] clusters do not violate Son-Seq. The alternations between [n]-[gn], [m]-[gm], [ŋ]-[ŋg], and [m]-[mb] can be explained uniformly in the cue-based framework without employing the Son-Seq constraint which relies on the traditional syllable-based typology.

Steriade (2000) proposes that faithfulness of correspondence constraints are projected from, and their ranking is determined by, a grammatical component called the P-map. The P-map is a set of statements about perceived distinctiveness differences between different contrasts in different contexts. For example, the P-map may tell us that the contrast between [mp] and [m] is better perceived than the contrast between [mb] and [m] after a vowel. That is why a voiceless stop never deletes after a nasal, e.g., pi[ŋk], ca[mp]. These comparisons are derived from statements about the absolute distinctiveness or perceptibility of contrasts. If it can be determined from the P-map that a contrast x-y/ __K is more perceptible than a contrast w-z/ __Q, then for any correspondence constraint, Corresp. x-y/ __K dominates Corresp. w-z/ __Q. The idea is illustrated in (16) using the same example discussed above.

(16) P-map effects on the ranking of correspondence conditions

P-map comparisons	More distinct contrast [p]-∅ in VN__]	vs.	Less distinctive contrast [b]-∅ in VN__]
Ranking of correspondence constraints	Higher ranked constraint Ident [voiceless]/ VN__	>>	Lower ranked constraint Ident [voiced] / VN __

P-map comparisons	More distinct contrast [m]-∅ in V__b]	vs.	Less distinctive contrast [b]-∅ in Vm__]
Ranking of correspondence constraints	Higher ranked constraint Ident [nas]/ VC-____[3]	>>	Lower ranked constraint Ident [stop] / VC-____

3) In this paper, X-Y indicates the co-occurrence of X and Y regardless of their position.

In addition to the correspondence constraints in (16), we have to take the fact that not all forms of adjacency are equal into consideration in calculating perceived distinctiveness differences between contrasts. External cues are more salient at CV transitions than at VC transitions, which is in turn more salient than at CC transitions (Fujimura et al., 1978; Wright, 1996). At this point, we need to introduce the Contrast constraint in (17) which avoids a sequence of auditorily similar sounds.

(17) Contrast[4)]
Segments without contrast are not licensed.

For instance, the sequence of a nasal and a voiceless stop satisfies Contrast but that of a nasal and a voiced stop violates it. A nasal and a voiceless stop have more acoustic cues to be distinguished from each other, compared to a nasal and a voiced stop. A voiceless stop has a longer VOT than a voiced stop and no voicing, in contrast to a voiced stop. Voiceless stops have more acoustic cues different from a nasal than voiced stops after a nasal, and they are identified in that position. The Contrast constraint directly captures the observation that the contrast between [mp] and [m] is better perceived than the contrast between [mb] and [m] after a vowel. In contrast, when followed by a vowel, a voiced stop has an additional external cue in the following vowel as opposed to in word-final position. Then the sequence of a nasal and a voiced stop is perceived in prevocalic position. Given that the sequence of a nasal and a voiceless stop satisfies Contrast but that of a nasal and a voiced stop violates it, Ident [voiceless]/ VN _____ and Ident [voiced]/ VN _____ constraints discussed in (16) can be replaced by the Contrast constraint in (17). Given the assumptions above, we propose the constraint ranking in (18) in order to account for CCS.

(18) Ident C/__V, Contrast >> Ident [nas]/ VC-_____ >>
Ident [stop] / VC-_____

The constraint ranking in (18) indicates that Contrast along with Ident C/__V determines whether the consonants will be subject to CCS but Ident [nas]/ VC-_____ and Ident [stop] / VC-_____ constraints regulate

4) We leave the formalization of the Contrast constraint for future research.

which segment will surface. Ident [nas]/ VC-_____ outranks Ident [stop]/ VC-_____ in that nasal murmur cue provides a stronger cue than the silent acoustic cue of a stop. Tableaux in (19) illustrate how the constraints interact to yield optimal outputs when the coda cluster consists of a nasal and a stop.

(19) a.

pink	Ident C / __V	Contrast	Ident [nas] / VC-_____	Ident [stop] / VC-_____
☞a. pi[ŋk]				
b. pi[ŋ]				*!
c. pi[k]			*!	

b.

long	Ident C / __V	Contrast	Ident [nas] / VC-_____	Ident [stop] / VC-_____
☞a. lo[ŋ]				*
b. lo[ŋg]		*!		
c. lo[g]			*!	

c.

longer	Ident C / __V	Contrast	Ident [nas] / VC-_____	Ident [stop] / VC-_____
☞a. lo[ŋg]er				
b. lo[ŋ]er	*!			*
c. lo[g]er			*!	

d.

sign	Ident C / __V	Contrast	Ident [nas] / VC-_____	Ident [stop] / VC-_____
☞a. si[n]				*
b. si[gn]		*!		
c. si[g]			*!	

e.

signature	Ident C / __V	Contrast	Ident [nas] / VC-_____	Ident [stop] / VC-_____
☞a. si[gn]ature				
b. si[g]ature	*!		*	
c. si[n]ature				*!

Notice that [ŋg] and [gn] violate Contrast only when the following external cues are missing in word-final position. In contrast, they do not violate Contrast when the external cues are given by the following vowel.

A sequence of a sonorant and a fricative can also be accounted for by the cue-based analysis with respect to CCS. As in 'pronoun[ns]-pronu[ns]iation', both consonants in the cluster [ns] surface. Unlike the alternation between [mb] and [m] as given in (15), e.g., 'bomb [m]-bombard [mb]', [ns] does not violate Contrast since [s] is in contrast with [n] by virtue of strong noise spectrum around at 4,200 Hz. [s] has a strong internal cue and it often surfaces in the position violating Son-Seq in (2). That is to say, /s/ is allowed in syllable-initial position as in 'stay' despite initial clusters of falling sonority. The occurrence of [s] both in initial clusters of falling sonority and final clusters of rising sonority naturally falls out from the cue-based analysis where a perceptually nonsalient segment deletes regardless of its position in the syllable.

Unlike previous analyses, the contrast-based analysis adopted here has shown that CCS in English is motivated by perceptual salience not relying on the syllabic theory. So far we have recapitulated the syllabic analysis of CCS in English in terms of cue-based contrast.

3.2.2. A Sequence of Sonorants

Turning now to the alternation between [m]-[mn] as in 'column-columnar' and 'hymn-hymnal', [n] deletion here cannot be accounted for under the constraint ranking given in (18). In this case, that is, both consonants are nasals and violate Contrast. The lower ranked constraints like Ident [nas]/ VC-_____ >> Ident [stop]/ VC-_____ cannot determine the optimal output either since the relevant consonants are all nasals. In order to cope with this problem, we propose that the consonant with more transitional cues surfaces; in the case at hand, [m] has stronger transitional cues than [n] since the former has VC transition as well as CC transition, while the latter has only a CC transition. Thus [n] deletes due to the lack of enough acoustic cues to be perceived.

In what follows, we will demonstrate that the cue-based theory also outperforms the syllabic theory through the alternation between [m] and [lm]. Rice (1992) contends that a consonant in English can be syllabified into rhyme as long as it is governed either in terms of place or sonority.5) Then /lm/ is expected to be syllabified as rhyme since the first consonant, /l/, has more structures than the second consonant, /m/, in SV structure.6) However, close examination of the cluster /lm/ reveals that /l/ is deleted depending on the preceding vowel. Let us consider the examples in (20).

(20) a. [long back vowel m]: calm halm holm qualm psalm
b. [lm]: film culmelm helm realm

As shown in (20a), when /lm/ clusters occur after back vowels, /l/ is deleted. When preceded by either front or central vowels, however, /l/ is not deleted, as shown in (20b). Thus we suggest that the constraint in (21) plays a role in this alternation.

(21) *[+back]lm

This constraint is independently motivated by the lack of contrast between a back vowel and a velarized [ɫ]. Laterals involve both a tongue dorsum and a tongue tip articulation. It has been observed that the tongue dorsum is raised early with respect to the tongue tip in VC. Then [ɫ] and a back vowel sound alike, and they do not contrast much. Here the relevant constraint is a kind of Contrast constraint. [ɫ] lacks a cue to be perceived enough after a back vowel. A piece of evidence for such an analysis comes from two variations, [kælmətɪv] and [ka:mətɪv] for the word 'calmative'. The backness of the vowel affects the realization of the cluster /lm/ such that /l/ is deleted only when the preceding vowel is realized as a back vowel. Note, however, that the constraint in (21) is stated not in syllabic unit but in syntagmatic term. Tableaux in (22) illustrate the point.

5) Roce (1992, p. 83) proposes two structural relationships, government for Place and Sonorant Voicing (SV) and binding for Place. Her definitions of government and binding are given in (i).

(i) a. A governs B if B has more relevant structure than A.
b. A binds B if A has equal or less relevant structure than B.

6) Rice (1992, p. 62) assumes that /l/ is specified for [lateral], while /m/ is unspecified for [nasal] under the Sonorant Voice node.

(22) a.

calm	Ident C /__V	*[+back]lm	Ident [nas] / VC-____
a. ca[l]			*!
b. ca[lm]		*!	
☞c. ca[m]			

b.7)

calmative	Ident C /__V	*[+back]lm	Ident [nas] / VC-____
a. c[æm]ative			
b. c[æl]ative	*!		*
☞c. c[ælm]ative			

c.

calmative	Ident C /__V	*[+back]lm	Ident [nas] / VC-____
☞a. c[ɑ:m]ative			
b. c[ɑ:l]ative	*!		*
c. c[ɑ:lm]ative		*!	

In 'calmative', [m] does not constitute syllabic coda any longer before a vowel-initial suffix but [l] still deletes after a back vowel. That fact can better be accounted for in terms of the cue-based constraints.

Up to this point, we have accounted for all the examples given in (15). But recall the questions raised in Section 3.1 with respect to the independent motivation for $*\text{Nasal-b/g}]_{\sigma}$. Two specific questions were asked: First, why do only non-coronal stops delete? Second, why does this constraint exclusively refer to voiced stops? We answered the second question in terms of contrast; the sequence of a nasal and a voiceless stop is better perceived than that of a nasal and a voiced stop. The Contrast constraint requires the faithfulness of the voiceless stop between the input and the output, while it bans the faithfulness of the voiced stop between the input and the output after a nasal. Now it is time to answer the first question: Why are coronal voiced stops perceived, as opposed to non-coronal voiced stops?

[mb] and [m] are perceptually same because we need releasedness to hear /mb/. After [m], however, /b/ is not released much. On the other hand, /nd/ is more audible than /mb/ since /d/ is more released than

7) Ident [lat]/V(C) ____ needs to be added to get the optimal output 'c[ælm]ative' in (22b).

/b/ (Crystal & House, 1988; Byrd, 1992). It is also reported that it is easier to release after [t] than after [p] than after [k] (Ross, 2000, p. 416). Then the asymmetry between coronals and noncoronals with respect to CCS falls out from released cue. In addition, the less contrast between /ŋ/ and /ŋg/ than /n/ and /nd/ comes from the difference in their function. That is to say, there are fewer instances of /ŋg/ occurrence than those of /nd/. For instance, Alpha 1999 corpus of Pete Keleher of written and spoken English yields the following frequency values:

(23)

cluster	Frequency (by token)	Remark
[uŋg] [und]	70 318	
[aŋg] [and]	108 432	
[oŋg] [ond]	148 90	exception
[eŋg] [end]	7 196	
[iŋg] [ind]	14641 122	due to 'ing' suffix

The table in (23) shows that /nd/ occurs much more frequently than /ŋg/, and /nd/ and /n/ make a difference in more cases than /ŋ/ and /ŋg/. Thus speakers try to keep the difference in /nd/, but not in /ŋg/. We, thus, suggest that /nd/ has more functional load than /ŋg/ and hence it is more likely to be preserved.

In this subsection, we have shown that the cue-based theory better accounts for CCS in English than the syllabic theory. The contrast-based constraints reflect the perceptual similarity/dissimilarity, while the constraints in the syllabic theory are relatively arbitrary.

4. Conclusion

Some empirical generalizations concerning CCS in English are uncovered. First, stops are more vulnerable to deletion than other consonants. The rule-based analysis is inadequate in that it does not provide any independent motivation for separate rules. Syllable-based constraints do not give a consistent account, either. We have shown that syntagmatic contrast plays a critical role in deletion. The role of the audibility in terms of internal and contextual cues has been discussed for the account of CCS in English. Stops relatively lack internal cues, compared to sonorants, and they are easily deleted. Second, voiceless stops survive, as opposed to voiced stops, after a nasal. The syllable-based account cannot explain the generalization since no sequences of a nasal and a voiced stop violate the Principle of Sonority Sequencing. The proposed perceptual approach achieves a substantial simplification and unification of the conceptual apparatus necessary to analyze CCS in English. Steriade (1999, 2001) maintains that languages tend to license segmental contrasts where they are maximally perceptible. A voiced stop lacks perceptual salience after a nasal and becomes more easily confusable with nothing. In contrast, the presence of a voiceless stop is more perceivable after a nasal and the voiceless stop is unlikely to be deleted. The identification of consonants relies on a number of internal and external acoustic cues.

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Seok-keun Kang
Department of English
Wonkwang University
344-2 Shinryong-dong, Iksan,
Jeonbuk 570-749, Korea
E-mail: skkang@wonkwang.ac.kr

Mira Oh
Department of English
Chonnam National University
300 Yongbong-dong, Buk-gu,
Gwangju 500-757, Korea
E-mail: mroh@chonnam.ac.kr

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