A GESTURE-BASED ACCOUNT OF CONSONANT PATTERNS IN KOREAN

By

Ok-Sook Park

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ABSTRACT

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By adopting basic tenets of Articulatory Phonology and Optimality Theory, this study shows that seemingly unrelated consonant patterns in Korean can be combined and treated as regular and related phenomena within a gestural approach

Consonant patterns such as Coda Neutralization (CN), Coda Consonant Cluster Simplification (CCCS), Post-Obstruent Tensification (POT), Post-Nasal Tensification (PNT), Post-Lateral Tensification (PLT), and Aspiration in Korean are investigated in this study.

These consonant patterns are treated as separate, as exceptions, or as unrelated phenomena in previous Korean literature. In addition, Korean linguistic studies (Cho 1990, Kim-Renaud 1974, S.A. Jun 1993 and 1995, Rhee 1997, and Silva 1993) have suggested implicitly and explicitly that various aspects of Korean consonant patterns would benefit greatly from an approach that takes into account the interplay between phonetics and phonology. However, few studies have been attempted that connect phonetic characteristics to phonological explanations in explaining consonant patterns in Korean. Therefore, this study examines the extent to which consonant patterns in Korean are accounted for in terms of phonetic considerations in a given context.

One common phonological characteristic involved in CN, POT, PNT, PLT, and Aspiration is neutralization in manner of articulation. Because manner of articulation is

closely related to constriction degrees of articulators, CN, POT, PNT, PLT, Aspiration, and other phonological phenomenon are analyzed using constraints sensitive to constriction degrees in the vocal tract in a given context.

This study illustrates that a gesture-based approach, which is based on the integration of phonetics and phonology, provides simplicity in explaining various aspects of consonant patterns in Korean and makes it easy to grasp generalizations that lie behind seemingly unrelated consonant patterns. Therefore, the analyses of consonant patterns in terms of gestures provide unified and systematic explanatins for seemingly unrelated consonant patterns in Korean. In addition, some idiosyncratic phonological phenomena are better able to be explained and understood.

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Chapter 1 Theoretical Issues

1.1 Introduction

Traditionally, consonants are categorized based on both places and manners of articulation. Manners of articulation classify sounds based on degrees of constriction in the vocal tract. This study investigates Korean consonant patterns in terms of the degree of constriction and presents a unified analysis of Korean consonant patterns within Articulatory Phonology (Browman and Goldstein 1986 and 1990a).

The phonological patterns that are investigated in this study are known as Coda Neutralization (CN), Coda Consonant Cluster Simplification (CCCS), Post-Obstruent Tensification (POT), Post-Nasal Tensification (PNT), Post-Lateral Tensification (PLT), and Aspiration or h-coalescence in Korean literature. CN deals with what consonants are legitimate in coda position. CCCS refers to a phonological phenomenon in which a consonant in a consonant cluster is selected as a legitimate consonant in coda position. POT, PNT and PLT refer to phonological phenomena in which obstruents are tensed after obstruents, nasals, and the lateral /l/ respectively. POT is known to occur obligatorily within an accentual phrase[1] regardless of morpheme boundaries according to Jun (1993). PNT and PLT are known to be sensitive to morphological conditions.

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[1] According to Jun 1993, an accentual phrase is determined by the syntactic and non-syntactic information and composed of a word or words and forms an intonational phrase of an utterance. In the Seoul dialect, also known as the standard dialect of Korean, an accentual phrase with one or two syllables has the rising tonal pattern (Low (L) + High (H)) while an accentual phrase with three or more syllables has the rise-fall-rise tonal pattern (LHLH). An accentual phrase is similar to the phonological phrase of Prosodic Phonology (Selkirk 1986, Nespor and Vogel 1986, and Hayes 1989)

Aspiration or h-coalescence refers to a phenomenon in which sequences of /h/ + /p, t, k/ or /p, t, k/ + /h/ are coalesced into aspirated obstruents, resulting in [p^h, t^h, k^h] respectively.

In previous studies (Kim-Renaud 1974, Cho 1990 and Sohn 1987), these phonological phenomena are treated with separate rules that are not relevant to each other, or are treated to be irregular or exceptions. This study, by presenting an alternative view of Korean consonant patterns, will show that these seemingly unrelated consonant patterns are both systematic and related. By investigating Korean consonants in terms of the degrees of constriction in the vocal tract, this study will lead to a better understanding of Korean phonology and sound patterns.

Chapter 1 provides a brief history of linguists' view of speech sounds, frameworks of Optimality Theory and Articulatory Phonology, phonological structure of Korean, and phonetic characteristics of Korean obstruents. Constriction degree hierarchies for Korean obstruents are introduced at the end of chapter 1 as a basis of analyses for this research. Chapter 2 investigates systematic principles that lie behind CN and CCCS, suggests context-sensitive markedness constraints based on the principles, and shows how the constraints interact with other constraints. Based on the context-sensitive markedness constraints suggested in chapter 2, chapter 3 examines the phonetic motivations for obstruents being tensed after obstruents (POT) and the relationship between POT and acoustic or aerodynamic properties in (C)$V_1C_1C_2V_2$(C) contexts. Chapter 4 investigates what phonetic and phonological motivations cause PNT and PLT sensitive to morphological or phonological conditions (4.2). The analyses of this research show that there is no need to treat POT, PNT and PLT separately. POT, PNT, and PLT result from interaction of the same phonetically grounded constraints. The analysis of h-coalescence in Section 4.3 adds another example to the claim that the overlap in inter-gestural timing between segments could cause neutralization (Steriade 1997: 76, Browman and Goldstein 1992, and Cho 1998a and 1998b). Chapter 5 concludes with implications of this study and possible directions of future research.

The analyses in this study are based on two main theoretical assumptions: Articulatory Phonology which integrates phonetics and phonology (Browman and Goldstein 1986, 1989, 1990a, 1990b, 1990c, 1991, 1992 and Browman 1994) and Optimality Theory (Prince and Smolensky 1993 and McCarthy and Prince 1993a, 1994 and 1995). Articulatory Phonology is adopted for the units of representation and Optimality Theory for relating an input to an output.

Throughout the history of speech studies, phonological theories have revolved around two main questions: What is the unit of phonological representation? and how does a phonological representation (an input) relate to a phonetic representation (an output)? The following introduces the theoretical frameworks related to these two questions and briefly describes the phonological structure of Korean consonants.

1.2 Background and theoretical assumptions

1.2.1 Before Generative Phonology

Prior to the late 1950s and early 1960s, linguists were concerned with how speech sounds are characterized articulatorily and acoustically (phonetics) and how sounds function in a particular language (phonology). At this time, phoneticians classified speech sounds on a physical basis: places and manners of articulation for consonants, with consonants represented in columns and rows of a chart. The chart implies that there is a one-to-one correlation between articulations and sounds. A one-to-one correlation between articulations and sounds was developed into the concept that segments are discrete, separable and permutable with an utterance being a linear concatenation of segments. Thus, linguists paid attention to isolating the individual sounds rather than the dynamics of speech.

After separating speech into segments, linguists paid attention to how a sound (or a segment) functions in a language, developing the concept of phonemes. For example, in English, [p] in [pɛg] and [b] in [bɛg] make words differ in meaning. Thus, [p] and [b] function as distinctive units (or phonemes) and are represented as /p/ and /b/ respectively. In addition, if an English speaker pronounces [pɛg], [p^hɛg] or [p'ɛg][1], the word is 'peg'

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[1] [p], [p^h] and [p']: Lax (or plain), aspirated and tensed voiceless bilabial stops respectively.

without differences in meaning. These sounds ([p] [p^h] or [p']) are considered as various pronunciations for the phoneme /p/ in a given context in English. Thus /p/ (phoneme) is a label for the set of [p, p^h, p'] (allophones) in English.

In Korean, however, [p] and [b] do not make words different in meaning. A Korean speaker can pronounce either [pap] or [bap] for the word /pap/ 'cooked rice'. Both [p] and [b] are considered as one of various pronunciations of the phoneme /p/. Thus, /p/ is a label that is put on the set of [p, b] in Korean. /p/ is typically a voiceless bilabial stop in both English and Korean. However, phonologically /p/ represents different sets of allophones in English and Korean (/p/ for [p, p^h, p'] in English and /p/ for [p, b] in Korean). Thus the phoneme becomes an abstract concept rather than representing a sound in its own right.

1.2.2 Generative Phonology

1.2.2.1 Early Generative Phonology

Early Generative Phonology began during the late 1950s and 1960s with Morris Halle's Sound Pattern of Russian (1959) and Chomsky and Halle's Sound Pattern of English (1968). Generative phonologists have focused on what speakers and listeners know about a language's sound system. Early Generative Phonology differs from previous phonologies (or classical phonologies) in several points.

First, speech is composed of two levels: phonological and phonetic representations, which are mediated by rules of phonology. The phonological representation of each lexical entry contains phonologically distinctive features, which determine the phonetic form of an item in all contexts according to the rules of the sound patterning in a particular language (Chomsky and Halle 1968:297). Phonological representation contains information that is not predictable or describable by phonological rules and is expressed with horizontal and vertical dimensions. The horizontal dimension stands for the successive phonemes of a language and the vertical dimension stands for names of distinctive features, as shown in (1).

(1)

$$
\begin{array}{llll}
/\text{a} & \text{k} & \text{i} & /\ \text{‘baby’ in Korean} \\
\begin{bmatrix}\text{-back} \\ \text{-hight}\end{bmatrix} & \begin{bmatrix}\text{-sonorant} \\ \text{-continuant} \\ \text{-anterior} \\ \text{-coronal} \\ \text{-spread glottis} \\ \text{-constricted glottis}\end{bmatrix} & [\text{-back}] &
\end{array}
$$

The (surface) phonetic representation indicates degree along a physically defined scale and may thus assume numerous coefficients, as determined by the rules of the phonological component (Chomsky and Halle 1968: 297).

Second, in classical phonology, phonemes were minimal units of phonological descriptions. However, phonological descriptions with phonemes as basic units had the problems of being redundant and failed to recognize generalizations. In Korean, for instance, /p/, /t/ and /k/ are voiced between two vowels. In classical phonology, three separate rules are needed for this voicing phenomena as in (2b) because /p/, /t/ and /k/ are the minimal units of phonological description. This fails to recognize the generalization that a set of sounds (/p/ /t/ and /k/) patterns together by sharing common features ([+consonant, -voice, -continuant, -constricted glottis, -spread glottis]).

Early generative phonologists claimed that human beings perceive speech in terms of class rather than individual sounds. The strategy of classification of sounds is a binary principle, namely the presence or absence of a feature. It was claimed that sounds represented by the presence or absence of a feature reflect what we know about our languages. Thus, distinctive features, which are expressed by a binary principle, are used in order to capture ‘natural’ classes, to generalize about occurring phenomena, and to formulate predictions about the behavior of class members. Thus, the voicing of stops between two vowels is stated with a rule (2a):

(2) a. Early Generative Phonology
[+consonant, -continuant, -constricted glottis, -spread glottis]→[+voice] / V_V

b. Classical Phonology
/p/→[b]/ V_V
/t/ →[d]/ V_V
/k/ →[g]/ V_V

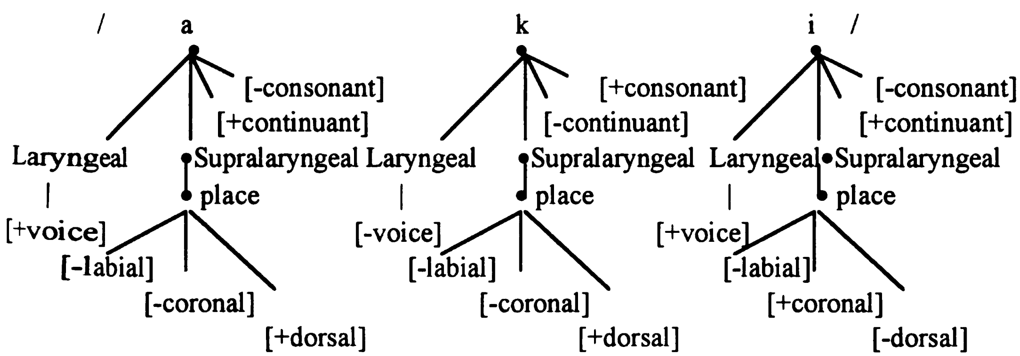
1.2.2.2 Non-linear Phonology

Since 1970, the linear view of phonological representation as shown in (1) has been challenged by studies of tones and stress (Woo 1969 and Leben 1973, and Liberman and Prince 1977). Studies on tones, stress and vowel harmony have shown no one-to-one relationship between a segment and a feature. Instead, segment patterns are independent from feature or tone patterns, resulting in a contour tone or mismatch between the number of tone bearing units and tones. Thus, in non-linear phonology, features or prosodic structures are placed on separate tiers (Clements and Keyser 1983, Goldsmith 1976, and van der Hulst and Smith 1982).

The non-linear view of phonological representation further developed into Feature Geometry theories (Clements 1985, Clements and Hume 1995, McCarthy 1988, and

Sagey 1986). The basic principle of Feature Geometry theories is that features are not only placed in separate tiers but also organized in a hierarchical tree structure, as shown in (3). For instance, /aki/ in (1) is composed of [-coronal], [-coronal], and [+coronal] at the coronal tier as shown in (3). Coronals, which are dominated by the place node, may pattern together with labials or dorsals in phonological rules involving the place node. This is because the labial, coronal and dorsal tiers are daughters of the place node.

(3) Based on Sagey (1986)



Feature Geometry theories explain why a group of features patterns together in assimilation and deletion by expressing dependency among features. The marriage between Feature Geometry theories and the early Generative Phonology's assumption that predictable information is absent in phonological representations led to Underspecification theories, in which not all nodes of a feature geometry are present phonological representations (Steriade 1987, Kiparsky 1982a and Archangeli 1988).

Although our understanding of phonological representation has increased greatly with the non-linear view of phonological descriptions, some basic principles of early Generative Phonology have been questioned. First, phonologists relied heavily on a series of ordered rules or rules and constraints in explaining phonological adjustments between an input and its output. However, rules are known to be too powerful to produce all and only surface forms of a language. For instance, there is nothing that prevents replacement of V_V with _{#, C} in (2a), resulting in [+voice] stops in coda position. However, having [+voice] stops is less common (or more marked) than having [-voice] stops in coda position in natural languages (Lisker and Abramson 1964, Lombardi 1995, Ohala 1983).

A theory of "markedness" is implemented to prevent occurrence of unnatural phonological alternation in natural languages. Usually "markedness" is expressed as constraints such as "sequences of obstruents within the syllable must agree for voicing (*αvoice-αvoice, Gussenhoven and Jacobs 1998:51)." or "no voiced stops in coda position (*+voice/_{#, C})." However, the rule-based approach with constraints is known to have "duplication problems" according to Gussenhoven and Jacobs (1998: 50) and Kenstowicz and Kisseberth (1977: 136). A rule that a voiced obstruent becomes voiceless after a voiceless obstruent is necessary to explain [bæks̲] from /bæk-z̲/[2] 'backs' in English. Native speakers of English also should have a constraint *αvoice-αvoice so that they are aware that *[æbs] and *[æpz] are ill-formed syllable structures while [ɔks]

[2] Examples are from Gussenhoven and Jacobs 1998:45-50.

'ox' and [ædz] 'adz' are well-formed syllable structures in English. The devoicing rule and the constraint *αvoice-αvoice work for the same purpose in English grammar but are expressed differently. In the 1990s, Optimality Theory (Prince and Smolensky 1993 and McCarthy and Prince 1993 and 1995) presents an alternative view on explaining phonological adjustments between input and output. Section 1.2.3 presents a brief overview of Optimality Theory.

Second, a binary principle is known to be too simple to connect to the physical reality of speech. Ladefoged (1972) claims that although two sounds are represented with [+/-X], the differences in these two sounds are not based simply on [X]. These two sounds may differ in length, shape of vocal tract, target positions, and in other ways. Thus, in the mapping between phonological and phonetic representations, distinctive features that are based on the binary principle are not adequate as an explanatory device, even though distinctive features are based on phonetic characteristics.

Third, most generative phonologists described isolated individual sounds and treated them out of context without paying attention to the dynamics of speech as classical phoneticians did. However, the traditional view of speech as the concatenation of discrete, separable and permutable segments, as shown in (1) and (3), has been changed by technological advances. Electromyography, for instance, allows linguists to study the motor control of the vocal tract during speech. Technological advances enabled linguists to realize that it is rarely possible to be sure about the beginning and ending of various sounds. Phoneticians and some phonologists started to become aware of how non-linear and non-discrete speech is and became reluctant to treat speech sounds as 'discrete units' and 'static phenomena' as in Classical Phonology and early Generative Phonology.

With the view of speech as continuity, phonologists have suggested several different approaches in order to overcome the problems of classical and early Generative Phonology. Speech is viewed as a 'dynamic' rather than a 'static' phenomenon in these approaches. These approaches are often referred to as phonetically motivated phonology. Among the phonetically motivated approaches to speech, Articulatory Phonology of Browman and Goldstein (1989 and 1990a) is significant in unifying phonological and phonetic descriptions. Section 1.2.4 provides a brief overview of Articulatory Phonology as presented by Browman and Goldstein (1989 and 1990a).

1.2.3 Optimality Theory

Although several different approaches on how to represent phonological units have been suggested, approaches on how to relate a phonological representation (input) to a phonetic representation (output) did not change significantly until the Optimality Theory (OT) proposed by Prince and Smolensky (1993) and McCarthy and Prince (1993 and 1995). In derivational approaches, a grammar is composed of a series of rules or rules and constraints (Chomsky and Halle 1968, Paradis 1988) while in OT, a grammar is composed of output constraints.

There are three components in OT: lexicon, generator and evaluator. The lexicon contains contrastive properties of morphemes and provides input specifications. The generator generates output candidates based on an input. The evaluator evaluates output candidates against a set of ranked output constraints and selects one candidate as the most optimal output (☞), as shown in (4). Using hypothetical languages, the process of selecting the most optimal candidate among output candidates is explained in (7).

(4)

Leixicon **Evaluator**

Generator

Input	Constraint 1	Constraint 2	Constraint 3
Candidate 1	*		
Candidate 2		*	
☞ Candidate 3			*

* : A critical violation.

One of the main issues that arises in OT is what an input should be. Constraints such as Morpheme Structure Condition (Kiparsky 1982b) are abandoned on the assumption that no constraints are imposed on the input (Richness of Base) in OT. As there are no constraints on the input, many inputs could be produced. However, based on the acquisition perspective, OT generally accepts the assumption that in the absence of empirical evidence for one input over another, the input should be the one that is closest to the output (Lexical Optimization). (For further discussion on what an input should be, see Prince and Smolensky 1993: 191-96, Archangeli and Langendoen 1997: 13, Kager 1999: 19-34 and Ito, Mester and Padgett 1995).

Using hypothetical languages, L1 and L2, the process of selecting the most optimal candidate among ouput candidates are explained. In L1, stops are voiced between two vowels and are voiceless in all other contexts as shown in (5a). In L2, there are no voiceless stops between two vowels while the contrast between [+/-voice] stops is maintained in outputs, as in (5b).

(5) a. L1

[+voice]	[-voice]	
[aba]	[pa]	[ap]
[ada]	[ta]	[at]
[aga]	[ka]	[ak]

b. L2

[+voice]			[-voice]	
[aba]	[ba]	[ab]	[pa]	[ap]
[ada]	[da]	[ad]	[ta]	[at]
[aga]	[ga]	[ag]	[ka]	[ak]

First, it is necessary to identify a set of relevant constraints. All languages use some voiceless stops while only a subset of languages uses voiced stops. Voiced stops are more marked than voiceless stops (Maddieson 1984). (6a) represents a context-free markedness constraint for the avoidance of voiced stops in languages.

However, in some languages where no words are contrasted by [+voice] and [-voiced] stops, there are cases when [-voiced] stops are voiced between two vowels (ex. Korean). Thus, voiceless stops are not allowed between two vowels. (6b) represents the disallowance of voiceless stops between two vowels.

In addition, there is a force in the grammar of a language that demands that features in input and output segments be identical. (6c) demands identity of correspondence segments in terms of [+/-voice].

(6) a. *[+voice]: Stops must not be voiced.
b. *[-voice]/V_V: No voiceless stops between two vowels.
c. IDENT-IO[+/-voice]:
Correspondent segments are identical in feature [+/-voice].

If IDENT-IO[+/-voice] is ranked higher than *[+voice] in a language, voiceless and voiced stops are contrastive as satisfaction of IDENT-IO[+/-voice] takes precedence over satisfaction of *[+voice]. However, no words are contrastive by [+/-voice] in L1. Thus, IDENT-IO[+/-voice] is ranked lower than *[+voice] in L1 (*[+voice] >> IDENT-IO[+/-voice][3]).

The constraints, *[+voice] and *[-voice] /V_V, are in conflict. The constraint *[+voice] demands that stops not be voiced. *[-voice] /V_V demands that stops be voiced between two vowels. If *[+voice] is ranked higher than *[-voice] /V_V, no words are voiced between two vowels. The undominated *[+voice] has to be satisfied first before satisfaction of *[-voice] /V_V. In L1, voiced stops appear between two vowels but not in other contexts. Thus, satisfaction of *[-voice] /V_V takes precedence over satisfaction of *[+voice], resulting in the ranking hierarchy *[-voice] /V_V over *[+voice]. By transitivity, *[voice]/V_V is ranked higher than IDENT-IO[+/-voice] in L1 as shown in (7)

[3] A>>B: A is higher than (dominates) B in a ranking hierarchy

(7) L1: *[-voice] /V_V >> *[+voice] >> IDENT-IO[+/-voice]

A.

/apa/	*[-voice] /V_V	*[+voice]	IDENT-IO[+/-voice]
a. apa	*!		
☞b. aba		*	*

!: A critical violation. Shaded cells: Constraints not relevant to select the most optimal candidates. A constraint in a left-hand column dominates constraints to its right.

B.

/aba/	*[-voice] /V_V	*[+voice]	IDENT-IO[+/-voice]
a. apa	*!		*
☞b. aba		*	

C.

/ap/	*[-voice] /V_V	*[+voice]	IDENT-IO[+/-voice]
☞a. ap			
b. ab		*!	*

D.

/ab/	*[-voice] /V_V	*[+voice]	IDENT-IO[+/-voice]
☞a. ap			*
b. ab		*!	

In (7A), (7Aa) violates the undominated constraint *[-voice] /V_V because of [p] between vowels. (7Ab) violates the context-free markedness constraint *[+voice] by having [+voice] stop [b] and violates a faithfulness constraint IDENT-IO[+/-voice] because [-voice] in input is changed to [+voice]. Although (7Ab) has two violations of constraints, (7Ab) is selected as the most optimal candidate. Thus, satisfaction of high ranked constraints is more important than satisfaction of low ranked constraints in OT.

In (7B), although there is a [+voice] stop [b] in input, constraints and their hierarchy suggested in (6) still select the same [aba] as the most optimal output.

In (7C) and (7D), both output candidates [ap] and [ab] satisfy the highest constraint *[-voice] /V_V because *[-voice] /V_V demands stops be voiced between two vowels. In fact, the constraint *[-voice] /V_V is not the relevant constraint for [ap] and [ab]. (7Cb) and (7Db) violate *[+voice] as they have the voiced consonant [b] in output. (7Cb) satisfies IDENT-IO[+/-voice] as the [-voice] stop [p] is maintained. However, (7Db) violates IDENT-IO[+/-voice] as correspondent segments are not identical in [+/-voice] features.

The comparison of tableaux (7A) to (7B) and (7C) to (7D) shows that stops are voiced between two vowels but not in any other context regardless of candidate's input voicing specification in L1. Thus (7) shows that rather than feature specification or conditions that are imposed on an input, it is the interaction of output constraints that determine the most optimal outputs (Kager 1999:19).

In L2 (2b), [+/-voice] stops are contrastive in outputs. However, [-voice] and [+voice] are neutralized to [+voice] between two vowels. Consider the fact that [+/-voice] stops are contrastive in outputs. If IDENT-IO[+/-voice] is ranked higher than *[+voice], outputs maintain the [+/-voice] specification of their input.

Minimal pairs such as [ba] vs. [pa] and [ag] vs. [ak] in L2 suggest that the faithfulness constraint, IDENT-IO[+/-voice] is ranked higher than *[+voice] as [-voice] and [+voice] are contrastive except between two vowels. Between two vowels, there are no [-voice] stops although [-voice] and [+voice] are contrastive in L2, resulting in positional neutralization. This means that [-voice] in inputs is changed to [+voice] in ouputs between two vowels, resulting in satisfaction of *[-voice] /V_V and violation of IDENT-IO[+/-voice]. Thus, the constraint *[-voice] /V_V should be ranked higher than IDENT-IO[+/-voice]. Otherwise, [-voice] and [+voice] stops would be contrastive regardless of their positions. (8) shows the constraint hierarchy and evaluation of constraints for L2.

(8) L2: *[-voice]/ V_V >> IDENT-IO[+/-voice] >> *[+voice]

A.

/apa/	*[-voice]/ V_V	IDENT-IO[+/-voice]	*[+voice]
a. apa	*!		
☞b. aba		*	*

B.

/aba/	*[-voice]/ V_V	IDENT-IO[+/-voice]	*[+voice]
a. apa	*!	*	
☞b. aba			*

C.

/ap/	*[-voice]/ V_V	IDENT-IO[+/-voice]	*[+voice]
☞a. ap			
b. ab		*!	*

D.

/ab/	*[-voice]/ V_V	IDENT-IO[+/-voice]	*[+voice]
a. ap		*!	
☞b. ab			*

[apa] in (8A) and (8B) is not the most optimal candidate as it violates the undominated *[-voice]/ V_V. [apa] in (8A) satisfies the constraint IDENT-IO[+/-voice] but the satisfaction of IDENT-IO[+/-voice] is not relevant in (8A) as it violates the highest

constraint *[-voice]/ V_V. In (8A), [aba] violates IDENT-IO[+/-voice] but [aba] is a more optimal candidate than [apa] because of satisfaction of *[-voice] /V_V. Contrary to L1, the faithful constraint IDENT-IO[+/-voice] plays a role in selecting the most optimal candidates in L2 as shown in the comparison of (8C) and (8D). In (8C) and (8D), the most optimal candidates always satisfy the faithfulness constraint IDENT-IO[+/-voice].

The comparison of (7) to (8) shows that language differences stem from language-particular rankings of violable but identical constraints. In OT, language universality is expressed in the same constraints that are violable. Language variations are expressed in terms of language-particular constraint rankings as shown in (7) and (8). Markedness is expressed with negative or positive constraints as in *[+voice], *NO CODA (syllables are open), or ONSET (syllables should begin with consonants). Language specific phonological patterns result from interaction of markedness constraints and faithfulness constraints.

For instance, voiced stops and voiceless stops are in complementary distribution in L1 because they never appear in the same environment. The constraint ranking *[-voice]/V_V over *[+voice] results in [+voice] stops between two vowels in L1. The constraint ranking *[voice] over IDENT-IO[+/-voice], in turn, disallows [+voice] stops in all other contexts as *[+voice], a context-free constraint, eliminates all voiced stops regardless of their positions.

Contrary to L1, voiced stops and voiceless stops appear in the same environments in L2 because of interaction between IDENT-IO[+/-voice] >> *[+voice]. However, the constraint ranking *[-voice]/V_V over IDENT-IO[+/-voice] results in no [-

voice] stops between two vowels. Thus, effects of IDENT-IO[+/-voice] appear when stops do not occur between two vowels as in (8C) and (8D). In (8C) and (8D), the most optimal candidates do not violate IDENT-IO[+/-voice]. Thus, the faithfulness constraint, IDENT-IO[+/-voice], plays a role in selecting the most optimal candidates. In L2, positional neutalization of [+/-voice] results from the domination of the context-sensitive marked constraint *[-voice]/V_V over the faithfulness constraint, IDENT-IO[+/-voice] and context-free marked constraints *[+voice].

Data in this research shows positional neutralization. Thus, in this study, context-sensitive markedness constraints are ranked higher than faithfulness constraints in general, as in L2. Relevant markedness constraints are introduced in each chapter. Relevant faithfulness constraints are introduced below based on Correspondence Theory (CT) suggested by McCarthy and Prince (1995).

CT (McCarthy and Prince 1995) deals with issues of faithfulness between an input and an output. Constraints in CT basically demand that S1 (input, base, etc.) be identical to S2 (output, reduplicant, etc.). Three of the constraint families that play an important role in this research are introduced in (9).

(9) McCarthy and Prince (1995:16)

A. The **MAX** Constraint Family: (No Deletion)
Every segment of S1 has a correspondence in S2.

B. The **DEP(ENDENCE)** Constraint Family: (No Insertion)
Every segment of S2 has a correspondence in S1

C. The **IDENT(ITY)** (Feature) Constraint Family (IDENT-IO[F])
(No Feature adjustment)
Let α be a segment in S1 and β be any correspondence of α in S2.
If α is [γF], then β is [γF].
(Correspondent segments are identical in feature F).

The MAX constraint family favors the preservation of every element of S1 in S2. Thus, the deletion of a segment is disfavored in the MAX constraint family. In the DEPENDENCE (DEP) constraint family, every segment of S2 requires a correspondence in S1. The epenthesis of a default segment or other segment is disfavored in the DEP constraint family, because the epenthetic segment does not have a relevant segment in input. The IDENTITY (IDENT-IO) (Feature) constraints favor the maintenance of underlying features in output. For instance, phonological changes such as deaspiration of a segment (/p^h/ $\rightarrow$ [p]) and palatalization of a segment (/s/ $\rightarrow$ [ʃ]) are disfavored.

As it will be discussed in 1.2.4, in Articulatory Phonology, gestures that are specified with phonological goals such as constriction degree, constriction location, constriction shape, stiffness and timing are phonological units. Thus, the IDENTITY (IDENT-IO) (Feature) constraints are revised to incorporate the concept of gestures as basic units of phonological representation:

(10) The IDENT(ITY) (Gesture) Constraint Family (IDENT-IO[G])

Gestures (constriction degree, constriction location, constriction shape, stiffness, and timing) in S1 are maintained in S2.

(Correspondent segments are identical in Gestures (G)).

1.2.4 Articulatory Phonology

In Articulatory Phonology, speech is considered as a two-layered process that is related to planning (phonology) and execution (phonetics). Phonology is the planning of how each utterance is to take place. Phonetics is thought of as taking over the plan and executing it.

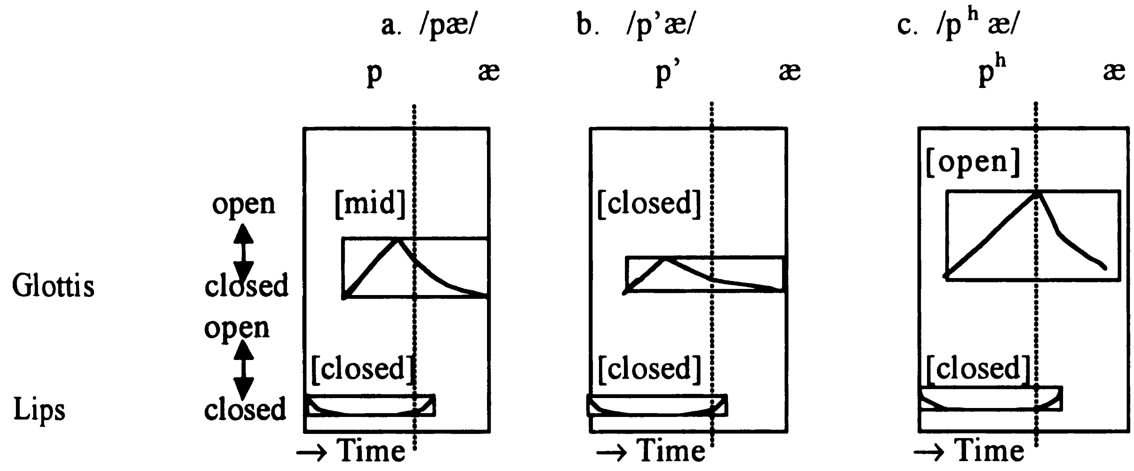
According to Tatham (1999), one of the motivations for modeling speech as a two-layered process is based on the difference between planning and execution. Tatham gives an instance from Estuary English. A plan for each word, cap, cat, cack, cab, cod and cag, is to end with a different stop, which is either voiceless or voiced. However the plan is somehow altered in the execution. Thus, a listener differentiates words with voice and voiceless stops by the length of the proceeding vowels rather than the voicing quality of final stops. In other words, phonologically (or in planning) they are differentiated by the voicing quality of final stops. Phonetically (or in execution), the difference is determined by the length of vowels.

According to classical and early generative phonology, these words are differentiated by voicing quality, regardless of phonological and phonetic levels. Thus, classical and earlier phonologies need another level that interprets the difference between planning and execution. At this level, [+/- long] may have to be used, even though it is not even a distinctive feature in Estuary English. Thus, classical or earlier phonologies either proliferate features and grammar, or miss generalizations that are present in a given context.

1.2.4.1 The unit of representation in Articulatory Phonology

A gesture, which is associated with space and time, is the basic atom of phonological structure in Articulatory Phonology. As a phonological unit, a gesture is an abstract characterization of coordinated task-directed movements. A gesture is specified with articulators involved, constriction degrees (CD), constriction locations (CL) and constriction shapes (CS) over time. The gestures for a given utterance are organized into a large coordinated structure, or constellation, namely a gestural score, as schematically shown in (11).

(11) Gestural Scores for Korean /pæ/, /p'æ/, /pʰæ/



In (11), each enclosed box represents an active articulator in the vocal tract, in this case the glottis and lips. The height of each box represents the constriction degree of the relevant articulators. The width of each box represents the time that an articulator takes to complete given gestures. The order of boxes across the time line represents the order of gestures along the time line. Thus, lip gestures with the [closed] constriction degree occur before glottal gestures in (11a, 11b, and 11c).

However, (11a), (11b), and (11c) differ from each other in constriction degree of the glottis. Plain /p/ in /pæ/ (11a) has the [mid] constriction degree of the glottis, and /p'/ in /p'æ/ (11b) has the [closed] constriction degree of the glottis. Aspirated /pʰ/ in /pʰæ/ (11c) has the [open] constriction degree of the glottis. The [closed] constriction degree refers to a tight articulatory closure for that particular gesture (Browman and Goldstein 1989: 226). [closed] permits glottalization or oral stops, depending on the set of articulators involved. The [closed] constriction degree of glottlal gestures creates the oral and nasal stops. The [open] constriction degree is a wide articulatory opening that permits aspiration or nonnasal sonorants, depending on the set of articulators involved. For instance, the [open] constriction degrees at the glottis and at the supralayngeal level generates aspiration (Browman and Goldstein 1989:238). The [mid] constriction degree of the glottis for the plain /p/ refers to an articulatory value that falls between the [closed] constriction degree of the glottis for the tense /p'/ and the [open] constriction degree of the glottis for the aspirated /p^h/. The constriction degree values of the glottis for Korean obstruents are discussed in detail in section 1.3.2.2.

The dotted lines in (11) represent the point where the [closed] constriction degree of the lips is released. At the burst of the oral closure, the width of the glottis is different according to types of /p/. Thus, aspirated /p^h/ has the widest opening ([open]) of the glottis at the lip-closure burst. Tense /p'/ has the narrowest opening ([closed]) of the glottis at the lip-closure burst.

As a phonetic unit, gestures are characterizations of the movements of articulators through space and time. A gestural score also shows which gestures are co-articulated with other gestures and how long they are co-articulated. The curved lines within the boxes in (11) characterize degrees of constriction over time. Thus, in (11c), the opening of the glottis reaches its maximum when the lip closing is released in /p^{h}a/.

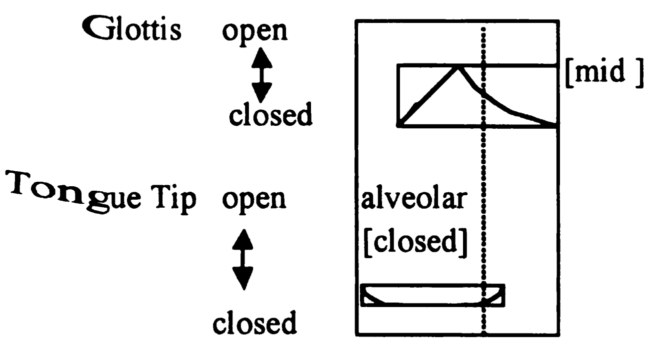
The gestures for a given utterance characterize the actual observed movement of articulators and function as units of contrast. In distinctive feature theories, contrasts of sounds are represented by the presence or absence of features. In Articulatory Phonology, the contrasts of sounds are represented by the presence or absence of a

Phonology, the contrasts of sounds are represented by the presence or absence of a gesture, the degree of constriction, the timing of gestures and the organization of gestures (Browman and Goldstein 1986 and 1991). For example, (11) above shows that the different degrees of constriction of the glottis are distinctive in Korean stops.

Gestures as phonological units differ from both features and segments. A gesture is larger than a feature; a feature refers to one specific character of sounds such as voicing or nasality. A gesture in a gestural score includes information related to articulators, constriction degrees, constriction locations and constriction shapes (CS) over time. Gestures are smaller than segments as gestures are linked together to form a segment (Browman and Goldstein 1989:210-11).

The phonological representations of Articulatory Phonology contain more information on a segment than the phonological representations of Underspecification theories do (Steriade 1987, Archangeli 1988, Archangeli and Pulleyblank 1993 and Paradis and Prunet 1991). For instance, in a language where [+/-voice] are contrastive as in English /tie/ and /die/, /t/ has all the relevant feature specifications, as in (12a) below.

(12) a. /t/



b. /t/ (based on Paradis and Prunet 1991)

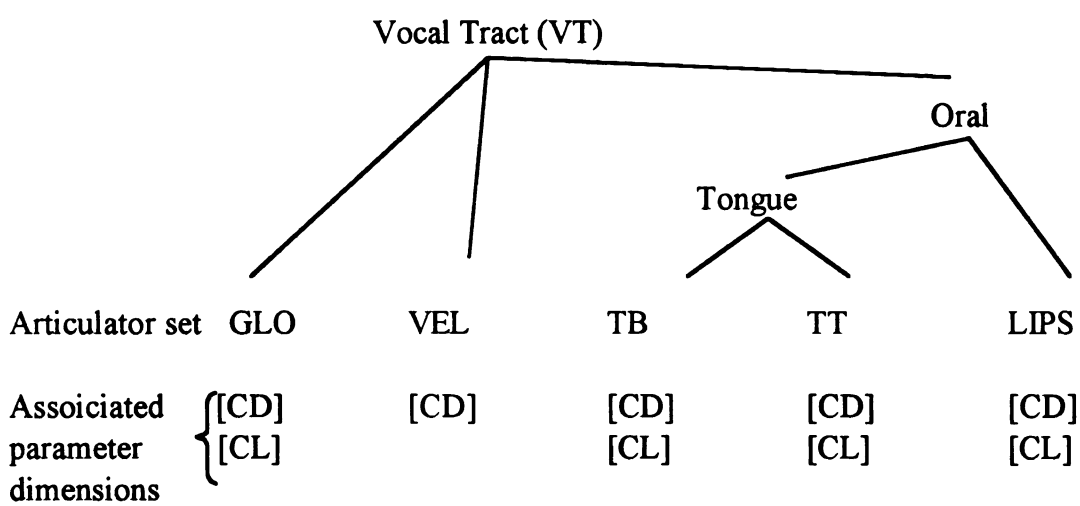
• Root
|
• Place

The active articulators for /t/, such as Glottis (GLO) and Tongue Tip (TT) are specified, including information on the location of constriction (alveolar) in (12a). However, the place node under the root node, as shown in (12b) above, is enough for the phonological representation of /t/ in Underspecification theories proposed by Archangeli 1988, Archangeli and Pulleyblank 1993 and Paradis and Prunet 1991.

1.2.4.2 Distinctiveness and natural classes in Articulatory Phonology

There are two ways of grouping sounds into natural classes in Articulatory Phonology. First, natural classes are grouped based solely on the moving articulators used, as shown in (13a).

(13) Articulatory Geometry Tree (Browman and Goldstein 1989:223)



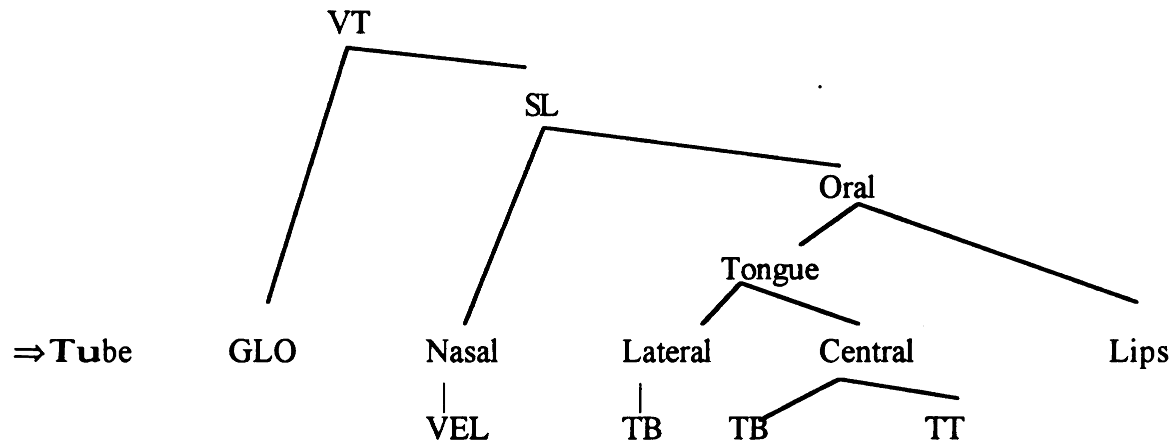
VT: Vocal tract GLO: Glottis VEL: Velum TB: Tongue Body TT: Tongue Tip
CD: Constriction Degree CL: Constriction Location

Gestures as independent moving articulators are specified with constriction degrees (CD) such as [open] or [closed], constriction locations (CL) such as [alveolar] and [palatal], and other parameters[4], as shown in (13). Articulatory Geometry (13) groups gestures into a hierarchy based on the anatomy of the vocal tract and classifies gestures into natural classes. Thus, [t, d, s, z, n, tʃ, dʒ, n, l] form a natural class by using the same articulator, Tongue Tip (TT).

In addition, the vocal tract is viewed as a tube or a series of tubes in Articulatory Phonology, as shown in (14). There are five basic tubes (nodes) in the vocal tract that are connected: Glottis, Nasal, Lateral, Central, and Lips (14). The active moving articulators of gestures, such as the tongue tip and the velum, reside in these tubes. The vocal tract (VT) as a tube is terminated by glottis and lip gestures. The simple nodes and/or the terminators of tubes (Glottis and Lips) form tube junctions such as Tongue, Oral, Supralaryngeal (SL) and VT junctions. These tube junctions are related to the superordinated nodes of feature systems.

[4] Other associated parameter dimensions are constriction shape [CS] and stiffness. Except for the stiffness of the glottis, these dimensions are not directly relevant for analyses in this research. Thus, they are omitted from the articulator geometry tree (13).

(14) Tube Geometry (Browman and Goldstein 1989:236)



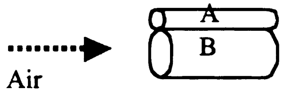
SL: Supralaryngeal

The second way of grouping sounds into natural classes is by using a constriction degree hierarchy (CDH) within the vocal tract based on Tube Geometry (14). Browman and Goldstein (1989:237) state that the CD at each superordinate is predictable "from the CD of the tubes being joined and the way they are joined" (see 15c).

If tubes are joined in parallel as in (15a), air flows through connected tubes at the same time. Thus, the effective CD value of the compound tube is equal to the widest CD value of the connected tubes (B value in (15a)). If tubes are joined in series as in (15b), air flows through connected tubes one after another. Thus, the effective CD value of the compound tube is equal to the narrowest CD value of the connected tubes (A value in (15b)). Based on aerodynamic principles, Browman and Goldstein (1989:237-39) predict constriction degrees for superordinate nodes as in (15d).

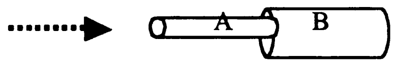
(15) The airflow value/ The effective CD of the compound tube

a. Tubes in Parallel



= B value (the widest CD)

b. Tubes in Series



= A value (the narrowest CD)

= A value (the narrowest CD)

c. Effective CD values for the superordinate tubes (Browman and Goldstein 1989:237-39)

> ...When tubes are joined in parallel, the effective CD of the compound tube has the CD of the widest component tube, that is, the maximum CD. When they are joined in series, the compound tube has the CD of the narrowest component tube, that is the minimum CD...

d. Percolation of CD up through Supralaryngeal node (Browman and Goldstein 1989:237)

Nasal	[CD] = VEL [CD]
Lateral	[CD] = TB [CD]
Central	[CD] = MIN (TT [CD], TB[CD])
Tongue	[CD] = MAX (Central [CD], Lateral [CD])
Oral	[CD] = MIN (Tongue [CD], LIPS [CD])
Supra	[CD] = MAX (Oral [CD], Nasal [CD])

Using (15d) as an example, the CD of the SL tube is predicted from the CD of the oral tube and the CD of the nasal tube. As air can flow through the oral tube and the nasal tube at the same time, they are connected in parallel. Thus, the CD of the SL node is equal to the maximum CD of the oral or nasal tubes.

In addition, the VT tube at the highest level is described in terms of the characteristics of the 'output' flow such as occlusion, resonance and noise as shown in (16a). This is because the airflow at this highest level is also influenced by the initiator action from the lungs as well as the constriction degrees of the glottis and the SL node. Thus, occlusion is either from the [closed] CD at the SL level or from the [closed] CD of the glottis. Resonance results from the [open] CD at the SL level and [critical] CD at the glottal level. Fricatives, which have turbulent airflow and noise, are from other combinations of CDs at the SL level and the glottis. (16b) shows default CD values for basic tubes when articulators in basic tubes are not active.

(16) a. VT output

Occlusion = SL [closed] **OR** GLO [closed]
Resonance = SL [open] **AND** GLO [critical] [5]
Noise = Otherwise
(Browman and Goldstein 1989:238)

b. Default constriction degree values for basic tubes and terminators

Nasal	[CD] = Closed
Lateral	[CD] = Central [CD]
Central	[CD] = Open
Lip	[CD] = Open
Glottal	[CD] = Critical (Crit)

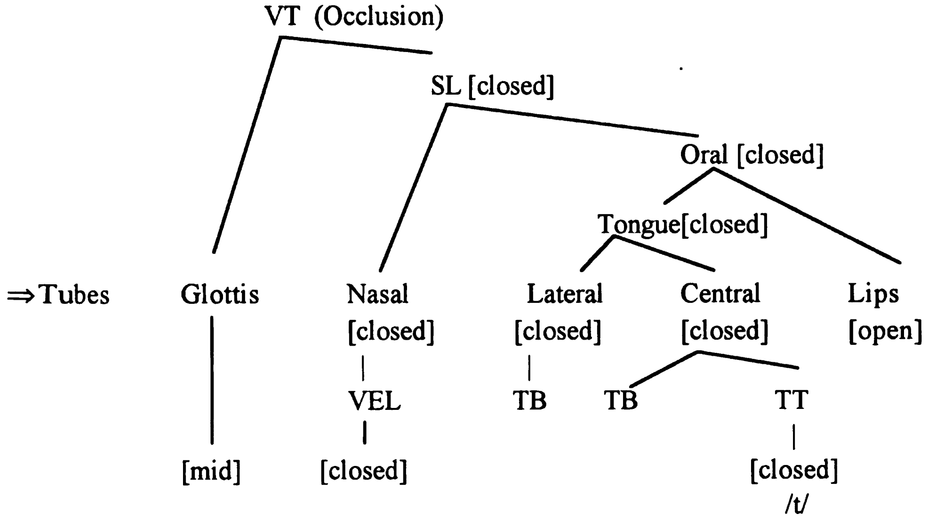
(Browman and Goldstein 1989:239)

(17) illustrates how the CD of the vocal tract for /t/ and /n/ are determined based on (15) and (16).

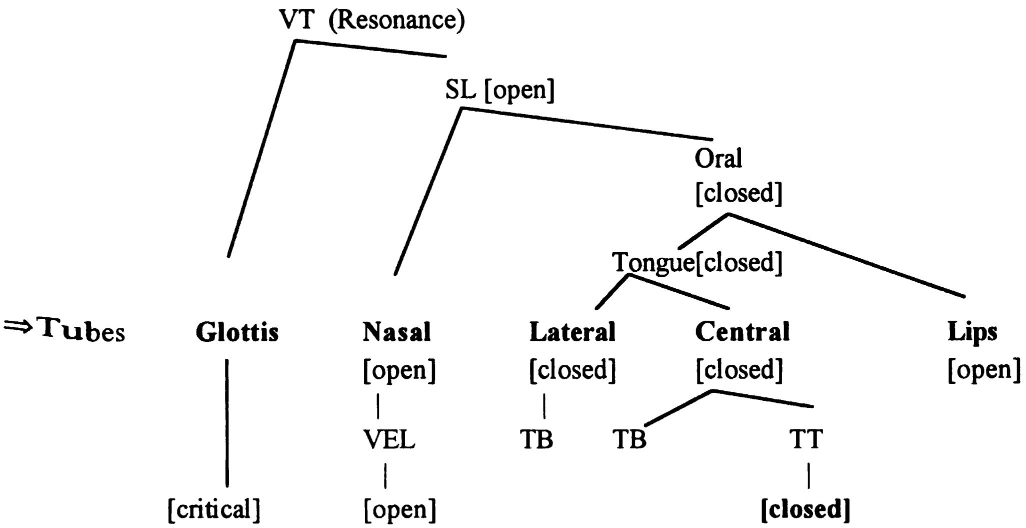
[5] [Critical] is an articulator value that permits frication (turbulence) or voicing, depending on the set of articulators involved (oral or laryngeal) (Browman and Goldstein 1989:225). A [critical] value within the oral node creates frication while the [critical] CD of the glottis creates voicing.

(17) Constriction degree hierarchies for /t/ and /n/

a. /t/



b. /n/



In (17a), when the TB is not an active articulator within the central tube, the default CD value of the TB is [open] as the default CD value of the central tube is [open] (see (16b)). If the default CD value of the TB is [closed], the default CD value of the central tube will be [closed] because the central node is formed by the serial connection of the TB and the TT, and thus takes the minimum CD value of the TB and the TT. In this study if TB gestures are not active within the central node, its default [CD] value, [open], is not specified in order to avoid confusion with the [open] CD value of TB for the lateral /l/ within the lateral tube.

In (17a), the CD at the central level is [closed] because the CD value of the central level is equal to the minimum CD value of the TB or TT, as shown in (15d). The central tube and the lateral tube are connected in parallel and form the tongue tube. If two tubes are joined in parallel, air can flow simultaneously through the two tubes that are connected. Thus, the higher node, namely the tongue node, has the maximum CD value of the central tube or the lateral tube. However, the CD value of the lateral tube is the CD value of the central tube by default (see 16b). Thus, the CD at the tongue level is [closed].

The tongue and lip tubes are connected by the oral tube in series. If tubes are joined in series, air flows through tubes one after another. Thus, the oral tube has the narrowest CD value of the tongue or the lip tubes. Although the CD value of the lip tube is [open], this is not the CD of the active gestures. Thus, the CD value of the oral tube is equal to the CD value of the tongue node.

The SL node is formed by the oral and nasal tubes in parallel. The CD value of the nasal tube is [closed] by default. Thus, the CD value at the SL level is [closed]. The highest tube VT is influenced by glottal gestures, the SL node, and air from the lungs, characterizing the overall 'output' airflow in terms of occlusion, resonance, and noise (frication). As occlusion is characterized by the [closed] CD either at the glottis or at the SL level, /t/ is occlusion because the CD value at the SL node is [closed].

The constriction degrees of hierarchy for [n] (17b) are the same up through the oral tube. However, the CD at the SL level for [n] is different from that of [t]. As the SL tube is connected in parallel with the nasal and oral tubes, the CD value at the SL level is equal to the maximum CD of the nasal or oral tubes. Thus, the constriction degree at the SL level is characterized by [open] for /n/. At the highest level, [n] is characterized as resonance because it has the [critical] CD of the glottis and the [open] CD at the SL level.

There are two main points in CDH that distinguish it from traditional feature systems. First, the CD of all levels are present at any given time regardless of whether some gestures are actively producing the constriction or not. Second, the CD of basic tubes and superordinated tubes can group sounds into natural classes at any level as the Articulatory Geometry of (13) does. /t/ and /n/, for instance, form a natural class at a lower (Oral) level of the hierarchy rather than the Vocal Tract or Supralaryngeal levels. /t/ and /n/ do not form a natural class at the lowest Nasal, SL, or VT levels (tubes). If a phonological pattern in a language is related to the Oral level or within the Oral level, /t/ and /n/ will pattern together. Otherwise [t] and [n] will not pattern together.

The CD at various levels can serve to categorize and distinguish phonological units in different ways. Browman and Goldstein (1989:240-41) claim that divergence among traditional feature systems in classifying sounds lies in the differences of the levels at which they classify sounds. Thus, Ladefoged defines [+/-sonorant] at the VT level while Chomsky and Halle (1968) define [+/-sonorant] at the SL level. Thus [?] and [h] do not belong to [+sonorant] in Ladefoged's classification system but [ʔ] and [h] belong to [+sonorant] in Chomsky and Halle's.

Each gesture possesses an inherent spatial aspect and an intrinsic temporal aspect. Thus, gestures are co-articulated in space and in time in a given context, generating contextual variations (Browman and Goldstein 1989:211-21). When gestures are overlapped in time, targeted gestures are achieved when the gestures are on different articulatory tiers or tract variables. An example is h-coalescence, which sequences of /h/ + /p, t, k/ or /p, t, k/ + /h/ are merged into aspirated obstruents. In h-coalescence, targeted glottal and oral gestures are achieved although these gestures are overlapped in time. h-coalescence will be discussed in Chapter 4 in detail. Gestures are blended when the gestures are on the same articulatory tier or tract variables. When two gestures are on the same tier, the two gestures are in competition to perform different tasks. Thus, they cannot overlap without perturbing each other's tract variable motions.

As manners of articulation are concerned with how tight the constriction of airflow is, CDH is closely related to the manners of articulation of traditional phonology. In the remaining chapters, CDH is adopted in analyzing Korean consonant patterns that are related to manners of articulation. As will be illustrated in the following chapters, CDH provides generalizations for Korean consonant patterns in a simple and unified way.

1.3 Korean consonants

In order to provide background for subsequent discussion, this section introduces the inventory of Korean consonants, Korean syllable structure, and articulatory, acoustic and aerodynamic characteristics of Korean consonants.

1.3.1 Phonological structure of Korean

As illustrated in (18), for the same place of articulation, there are two or three different types of obstruents that differ in the manner of articulation. These obstruent types are labeled as plain or lax, tense and aspiration. They are specified with features such as [+/-constricted glottis] and [+/-spread glottis] in literature (Cho 1990, Sohn 1987 and Silva 1993)

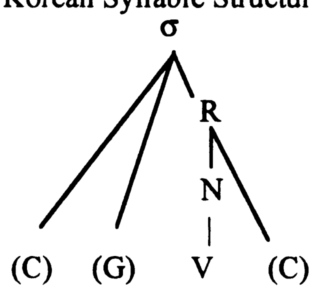
(18) Korean consonant inventory

		Bilabial	Alveolar	Palatal	Velar	Glotttal
Stop	Plain	p	t		k	
	Tense	p'	t'		k'	
	Aspirated	p^h	t^h		k^h	
Affricate	Plain			c		
	Tense			c'		
	Aspirated			c^h		
Fricative	Plain		s			h
	Tense		s'			
Nasal		m	n		ŋ	
Liquid			l			

Not all consonants of the inventory in (18) appear in all syllable positions. All the consonants in the above inventory except /ŋ/ appear at syllable-initial position. However, there are limitations on what consonants can appear in syllable-final position. Only unreleased stops [$p^{\urcorner}$, $t^{\urcorner}$, $k^{\urcorner}$], nasals [m, n, ŋ], and the lateral [l] occur before a consonant or at the word-final position (__ {C, #}). This limitation on what sounds can appear before a consonant or at the word-final position causes obstruents to be altered in manners and places of articulation. In syllable-final position, bilabial, alveolar, and velar obstruents are merged into [$p^{\urcorner}$, $t^{\urcorner}$, $k^{\urcorner}$] respectively. Palatal and glottal obstruents, /c, c', c^h, h/, are merged into [$t^{\urcorner}$].

Although there are several different views on Korean syllable structure (Ahn 1985, Kim 1986, Sohn 1987 and Kang 1992), the syllable structure adopted in this study is that shown in (19). Various studies on Korean syllable structure agree that Korean syllable structure is composed of $[(C)\ (G)\ V\ (C)]_\sigma$.

(19) Korean Syllable Structure (based on Ahn 1985 and Sohn 1987)



G= Glide

Unless the second consonant of onset consonants is a glide, Korean does not allow consonant clusters in onset or syllable-final positions as shown in (19). In word-medial position, only two consonants are allowed in an output, one for coda and the other for the onset of the following syllable, as in the examples of (20a). This even applies to cases where morphology creates more than two consonants in word-medial position as in the examples of (20b).

(20)

	Input	Output	
a	/pal<u>p</u>+ə/	[pal.<u>b</u>ə]	'step on'
	/ə<u>ps</u>+ə/	[ə<u>p</u>˺ . <u>s</u>'ə]	'do not have'
b	/pa<u>lp</u>+<u>k</u>o/	[pa<u>p</u>˺ . <u>k</u>'o]	'step on and'
	/ə<u>ps</u>+<u>k</u>o/	[ə<u>p</u>˺ . <u>k</u>'o]	'do not have and'
	/ɨ<u>lp</u>^{h}+<u>k</u>o/	[ɨ<u>p</u>˺ . <u>k</u>'o]	'recite and'

+ : morphological boundaries (Verb stem + inflectional suffix)
. : a syllable boundary

The examples in (20a) illustrate that when there are two consonants between two vowels, the two consonants are maintained even though there may be phonological alternations and the edges of morphological and syllable boundaries do not agree. When there are three (or possibly more) consonants between two vowels as in (20b), only two of the consonants are maintained in the output, resulting in consonant deletion. /l/ and /s/, for instance, are not maintained in the outputs of (21a), (21b) and (21c). In addition, the plain /p/ and aspirated /p^h/ become [p˺] in syllable-final position as shown in (21a), (21b) and (21c).

(21)		a.	b.	c.
	Input	/p a l p k o/	/ə p s k o/	/ɨ l p^h k o/
	Output	[p a p˺ k o]	[ə p˺ k o]	[ɨ p˺ k o]
		σ σ	σ σ	σ σ

A comparison of (21a) to (21b) reveals that consonant position in the input does not cause a segment to be deleted. The first segment after the first vowel is deleted in (21a) while the second segment after the first vowel is deleted in (21b). (21a), (21b) and (21c) reveal the preference for [p˺] over [l] or [s] as the syllable-final consonant. Contrary to [s] in (21b), both [l] and [p˺] in (21a) and (21c) are possible candidates to be in syllable-final position. However, [p˺] is maintained in the output, but not [l]. Chapter 2 explores issues related to phonological alternations in syllable-final position.

1.3.2 Characteristics of Korean obstruents

In this section, characteristics of Korean obstruents in word and syllable-initial position are summarized. This is because obstruents in word and syllable-initial position achieve target gestures that are planned, contrasting all types of consonants in the consonant inventory (18) except [ŋ]. The other reason is that consonants in word-medial and final position are more likely to be influenced by the preceding and/ or following consonants.

1.3.2.1 Articulatory characteristics

Hirose, Lee, and Ushijima (1974) Fujimura (1972) and Kagaya (1974) have observed the movements of the laryngeal muscles in Korean obstruents by using fiberscopes and electromyographs and concluded that different types of Korean obstruents result from "the coordinated actions of the intrinsic laryngeal muscles" (Hiroese et al. 1974: 151). According to Hirose, et al, different types of Korean obstruents have the following activity patterns of the laryngeal muscles:

(22) The activity patterns of the intrinsic laryngeal muscles for Korean obstruents: (From Hirose, Lee, and Ushijima 1974)

CV	Plain	Tense	Aspirated
Interarytenoid (INT)	suppression of abductor muscles is less dominant than that of aspirate obstruents.	suppression of abductor muscles is less dominant than that of aspirate obstruents.	suppression of all adductor muscles of the larynx just before the oral closure release. a steep increase in activity after the suppression.
Lateral Cricoarytenoid (LCA)	no significant increase in the activity before the oral closure release.	a sharp increase in activity immediately before the oral closure release.	an intermediate level of activity but not significant.
Vocalis (VOC)	no significant increase in the activity before the oral closure release.	a marked increase in activity immediately before the release, resulting in an increase in inner tension of the vocal folds and constriction of the glottis.	an intermediate level of activity but not significant.

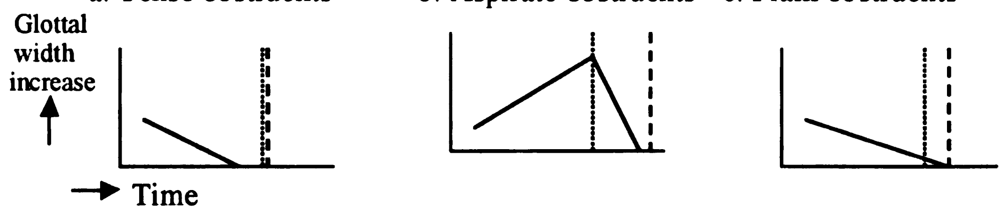
Orbicularis Oris (OO)	minimal activity in word-medial position		
Glottal Width	begins to close earlier relative to the oral closure release.	closes more rapidly than plain stops and a complete contact of the vocal process before the oral closure release.	stays wide open until the oral closure release.

(22) illustrates that Korean obstruents are grouped differently according to the activity of laryngeal muscles (Grayed areas vs non-grayed areas in (22)). The activity patterns of INT separate aspirate obstruents from plain and tense obstruents while the activity of LCA and VOC separate tense obstruents from plain and aspirate obstruents. According to Hirose, et al (1974: 151), a marked increase in the activity of VOC before the oral closure release in tense obstruents is closely associated with "an increase in inner tension of the vocal folds" and "constriction of the glottis during or immediately after the articulator closure".

Hirose et al. (1974:152) also found that the activity patterns of OO remain the same for plain, tense and aspirate obstruents. However, the activity of OO is minimal for plain obstruents in word-medial position Thus, the activity patterns of OO separate plain obstruents from tense and aspirate obstruents in the word-medial position.

Kagaya (1974) recorded the glottal width for different types of Korean obstruents, using the glottal images over time. The results of Kagaya's study are summarized in (23) with graphics. The glottal width of tense stops consistently decreases and achieves complete contact earlier before the oral closure release (23a). The oral closure release occurs immediately before VOT. The glottal width of aspirate obstruents increases gradually, reaches its maximum value at or around the oral closure release and decrease rapidly after the oral closure (23b). The oral closure release occurs 140ms to 220 ms before voice onset time. The glottal width of plain obstruents gradually decreases and comes to a near close at or around the oral closure release (23c).

(23) a. Tense obstruents b. Aspirate obstruents c. Plain obstruents



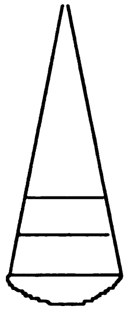
.... : the oral closure release ---- :voice onset time (VOT)

1.3.2.2 Acoustic and aerodynamic characteristics

Acoustic studies of Korean obstruents agree that different Voice Onset Time (VOT) values are one of the important properties for different types of Korean obstruents (Han and Weitzman 1970, Hardcastle 1973, Kagaya 1974, and Kim 1970). In general, tense obstruents have the shortest VOT after the oral closure release and aspirate obstruents have the longest VOT. The VOT values of plain obstruents fall between those of tense and aspirate obstruents as shown in (23). Kim (1970) suggests that the difference in VOT is nothing but a function of the glottal opening at the time of the oral release. The wider the glottal opening is at the time of the oral release, the longer the

VOT is. Thus the constriction degree of the glottis for three types of Korean obstruents are schematically represented as follows:

(24) The constriction degree of the glottal aperture for Korean obstruents



tense stops [closed]
plain stops [mid]
aspirated [open]

In addition to different VOT values, qualities of voice onset such as fundamental frequency value, are known to be important properties for the perception and production of Korean obstruents (Han and Weitzman 1970, Kagaya 1974, and Kim 1965).

The fundamental frequency after tense obstruents is highest. The fundamental frequency after aspirate obstruents is higher than plain obstruents (Han and Weitzman 1970: 117). The fundamental frequency is closely related to stiffness of the laryngeal muscles and inner-tension of the vocal tract and the pharynx (Kagaya 1974 and Hardcastle 1973). Hirose, et al. (1974:151) also observed that marked increased activity of VOC and LCA before the oral closure release of tense obstruents "resulted in an increase in inner-tension of the vocal cords" and " in constriction of the glottis during or immediately after the articulatory closure". Thus there is a close correlation between high fundamental frequency in tense and aspirate obstruents and active gestures of VOC and LCA.

In addition, Hardcastle (1973) and Kim (1965) found that the duration of the first full glottal cycle of a vowel following obstruent release is always longer after plain obstruents than after aspirated or tense obstruents. This phenomenon is due to slow and weak airflow after plain obstruents according to Kim (1965). The large amount of airflow after aspirated and tense obstruents is closely correlated with tension or stiffness of the vocal folds according to Kim (1965: 351).

Han and Weitzman (1970) and Kim (1965) found that differences in the duration of increased air pressure behind the oral closure and the speed of intensity build-up after each type of obstruents are also important properties in the production and perception of Korean obstruents. Duration of the increased air pressure is longer in tense and aspirate obstruents than in plain obstruents. The speed of intensity build-up after tense and aspirate obstruents is more rapid than that of lax obstruents due to subglottal pressure and airflow. Tense and aspirate obstruents have higher subglottal pressure than plain obstruents.

(25) summarizes acoustic and aerodynamic characteristics of Korean obstruents and correlates these characteristics to articulatory gestures of Korean obstruents based on experimental studies of Korean obstruents (Hardcastle 1973, Han and Weitzman 1970, Hirose, et al. 1974, Kagaya 1974, Kim 1965, Lee, and Smith 1973):

(25) The acoustic and aerodynamic characteristics of Korean obstruents in CV contexts:

	Plain	**Tense**	**Aspirated**	**Sources**
a. VOT	intermediate	shortest	longest	glottal width
b. *f0* at the voice onset	lowest	highest	higher	stiffness from the activities of VOC and LCA
c. Duration of the initial glottal cycle for the following vowels	longest	shortest	slightly longer than the tense obstruents	amount airflow from the lung
d. Stiffness	slack	most stiff	stiff	activities of VOC and LCA
e. Air flow	smallest	large	large	glottal width and stiffness
f. Subglottal pressure	low	highest	high	stiffness, air flow
g. Duration of the pressure build-up	short	long	longest	stiffness, air flow
h. Speed of the pressure build-up	gradual	sharp	sharp	stiffness, air flow

Based on the articulatory, acoustic, and aerodynamic characteristics of Korean obstruents, the following gestures for the glottal articulator are suggested for Korean obstruents in this study.

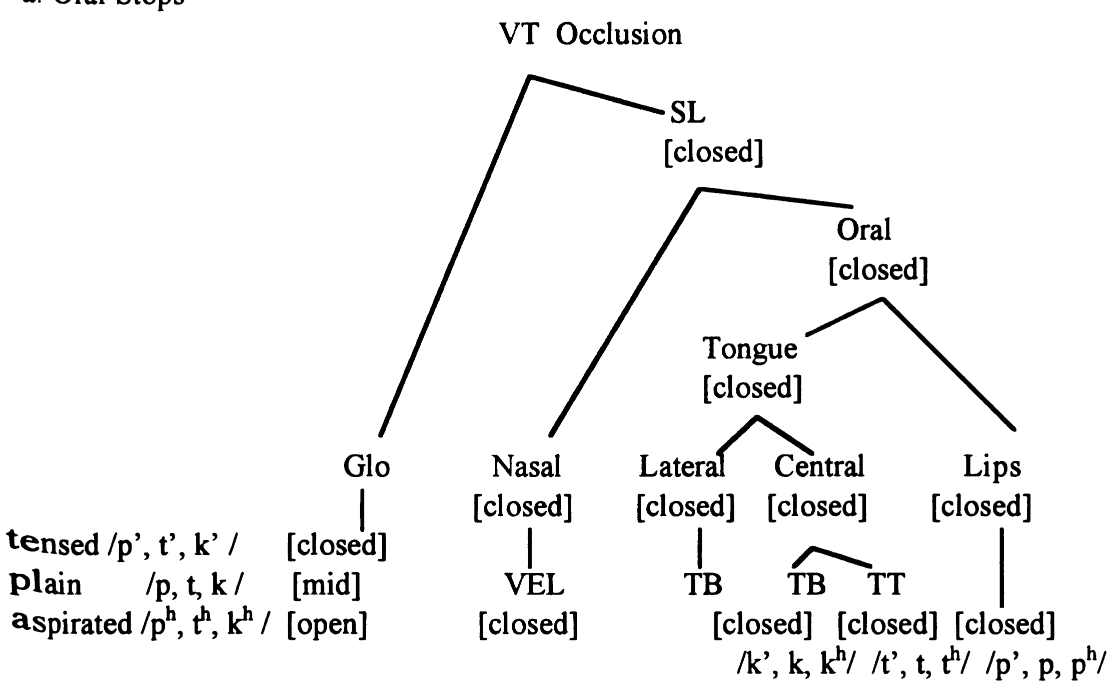
(26)	Constriction Degrees	Stiffness
Plain:	[mid]	[slack]
tense:	[closed]	[high stiffness]
aspirated:	[wide]	[stiff]

1.3.2.3 Constriction Degree Hierarchies

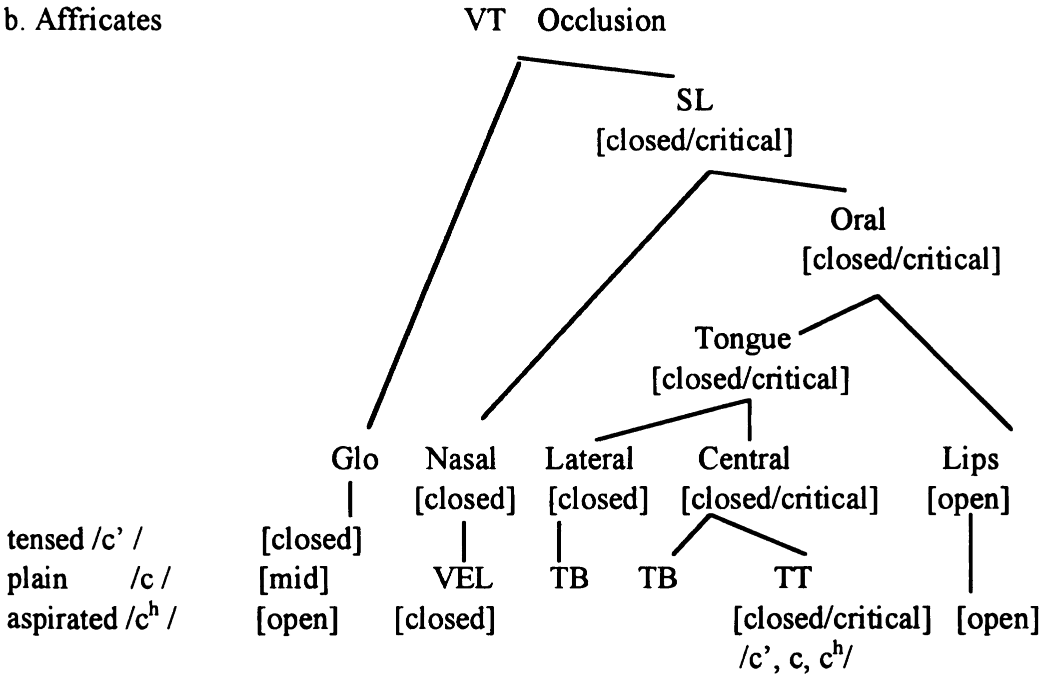
Korean obstruents are characterized by three types of constriction degrees: [closed], [mid], or [open] for the glottal gestures at the time of oral articulator release as shown in (26). Based on (26) and the framework of Articulatory Phonology, the following constriction degree hierarchies are assumed for Korean obstruents.

(27) Constriction degree hierarchies for Korean consonants

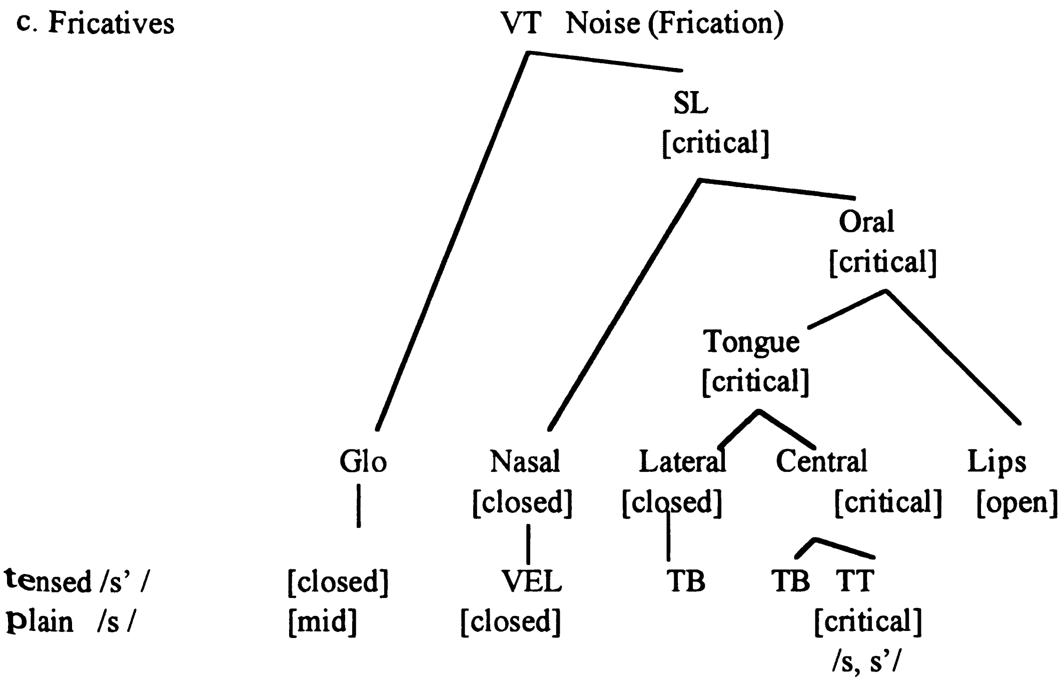
a. Oral Stops



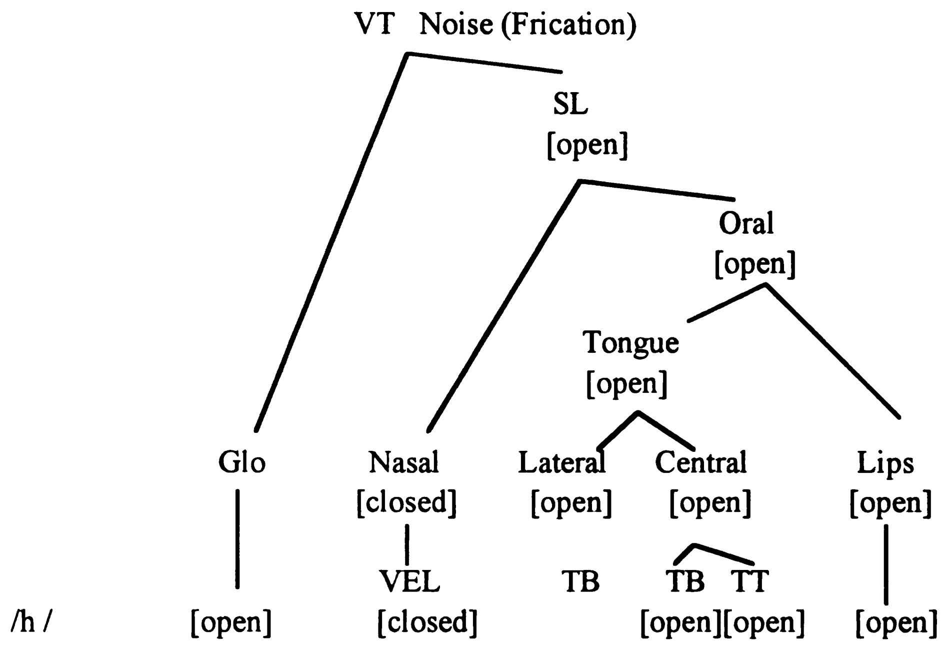
b. Affricates



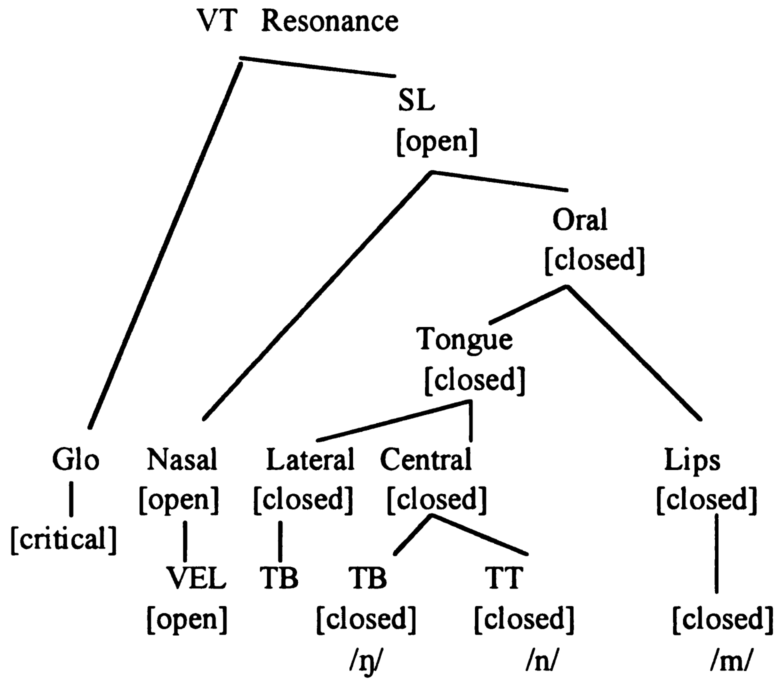
c. Fricatives



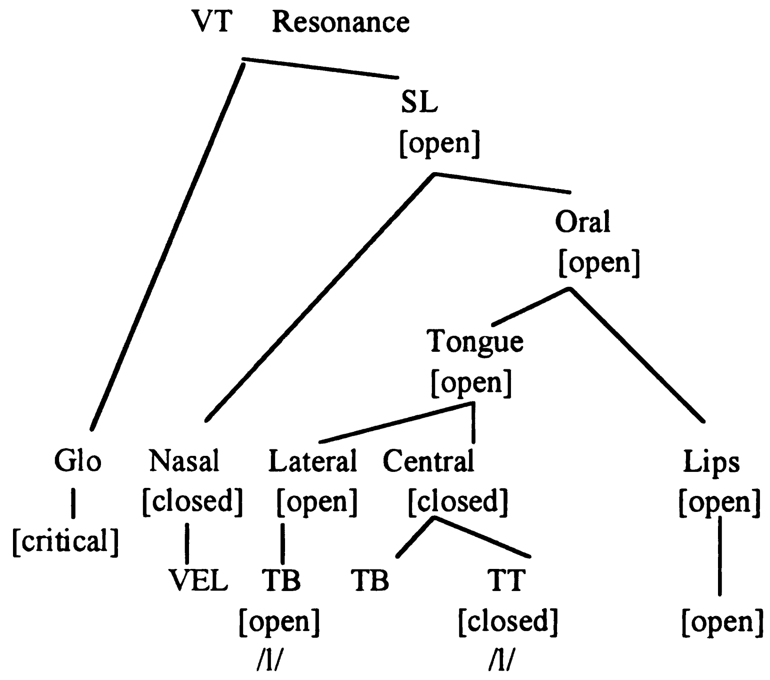
d. /h/


VT Noise (Frication)
SL
[open]
Oral
[open]
Tongue
[open]
Glo
Nasal
[closed]
Lateral
[open]
Central
[open]
Lips
[open]
VEL
TB
TB TT
/h /
[open]
[closed]
[open][open]
[open]

e. Nasals


VT Resonance
SL
[open]
Oral
[closed]
Tongue
[closed]
Glo
[critical]
Nasal
[open]
Lateral
[closed]
Central
[closed]
Lips
[closed]
VEL
[open]
TB
TB
[closed]
TT
[closed]
[closed]
/ŋ/
/n/
/m/

f. Lateral



The above CDH shows that both stops and affricates have similar characteristics at the oral, supra laryngeal, and vocal tract levels. Thus, the prediction is that, everything being equal, stops and affricates pattern together in Korean phonology. Nasals and the lateral /l/ have a similar characterization at the vocal tract level and the supralaryngeal level. However, nasals separate themselves from the lateral /l/ at the oral level. Nasals, stops and affricates have a closed degree of constriction at the oral level. Thus, another prediction is that nasals, stops, and affricates will sometimes pattern together in phonology. /h/ has a characterization similar to nasals and the lateral /l/ at the supralaryngeal level and the oral level. Thus, it is predicted that /h/ could pattern together with nasals and the lateral /l/ in some cases. However, /h/ separates itself from nasals and the lateral /l/ at the vocal tract level, and forms a natural class with fricatives. /h/ and fricatives have noise output at the vocal tract level. However, fricatives are likely to form a natural class with stops and affricates. Fricatives, stops, and affricates have a similar characterization at the supralaryngeal and oral levels by having a narrower constriction degree than nasals, the lateral /l/ and /h/.

The following chapters illustrate how natural classes formed by the CDH function together in Korean consonantal phonology, especially manner alternations.

Chapter 2
Coda Neutralization and Coda Consonant Cluster Simplification

2.1 Coda Neutralization

2.1.1 Introduction

There are limitations on what consonants can appear in word-final position or before a consonant in Korean (_{# or C}). Sonorants /m, n, ŋ, l/, are allowed in word-final position or before a consonant, as shown in (1).

(1) Word-final position

/kam/	→ [kam] 'persimmon'	/kamki/	→ [kam.gi][1] 'cold' noun
/kan/	→ [kan] 'liver'	/kanjaŋ/	→ [kan.jaŋ] 'soy sauce'
/koŋ/	→ [koŋ] 'ball'	/koŋki/	→ [koŋ.gi] 'a bowl'
/əl/	→ [əl] 'spirit'	/əlkul/	→ [əl.gul] 'face'

(Left column: Word-final position; right column: Before a consonant)

cf. /kam +i/→[ka.mi] 'persimmon + subject marker'
/kan + i/ → [ka.ni] 'liver + subject marker'
/koŋ+i/ → [koŋ.i] 'ball + subject marker'
/əlkul+i/ → [əl.gu.ri] 'face + subject marker'

[1] Lax stop voicing between two [+voice] phones is not discussed here for simplicity.

In the case of obstruents, only unreleased [p˺, t˺, k˺] appear at word-final position or before a consonant, as shown in (2). Stops, affricates, and fricatives are neutralized to unreleased stops (S˺) in word-final position or before a consonant, resulting in Coda Neutralization (CN). (2) shows patterns of obstruents in word-final position or before a consonant. (2d) illustrates evidence for neutralization of obstruents in syllable-final position.

(2) Patterns of obstruents in coda position

	Input	Output		Examples[2]
a. Stops	/p, p^h/	[p˺]	/_ {#, C}	/a$\underline{p}^h$/ [a$\underline{p}$˺] 'front'
	/t, t^h/	[t˺]		/pa$\underline{t}^h$/ [pa$\underline{t}$˺] 'field'
	/k, k', k^h/	[k˺]		/na$\underline{k}$'si/ [na$\underline{k}$˺.s'i] 'fishing'
b. Affricates	/c, c', c^h/	[t˺]		/na$\underline{c}^h$/ [na$\underline{t}$˺] 'face'
c. Fricatives	/s, s', h/	[t˺]		/na$\underline{s}$/ [na$\underline{t}$˺] 'sickle'
				/no$\underline{h}$+ko/[no$\underline{t}$˺ . $\underline{k}^h$o]'and place (verb)'

d.	/a$\underline{p}^h$/	+	/i/$_{\text{Subeject marker}}$	[a.$\underline{p}^h$i] 'front'
	/pa$\underline{t}^h$/	+	/ɛ/ $_{\text{Location marker}}$	[pa.$\underline{t}^h$ɛ] 'at the field'
	/na$\underline{k}$'/$_{\text{Verb stem}}$	+	/a/$_{\text{declarative}}$	[na.$\underline{k}$'a] 'fish (verb)'
	/na$\underline{c}^h$/	+	/ɛ/ $_{\text{Location marker}}$	[na.$\underline{c}^h$ɛ] 'at the face'
	/na$\underline{s}$/	+	/i/$_{\text{Subeject marker}}$	[na.$\underline{s}$i] 'sickle'
	/no$\underline{h}$/	+	/a/$_{\text{declarative}}$	[no_.a]'place (verb)'

In addition, complex onsets and codas are not allowed in Korean syllable structure, as shown in (20) in section 1.3.1. For convenience's sake, the word-final position and the position before a consonant are referred to as coda positions in this study. Because Korean does not allow a consonant cluster in onset and coda positions,

[2] There are no occurrences of /p'/ and /t'/ in word-final position and before a consonant.

the word-final position and the position before a consonant are equivalent to a coda position.

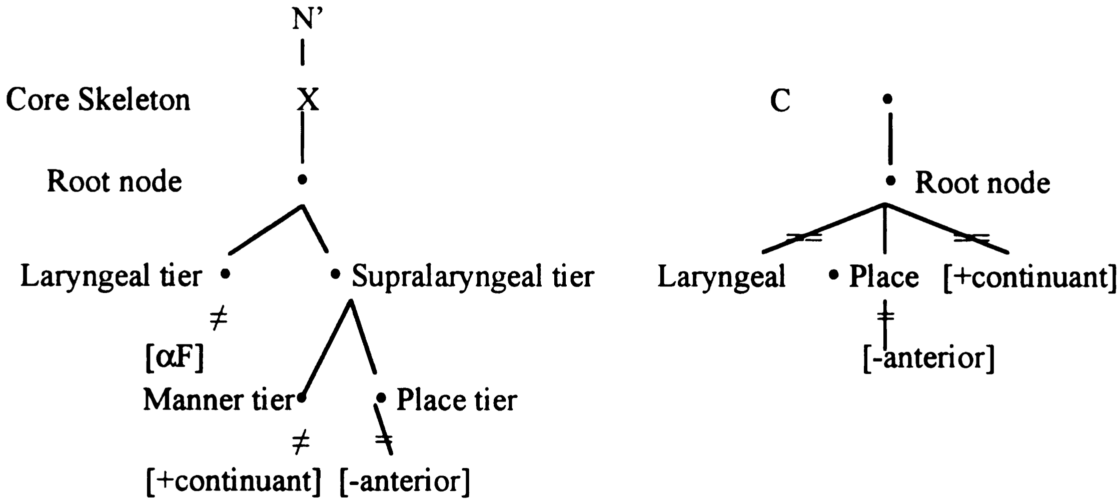
The limitations on how many and what types of consonants are possible in coda position result in CN and Coda Consonant Cluster Simplification (CCCS). The purpose of this chapter is to investigate systematic principles in CN and CCCS and to present output constraints based on these principles.

2.1.2 Previous analyses

CN is described in previous studies (Cho 1990 and Sohn 1987) as a phonological adjustment in the coda that delinks laryngeal features, [+continuant], and [-anterior] under the place node. Thus, stops with laryngeal features /S', S^h/ (S=stops), continuants /s, s', h/, and palatals /c, c' c^h/ are prevented from occurring in coda position, as shown in (3).

(3) Coda Neutralization

a. Sohn (1987: 266)   b. Cho (1990:106)



N': noun phrase, ≠: delinking of features, [αF] =[+ spread glottis, + constricted glottis]

According to the CN in (3), delinking of laryngeal features such as [+spread glottis] and [+constricted glottis] and delinking of [+continuant] are changes in manner of articulation. Features such as [spread glottis] and [constricted glottis] refer to how tight the glottal opening is. [continuant] refers to how tight an oral opening is so that air can flow continuously, creating frication. Thus features such as [spread glottis], [constricted glottis] and [continuant] concern constriction degrees of articulators in the vocal tract. However, delinking of [-anterior] changes place of articulation. Thus, CN is considered as phonological adjustments in coda position that change both manner and place of articulation as shown in (3).

However, CN as delinkings of laryngeal features (3a) or the laryngeal node (3b), [+continuant], and [-anterior] under the place node in (3) does not support one of the premises that Feature Geometry theories are based upon. Based on Clements (1985) and

Clements and Hume (1995)'s claim that certain features as a group recurrently participate in phonological rules and constraints, Kenstowicz (1994:147) claims that "two features can thus be expected to co-occur in rules or constraints only if they share a common node in the tree". (3) shows that the common node which is shared by laryngeal features, [+continuant] and [-anterior] is the root node in both Sohn's (1987) and Cho's (1990) studies.

Thus, CN should be expressed as delinking of the root node according to assumptions of Feature Geometry theories. If the root node is delinked, either deletion of a segment or geminate occurs in languages. However, Korean data in (2) shows that CN is neither deletion of a segment nor formation of a geminate. Thus, CN as delinkings of laryngeal features, [+continuant] and [-anterior] needs to be reanalyzed or modified.

In addition, CN as represented in (3) differs from other phonological processes in Feature Geometry Theories. Generally, in Feature Geometry Theories, a phonological rule operates on a single node rather than several nodes simultaneously. For instance, voicing neutralization in word-final position in German is a phonological rule that operates on the laryngeal node that dominates [+/-voice] features. Assimilation of coronal consonants to the following labial or dorsal consonants in Korean is a phonological rule that operates on the place node. Thus, in Feature Geometry Theories, a phonological process is expressed as an operation on a single node that groups certain features together. However, the phonological rules in (3) operate on several nodes simultaneously, affecting both manner and place of articulation.

This chapter argues for the following four points: First, CN is neutralization in manner of articulation that occurs systematically in coda position in Korean. Second, Korean CN is better understood with phonetically motivated output constraints. Third, CN results from impoverished articulatory gestures in a given context. The mending of impoverished gestures may be language specific. In the case of Korean, there is a relatively higher ranked output constraint that requires no contrastive constriction degrees in the vocal tract when relevant gestures to obstruents are impoverished. Thus, output forms in (2) result from the best possible satisfaction of output constraints. Fourth, different rankings of the same constraints are responsible for different patterns in CCCS between the Standard Korean (SK) and the Kyoung-Sang Korean (KSK).

The patterns of stops, fricatives and affricates in coda position are discussed in section 2.1.3.1, section 2.1.3.2 and section 2.1.3.3 respectively. Based on the analysis of stops, fricatives and affricates in coda position, I will demonstrate in section 2.2 that there are principled reasons behind CCCS in Korean regardless of dialects.

2.1.3 Patterns of obstruents in coda position

2.1.3.1 Patterns of stops in coda position

2.1.3.1.1 Introduction

The delinking of laryngeal features such as [spread glottis] and [constricted glottis] in (3a) or the laryngeal node (3b) is mainly proposed for bilabial, alveolar, and velar stops. These stops are neutralized into unreleased stops [p˺, t˺, k˺] respectively in coda position without changing their places of articulation, as shown in (4a) and (4b).

(4) Patterns of stops in coda position

a. Word final position

/a$\underline{p}^{h}$/	→	[a$\underline{p}$˺]	'front'
/pa$\underline{t}^{h}$/	→	[pa$\underline{t}$˺]	'field'
/i$\underline{p}$/	→	[i$\underline{p}$˺]	'mouth'
/puə$\underline{k}^{h}$/	→	[puə$\underline{k}$˺]	'kitchen'

b. Before a consonant

/a$\underline{p}^{h}$+kwa/	→	[a$\underline{p}$˺ . k'wa][3]	'front and'
/pa$\underline{t}^{h}$+kwa/	→	[pa$\underline{t}$˺ . k'wa]	'field and'
/ip+kwa/	→	[i$\underline{p}$˺ . k'wa]	'mouth and'
/puə$\underline{k}^{h}$+kwa/	→	[puə$\underline{k}$˺ . k'wa]	'kitchen and'
/na$\underline{k}$'ta/	→	[na$\underline{k}$˺ . t'a]	'fish' (declarative)

[3] Tensification after unreleased stops (Post-Obstruent Tensification) is discussed in Chapter 3.

c. Between vowels

/a$\underline{p}^h$+ɛ/ → [a.$\underline{p}^h$ɛ] ‘ in the front’
/pa$\underline{t}^h$+ɛ/ →[pa.$\underline{t}^h$ɛ] ‘in the face’
/i$\underline{p}$+ɛ/ → [i.bɛ] ‘in the mouth’
/puə$\underline{k}^h$+ɛ/ →[puə.$\underline{k}^h$ɛ] ‘in a kitchen’
/na$\underline{k'}$+a/→[na.$\underline{k'}$a] ‘fish +declarative’

Underlying forms in (4a) and (4b) are justified by the comparison of (4c) to (4a) and (4b). For instance, if the words in (4a) have underlying forms that are the same as the phonetic forms in (4a) and (4b), /puə$\underline{k}$˺/ for 'kitchen' and /na$\underline{k}$˺t'a/ for 'fish +declarative', there is no way to predict when unreleased stops become tense, aspirated or voiced stops between two vowels, as shown in (4c). Thus, underlying forms in (4a) and (4b) are justified. Therefore, different types of stops are neutralized to [p˺, t˺, k˺] in coda position without changing their places of articulation, as shown in (4a) and (4b).

2. 1. 3. 1. 2 Gestural characteristics of Korean stops

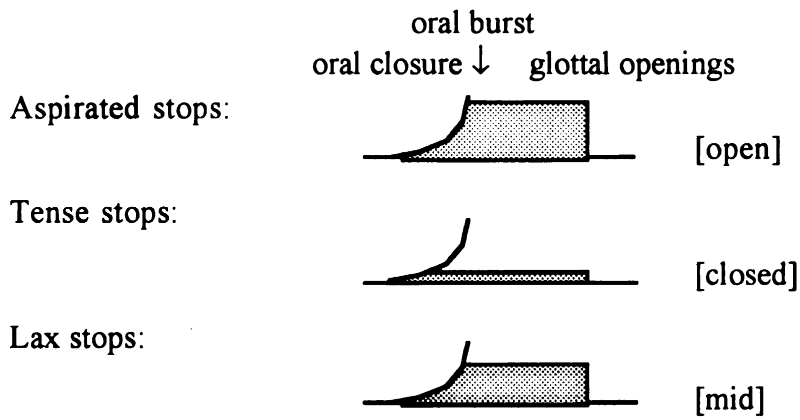
Before presenting a phonetic-based output constraint for patterns of three types of Korean stops in coda position, an overview of gestural characteristics of Korean stops is in order. Glottal gestures for stops continue after the oral-closure release in syllable-initial position, as in (5a), according to Steriade (1997:16) and Hirose et al. (1974). The schematic CDs of glottal gestures after oral closure and release are presented in (5b) based on experimental studies of Hirose et al. (1974), Kagaya (1974), and Kim (1965). At the time of oral burst, the CDs of the glottis for aspirated, tense and lax stops are [open], [closed], and [mid] respectively, as mentioned in (24) section 1.3.2.2. The glottal gestures across time are illustrated in (5c) for three types of Korean obstruents. Glottal gestures begin with opening gestures and end with closing gestures after reaching its targeted opening gestures over time (Browman and Goldstein 1986 and Steriade 1997).

(5) Gestural characteristics of Korean stops in CV- position:

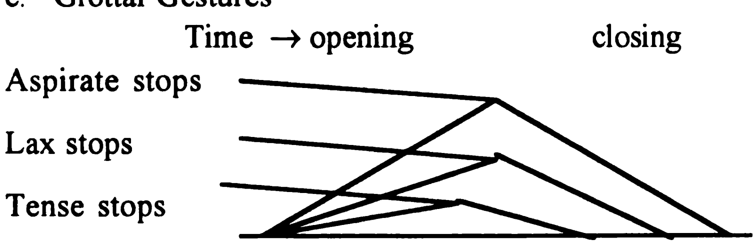
a. Timing (Steriade 1997:16)

Glottal Gestures	[-----glottal open/close --------]
Oral Gestures	[-----oral closure release-----]🡅
	contextual cues for laryngeal features

b. Glottal CDs at the time of or after the oral burst



c. Glottal Gestures



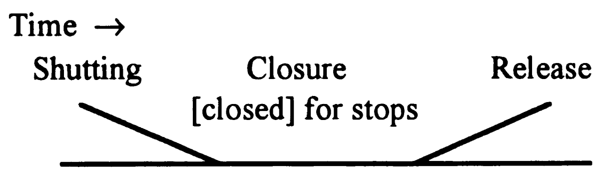
In general, the CD of lax stops is determined by contexts in Korean phonology. Lax stops are slightly aspirated, voiced, tensed or unreleased depending on contexts where they appear, as shown in (6).

(6)	a.	b.	c.
	Lax /p, t, k/	Aspirated /p^h, t^h, k^h/	Tensed /p', t', k'/
#_	slightly aspirated [tal] 'moon'	[t^hal] 'problem, mask'	[t'al] 'daughter'
V_V	voiced [agi] 'baby'	[ap^ha] 'sick'	[na.k'a.yo] 'to fish, informal'
VC_1_V	tensed [mak˺.t'æ] 'stick'	[kuk˺.t^ho] 'land of a country'	[kak˺.t'i] 'sash'
V_C_2V	unreleased [kak˺.k'i] 'separately'	unreleased [əp˺.k'o] 'and carry'	unreleased [nak˺.t'a] 'fish, statement'
_#	unreleased [ak˺] 'devil'	unreleased [k'ɨt˺] 'end'	

Based on this context sensitivity of lax stops, Kagaya (1974) and Fujimura (1972) suggest that there is no dynamic target CD in the glottis for lax stops, although the CD of lax stops is [mid] in the syllable and word-initial position. In this study, based on Hirose et al. (1974), Kagaya (1974), Ladefoged (1973) and Kim (1970), I adopt the premise that the target CD of the glottis for lax stops is [mid], which is an intermediate value that comes between those of aspirated and tense stops. This is because lax stops are contrastive when they appear in the syllable and word-initial position, as shown in [tal] 'moon', [t^hal] 'problem or mask', and [t'al] 'daughter'.

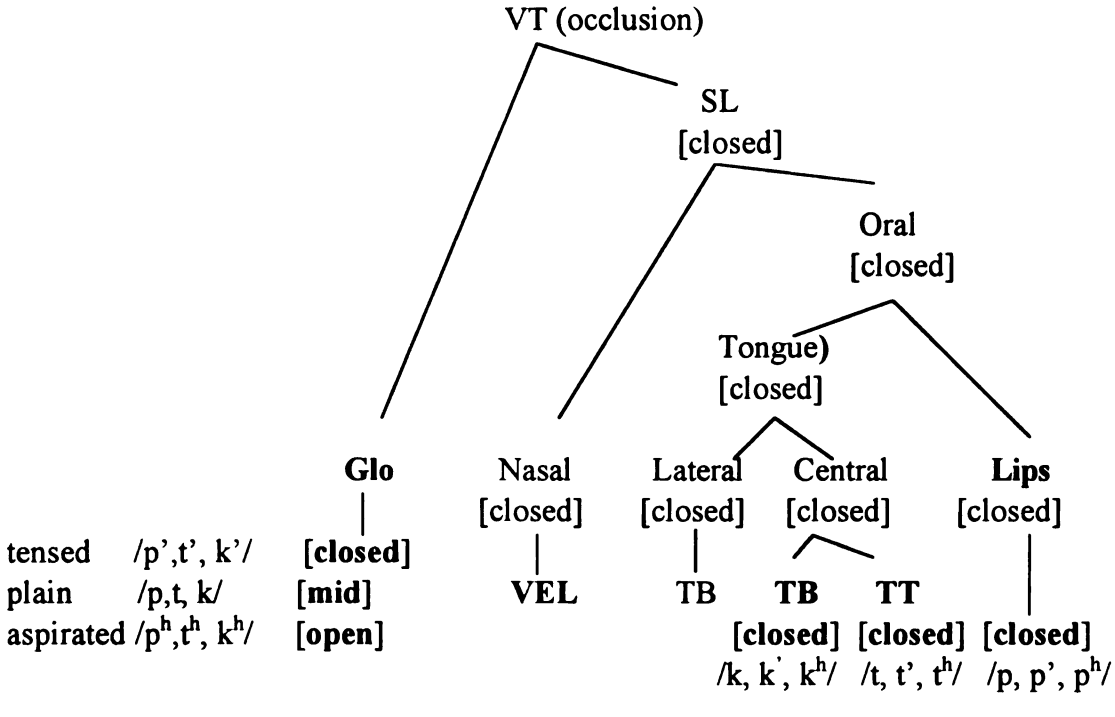
In addition to the contrastive glottal gestures for different types of Korean obstruents, as shown in (5b), there are also three articulatory stages for obstruents at the oral level. These three articulatory stages, which occur across time are shutting, closure and release, as shown in (7). Stops are characterized by the [closed] CD value in lips, the TT or the TB.

(7) Oral gestures



The oral gestures shown in (7) are co-articulated or overlapped with the contrastive glottal gestures across time, as shown in (5a). Co-articulation of contrastive glottal gestures (5b), the oral articulator gestures (7), and other gestures such as the velum gestures, and the amount of airflow from the lungs create the overall output characteristic of stops at the VT level, namely occlusion, as shown in (8). The CDs in active articulators, represented in bold face in (8), are input gestures for different types of Korean stops, functioning as contrastive units in the input. The combined effects from the CD of each articulator at a given time are reflected in the CDH for three types of Korean stops in (8). Thus, (8) is considered to be the CDH in the input for three types of Korean stops. (8) illustrates that three types of Korean stops have different CDs at the glottis but the same CD, [closed], at the oral articulators.

(8) The CDH for three types of Korean oral stops



2.1.3.1.3 The gesture-based account of stops in coda position

Gestures of moving articulators are likely to be reorganized according to the context, creating different constriction, acoustic, and aerodynamic effects in the vocal tract (Byrd 1996, Steriade 1997, Ohala 1983, and Browman and Goldstein 1991b). However, the presence or absence of gestural modifications, degrees of gestural modification, and types of modification in a given context are language specific.

In addition, gestural modifications are sensitive to linguistic factors such as gestures involved for a given utterance, prosodic categories and positions, and morpheme categories, as documented in the experimental studies of Byrd (1996), Byrd and Tan (1996), Browman and Goldstein (1990b), Cho (1998a and b), Kim and Jongman (1996), and Kim (1998).

Stops in coda position are more subject to gestural reduction spatially and temporally than are stops in onset position (Byrd 1996 and Cho 1998a and b). Kim (1998), for instance, compares releasedness between English and Korean stops in syllable and word-final position.

(9) Kim (1998: 352 and 359)

Acoustic characteristics of coda consonants	English	Korean
a. aspiration together with oral burst	51.2%	0%
b. brief low amplitude oral burst after silences	35.7%	83%
c. silence corresponding to oral closure	13.1%	17%

Coda stops of English /p, t, k/ are characterized by aspiration together with an oral burst (51.2%), a brief low amplitude oral burst after silence (35.7%), or silence corresponding to oral closure (13.1%), as shown in (9). Coda stops of Korean /t, t^h, s/[4] are characterized by either a brief low amplitude oral burst after silence (83%) or silence corresponding to oral closure (17%).

[4] /s/ is included in Kim's study (1998) because the phoneme /s/ is realized as [t˺] in coda position as is the phoneme /t/ (see 2.3.1.2 for further discussion).

Kim (1998) claims that if the oral burst, which is closely related to the removal of oral articulators after the oral closure, is interpreted as [+release], both English and Korean stops are released. Both languages have the oral burst (86.9% in English and 83% in Korean). Therefore, English and Korean stops differ from each other by the presence or absence of aspiration after the removal of oral closure, as shown in (9a).

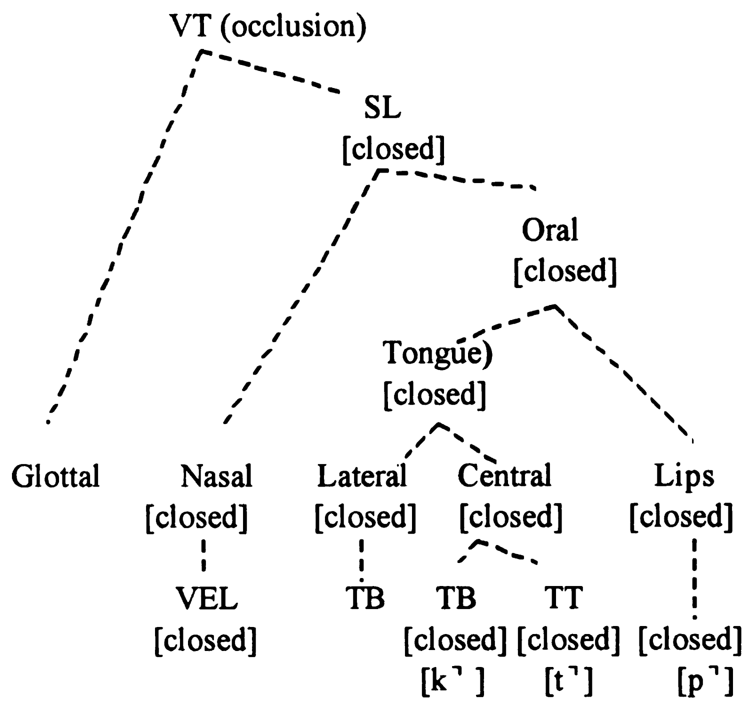
Kim also observes that some English coda consonants have a diffusing-rising shape that is similar to a released onset consonant but Korean stops do not have this. Kim (362) claims that ""release" is associated with the presence of a pulmonic-egressive airstream which flows through the oral tract after the removal of the oral closure, before or during the articulation of a following segment."

As acoustic and articulatory characteristics of a segment are not independent from each other, it may be assumed that the presence or absence of a pulmonic-egressive airstream after the oral-closure release is closely associated with the presence or absence of the targeted glottal gestures after the oral-closure release. Especially, the presence or absence of aspiration after the removal of oral closure in (9a) is closely correlated to CDs of the glottis. Therefore, Kim's (1998) acoustic definition of [+/-release] could be stated in articulatory terms: [+/-release] articulatorily refers to the presence or absence of the targeted glottal gestures after the oral-closure release, before or during the articulation of a following segment.

Therefore, articulatorily, Korean stops in coda position are unreleased because targeted glottal gestures are either absent or impoverished. Especially, different CD values of the glottis for different types of stops are either absent or impoverished after the oral-closure release. This absence of targeted glottal gestures, in turn, changes the overall CDH of the vocal tract because a CDH results from CDs of moving articulators that are active concurrently. (10) shows the output CDH for three types of Korean stops in coda position.

In order to avoid confusion, a CDH with dotted lines, as in (10), represents an output CDH, and a CDH with a solid line, as in (8), represents an input CDH hereafter. The comparison of (8) and (10) indicates that there is discrepancy between the planning of an utterance (8) and executing the plan in a given context.

(10) The CDH for three types of Koran oral stops in coda position



The CDH in (10) reflects the fact that contrastive CDs at the glottis are absent in Korean when stops are in coda position. Although CDs of glottal gestures are absent, the overall output characteristic in VT remains as occlusion because the CD value at the SL level is still [closed]. Based on (10), unreleased stops (S˺) may be defined as stops whose targeted glottal gestures are either absent or weakened but have the [closed] CD value at the SL level.

Based on the fact that consonants are likely to be unreleased in word-final position or before a consonant (Hudson 1995), a marked constraint that is sensitive to releasedness of stops and context, is suggested in (11).

(11) * Contrastive Constriction Degrees of glottis /_{#, C}

(*CCD$_{\text{GLOTTIS}}$ /_{#, C} hereafter)

No contrastive constriction degrees of the glottis when stops appear in word-final position or before a consonant.

(11) demands that stops not be contrastive in terms of the CD of the glottis before a consonant or in word-final position. However, the constraint (11) conflicts with the faithfulness constraint suggested in (10) in section 1.2.3. The faithfulness constraint is shown below.

(12) IDENT(ITY)-IO(Gestures) (IDENT-IO[G])
Let α be a segment in S1 and β be any correspondent of α in S2.
If α is [γ**G**], then β is [γ**G**].
(Correspondent segments are identical in gestures (**G**))

The faithfulness constraint (12) demands that a surface form (output) be identical to its lexical entry (input). Any deviation of the surface form from its lexical entry violates the faithfulness constraint (12). If the context-sensitive markedness constraint (11) dominates the faithfulness constraint (12) in a language, contrastive CDs of the glottis are absent or weakened in coda position, resulting in positional neutralization in terms of the CD of the glottis. If the faithfulness constraint (12) dominates the context-sensitive markedness constraint (11), stops in coda position are contrastive with regard to the CD of the glottis, resulting in no positional neutralization.

Two generalizations are drawn from data (4). First, contrastive CD values for different types of stops are absent or weakened in coda position, namely CN. As a consequence, coda stops do not have identical glottal gestures between surface forms and their lexical entries, as can be seen in (8) and (10). Second, no efforts are made to compensate for the lack of contrastive glottal gestures in coda position. Therefore, in Korean, the constraint $*CCD_{GLOTTIS}/\_\{\#, C\}$ is ranked higher than IDENT-IO[G], as shown in (13). Otherwise, the contrastive CD values of the glottis would be maintained in the output.

(13) a. $*CCD_{GLOTTIS}/\_\{\#, C\}$ >> IDENT-IO[G]

A. /ip^h/ 'leaf'

/p^h/: GLO[open], SL[closed], Lips[closed]

/ip^h/	$*CCD_{GLOTTIS}$ /_{#, C}	IDENT-IO[G]
a. ip^h	*!	
b. ip'	*!	* (GLO): [closed]
c. ip	*!	* (GLO): [mid]
☞d. ip˺		* (GLO)

B /ip/ 'mouth'

/p/: GLO[mid], SL[closed], Lips[closed]

/ip/	$*CCD_{GLOTTIS}$ /_{#, C}	IDENT-IO[G]
a. ip^h	*!	* GLO: [open]
b. ip'	*!	* GLO: [closed]
c. ip	*!	
☞d. ip˺		* (GLO)

In the examples of (13), any output candidates with [p^h, p', p] violate the constraint $*CCD_{GLOTTIS}/\_\{\#, C\}$. This is because stops cannot be contrastive with different CDs of the glottis in positions where different CDs of glottal gestures are impoverished or weakened, as shown in (10). The unreleased bilabial stop in [ip˺] indicates that there is only the [closed] CD of the lips in coda position without any targeted glottal gestures. However, candidates (13Ad) and (13Bd) violate IDENT-IO[G] because gestures in the input are not maintained in the output. However, satisfaction of $*CCD_{GLOTTIS}/\_\{\#, C\}$ takes precedence over IDENT-IO[G] in Korean.

Note that the lack of active glottal gestures in [p˺] in [ip˺] ((13Ad) and (13Bd)) does not necessary mean that there are no glottal gestures at all for obstruents in coda position. I follow Browman and Goldstein (1992) and Sawashima et al. (1980) in assuming that the default CD of laryngeal gestures is [critical] or a small degree of glottal opening. The default [critical] CD of glottal gestures is as narrow as or narrower than that of voicing. However, unlike the [critical] or [closed] CD of glottal gestures for voicing, the default [critical] CD of glottal gestures in coda position does not function as a contrastive unit because of the phonetic implementational conditions that will be discussed later in this section. Therefore, the default [critical] CD of glottal gestures in coda position does not violate *[critical]/ _{#, C} because the default [critical] CD of the glottis is not contrastive in coda position.

According to Steriade (1997), where cues refer to acoustic properties that influence the perception of sound categories, laryngeal neutralization is closely related to the distribution of cues to a relevant contrast. For example, Steriade states that [voice] in obstruents is more likely to be contrastive between two vowels (V__V) than in word-final position (__#). This is because acoustic cues to [voice] such as VOT value, F0, and F1 values at the onset of voicing in the following vowel, are lacking in word-final position. Thus, cue–based constraints such as Context cue[5] (voice) are suggested as a part of phonological grammar. Context cue (voice) demands [voice] not be contrastive in positions where acoustic cues to [voice] are absent.

The gesture-based account of laryngeal neutralization of coda stops in (13) parallels the cue-based analysis of laryngeal neutralization of Steriade (1997). For instance, different CDs of the glottis are closely related to different VOT values according to Kim (1970) and Ladefoged (1973). In addition, different VOT values are known to be critical acoustic cues in distinguishing different types of obstruents in Korean (Han and

[5] Contextual or transitional cues refer to cues that are distributed before and after the oral closure stage of obstruents. Onset cues: Cues that are distributed before the oral closure. Offset cues: Cues that are distributed after the oral closure. Internal cues: Cues that are distributed during the oral closure (Steriade 1997).

Weitzman 1970 and Kim 1970). The lack of contrastive CDs of the glottis in coda position means there is also a lack of contrastive VOT values for different types of Korean stops in coda position. Therefore, the lack of contrastive glottal gestures in coda position is also closely related to laryngeal neutralization.

(14) displays articulatory or aerodynamic properties of different types of Korean stops distributed in # _ V , V_V , and _ {#, C} contexts.

(14)

C in # _ V or V_V	C in _ {#, C}
different CDs of the glottis at oral-closure release	no different CDs of the glottis at oral-closure release
different oral closure duration. tense and aspiration : relatively long (J. I. Han 1997)	not observable
heightened subglottal pressure for tense stops	slightly heightened subglottal pressure for all stops

(14) shows that the constraint $*CCD_{GLOTTIS}/\_\{\#, C\}$, which is responsible for laryngeal neutralization, is closely related to the distribution of gestures in a given context. For example, different CD values of the glottis are not contrastive in positions where relevant gestures are absent or weakened. If the meaning of cues used in Steriade (1997) is expanded to include articulatory gestures or aerodynamic properties that are employed to distinguish one sound from another in production, the gesture-based account of stops in coda position provides one more example to strengthen Steriade's claim that "relative poverty of cues induce neutralization" (Steriade 1997: 7).

I propose that unreleased stops in _ {#, C} are more similar to tense stops in Korean than to aspirated or lax stops in two aspects: heightened subglottal pressure and the default [critical] CD of the glottis. First, unreleased stops are likely to have heightened subglottal pressure because air from the glottis is captured behind the area where a [closed] CD of an oral articulator is formed. The heightened subglottal pressure of unreleased stops is also closely related to the patterns of Post-Obstruent Tensification (POT) in Korean, as will be discussed in Chapter 3.

Second, the CD of the glottis for unreleased stops is [critical] by default as is that of voiced obstruents. Browman and Goldstein (1992:239) assume the default laryngeal gesture is appropriate for voicing if there is no specification for the laryngeal gesture. However, Korean coda stops cannot be voiced because one of the requirements for obstruents to be voiced is not met in Korean. For stops to be voiced, both a slightly adducted status of the glottis and sufficient airflow through the adducted glottis are required (Ohala 1983:294). In the case of Korean coda stops, the latter condition is not met because there is no airflow through the adducted status of glottis as shown in Kim's study (1998).

In summary, the different CDs of the glottis after oral-closure release are very critical in distinguishing different manners of Korean stops. However, the different CDs of the glottis are not contrastive in coda position because the targeted CDs of the glottis (5) are not observable or not achieved after oral-closure release. The context-sensitive markedness constraint (11) takes into account implementation conditions that are related to contrastive CDs of the glottis in coda position. (11) requires no contrastive CDs of the glottis for different types of stops before a consonant or in word-final position where the relevant CD gestures of the glottis are absent. Thus, laryngeal neutralization in data (4) results from the interaction between the context-sensitive markedness constraint (11) and the input-output faithfulness constraint (12), as shown in (13).

2.1.3.2 Patterns of fricatives in coda position

2.1.3.2.1 Introduction

According to Feature Geometries of Sagey (1986), McCarthy (1988), and Cho (1990), /s, s', h/ form a natural class of fricatives by sharing [+continuant]. When /s, s'/ occur between vowels, as in (15a), corresponding segments of /s, s'/ have identical gestures in the output. When /h/ occurs between two vowels, /h/ is deleted as in [no_a] from /noha/ 'to place + declarative'. However, neither the oral fricatives /s, s'/ nor the glottal fricative /h/ appear in coda position, as shown in (15b). Instead, /s, s', h/ are merged into the unreleased alveolar stop [t˺] in coda position.

(15) a. Fricatives between vowels — b. Fricatives in coda position

Input	Output		Input	Output	
/nas+ i/	[na.si]	'sickle + sub'	/nas/	[nat˺]	'sickle'
/ul+əs'+ə/	[u.lə.s'ə]	'wept + declarative'	/ul+əs'+ko/	[u.rət˺ . k'o]	'wept'
/noh+a/	[no._a]	'place +declarative'	/noh+ko/	[not˺ . k^ho][6]	'and place' (verb)'

In previous analyses based on Underspecification Theories (Cho 1990 and Sohn 1987), the change of /s/ to [t˺] in coda position is represented as delinking of [+continuant] as in (16a). The change of /s'/ to [t˺] is represented as delinking of

[6] /h/ + /p, t, k/ are coalesced into aspirated obstruents, resulting in [p^h, t^h, k^h] in the fast, informal, or casual styles of speech. However, in the slow, formal, or careful styles of speech, [tp^h, tt^h, tk^h] are heard.

[constricted glottis] and [+continuant], as in (16b). The change of /h/ to [t˺] is represented as delinking of [spread glottis], as in (16c).

(16) a. /s/ b. /s'/ c. /h/

a. /s/: Laryngeal • • Supralaryngeal — [+continuant] (delinked)

b. /s'/: • • — [constricted glottis] (delinked), [+continuant] (delinked)

c. /h/: • • — [spread glottis] (delinked)

In addition, the alveolar unreleased stop [t˺], which is a default consonant in Korean, is inserted for /h/ at the later stage of derivation, resulting in the surface forms in (15b). Therefore, neutralization of /s, s', h/ to [t˺] in coda position are treated with separate rules, such as delinking of laryngeal features and/or [+continuant].

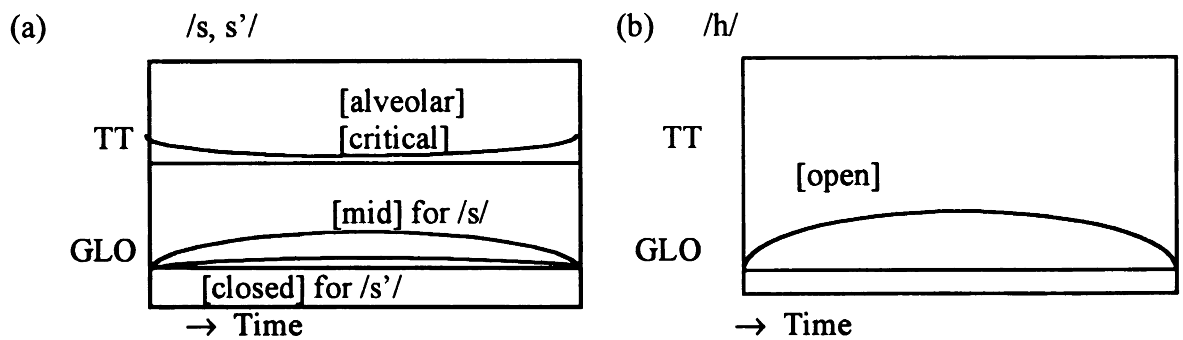
In this analysis, I will show that the neutralization of /s, s', h/ to [t˺] results from an effort to satisfy output constraints, especially *Contrastive Constriction Degree (CCD) /_ {#, C}. The constraint *CCD/_ {#, C} demands there be no contrastive CDs at the vocal tract in word-final or before a consonant. The parallelism between the pattern of fricatives /s, s', h/ and the pattern of stops in coda position will be shown in 2.1.3.2.2.

2.1.3.2.2 Gestural characteristics of fricatives

Gesturally, /s, s'/ have the [critical] CD of TT at the alveolar region, as shown schematically in (17a). /s/ and /s'/ are distinguished from each other by different CDs of the glottis. /s/ is characterized by the [mid] CD at the glottis and /s'/ by the [closed] CD at the glottis.

/h/ is characterized by the [open] CD at the glottis without any obstacle in the oral cavity, as shown in (17b). The [open] CD at the glottis for /h/ refers to an articulatory value that is relatively wider than those of the glottal stop [?] or voiced stops, thus creating weak noise or aspiration.

(17) Gesture scores of fricatives - modified from Kagaya (1974:164)



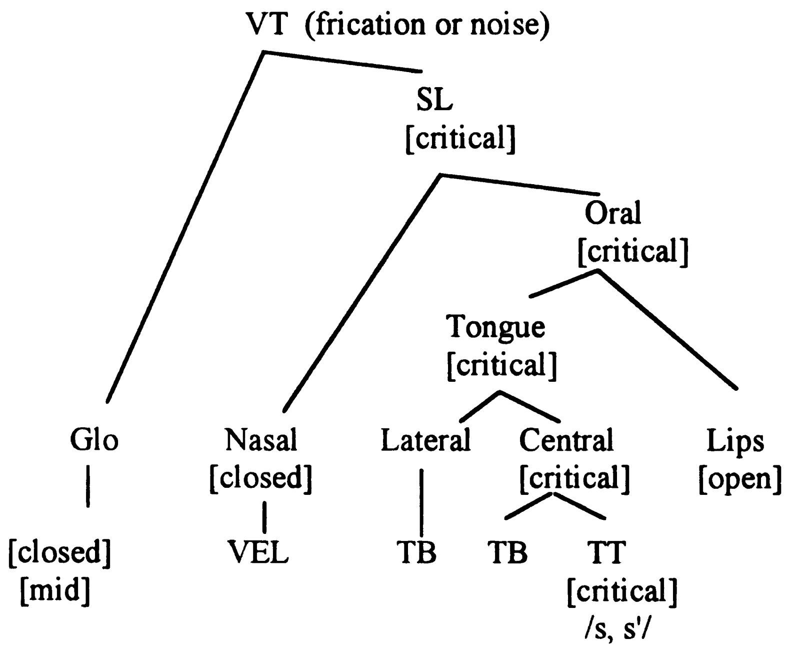
According to Browman and Goldstein (1992), the peak of glottal gestures for oral fricatives occurs while [critical] CD of TT gestures is maintained, as shown in (17a). In other words, [mid] or [closed] CD of glottal gestures synchronizes with [critical] CD of the TT for /s, s'/. The synchronized timing of glottal gestures relative to oral gestures arises in order to create turbulent noise efficiently for /s, s'/ (Iverson and Salmons 1995).

This is because the amplitude of turbulent noise is increased by the presence of an obstacle in the oral cavity.

The co-articulation of different CDs at the glottis and the [critical] CD of TT gestures for the oral fricatives /s, s'/ and the [open] CD at the glottis for /h/ are important articulatory gestures. Assuming the 'average' amount of airflow through the vocal cavity, the co-articulation of glottal gestures and the [critical] CD of TT gestures for /s, s'/ and the [open] CD of the glottis for /h/ are closely correlated to static acoustic targets of fricatives, namely continuous frication noise (Johnson 1997). /s, s'/, namely [+strident], are known to have higher turbulent noise than other fricatives such as /x/ and /h/ (Shriberg and Kent 1995).

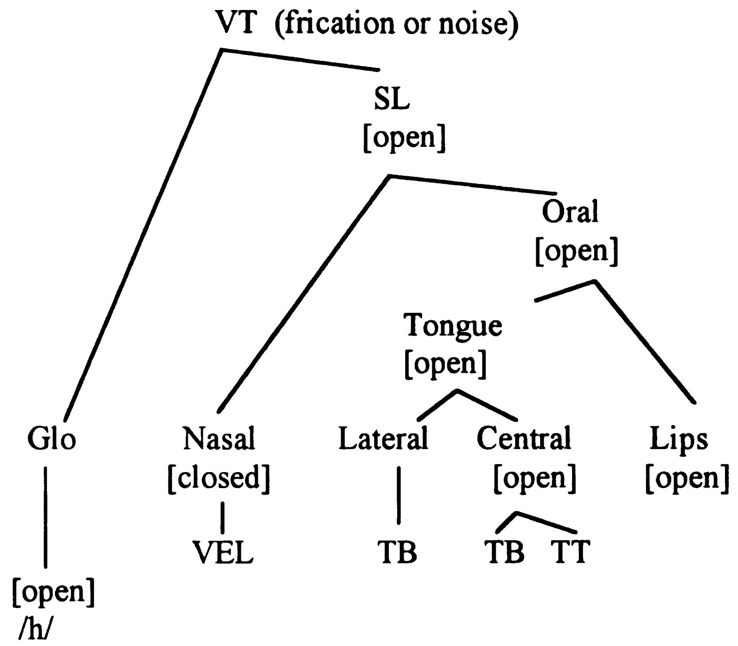
The CDs of TT gestures and glottal gestures creates the CDHs in (18a) and (18b) for the oral fricatives /s, s'/ and the glottal fricative /h/, respectively. /s, s', h/ form a natural class at the VT level by having the characteristic of frication or noise, as shown in (18).

(18) a. /s, s'/



tensed /s'/
plain /s /

(b) /h/



2. 1. 3. 2. 3 Gestural characteristics of fricatives in coda position

In this section, I will discuss how the [critical] CD of TT gestures for /s, s'/ and the [open] CD of glottal gestures for /h/ are adjusted gesturally in coda position. An output CDH, which is created by gestural adjustments of fricatives in coda position, is illustrated in (19). The phonetic motivations for gestural adjustments of fricatives in coda position are discussed in 2.1.3.2.4.

Kim and Jongman 's (1996) study is introduced first because their study provides insight for understanding CN in Korean. In one of their experiments, V_1 duration in $CV_1.sV_2$ and $CV_1.t^hV_2$ sequences is examined to see if the length of V_1 is influenced by the underlying manner of following consonants (/s, t^h/). This experiment uses words such as [ki̲.s̲a] from /kis̲a/ 'newspaper article' and [ki̲.t̲^{h}a] from /kit̲^{h}a/ 'etc.'. Kim and Jongman observe that V_1 duration before [s] is longer than V_1 duration before [t^h], as vowels before fricatives within a syllable are longer than vowels before affricates in English (Dorman and Raphael 1980, Johnson 1997, and Ferrero et al. 1982). Thus, Kim and Jongman conclude that vowel duration is sensitive to the manner of a following consonant in Korean.

In other experiments, Kim and Jongman (1996) investigate /t, t^h, s/ in syllable and word-final position in terms of production and perception. Kim and Jongman measure vowel durations in words such as [mu̲t˺] from /mus/ 'many' and [mut˺] from /mu$\underline{t}^h$/ 'land'. These words are chosen to see if vowel durations in surface forms with the identical coda consonant [t˺] are influenced by underlying manners of following consonants /s, t^h/, as in [mut˺] from /mus̲/ and /mu$\underline{t}^h$/. In surface forms, average vowel durations before underlying fricatives and stops are 100.5 ms and 101.75ms respectively, which is not a significant difference. Therefore, Kim and Jongman conclude vowel durations in surface forms are not influenced by underlying manners of following consonants if following consonants appear in word-final position or before a consonant.

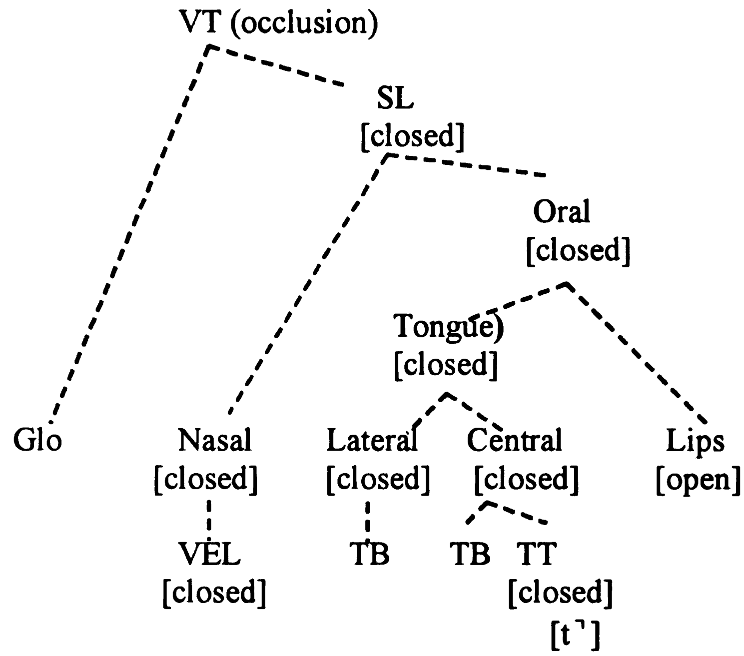
Furthermore, in Korean, /s/ at the word-final position or before a consonant is realized as silence corresponding to oral closure rather than relatively long turbulent noise as in English. The average closure duration of [t˺], which is relevant to underlying /t, t^h and s/ in coda position, is 73.5 ms for /t/, 74 ms for /t^h/ and 73.25 ms for /s/. Therefore, there are no significant differences in closure according to different manners of underlying consonants, resulting in neutralization of /t, t^h, s, s'/ to [t˺] in coda position.

Dorman et al.'s study (1980) is comparable to Kim and Jongman's study (1996). After examining /ʃ/ in 'dish' and /tʃ/ in 'ditch', Dorman et al. conclude that in English, acoustic properties for fricatives in coda position are not different from acoustic properties for fricatives in onset position. Acoustic properties of fricatives evident regardless of syllable positions are slow rise time of fricative noise and long duration of fricative noise.

A comparison of Kim and Jongman (1996) and Dorman et al. (1980)'s studies indicates that different languages use different gestures for underlyingly identical segments in the same prosodic position. For example, as discussed earlier, the [critical] CD of TT gestures for /s, s'/ and the [open] CD of glottal gestures for /h/ are responsible for continuous or long duration of fricative noise. In English, the CD of TT gestures for oral fricatives /ʃ/ in coda position is [critical], as Dorman et al's study shows. However, in Korean, the [critical] CD of TT gestures for oral fricatives is absent in coda position. Instead, the [critical] CD of TT gestures is adjusted to the [closed] CD of TT gestures in coda position, acoustically resulting in silence, as shown in Kim and Jongman's study. In addition, I assume that the [open] CD at the glottis for /h/ is also absent in coda position because there are no active glottal gestures in coda position, resulting in [t˺] from /h/.

Any adjustment of targeted CD gestures, in turn, creates a different CDH. Therefore, I suggest (19) as an output CDH for underlying fricatives /s, s' h/ in coda position. (19) reflects gestural adjustments made in the TT and glottis in coda position. In (19), the targeted [critical] CD of the TT for /s, s'/ and the [open] CD of the glottis for /h/ are adjusted to [closed] CD of TT gestures in coda position because of the phonetic implementation condition that will be discussed in 2.1.3.2.4.

(19) Output CDH for underlying fricatives /s, s', h/ in _{#, C}



In (19), there are no contrastive CD of glottal gestures for fricatives in coda position, as three types of Korean stops do not have contrastive CDs of glottal gestures in coda position (see (10) in section 2.1.3.1.3). The [critical] CD of TT gestures and contrastive CDs of glottal gestures for fricative /s, s', h/ are not achieved due to phonetic reasons that will be discussed below. Instead, the [critical] CD of TT gestures and contrastive CDs of glottal gestures are adjusted to the [closed] CD of TT gestures. This adjustment changes the overall output characteristic of the vocal tract from frication to occlusion.

In (19), the CD value at the central node is [closed] because the central node takes the minimum CD value of TT or TB gestures because the TT and TB are connected in series. The CD value at the tongue node is [closed] because the lateral and central nodes are connected in series. Remember that the default CD of the tongue body gestures is

[open]. The predicted CD at the oral node is [closed] because the tongue and lip nodes are connected in series. The predicted CD at the SL level is the maximum CD of the nasal or oral nodes due to their parallel connection. However, both nasal and oral nodes have [closed] CD in (19), therefore resulting in the [closed] CD at the SL level. The [closed] CD at the SL level, in turn, creates occlusion, which results from either the [closed] CD of glottal gestures or the [closed] CD at the SL level (see (16) in section 1.2.4.2).

2. 1. 3. 2. 4
Phonetic motivations for neutralization of fricatives in coda position

Now it is time to discuss why fricatives in word-final position or before a consonant behave as they do in Korean. First, I will discuss phonetic motivations for phonological adjustments of /s, s'/ to [t˺].

Two points from previous discussion are important to understand neutralization of /s, s'/ to [t˺] in coda position. The first point is articulatory and acoustic characteristics of [+/-release]. Articulatorily, [+/-release] refer to the presence or absence of targeted glottal gestures after oral-closure release. Acoustically, [+/-release] refer to the presence or absence of airflow escaping through the oral cavity after oral-closure release. The second point is Browman and Goldstein's (1992) observation that the peak of glottal gestures occurs simultaneously while the [critical] CD of TT gestures for /s, s'/ is maintained in order to create continuous frication effectively, as shown in (17).

I suggest that the primary phonetic motivation of [t˺] from /s, s'/ in coda position is closely tied to the lack of active glottal gestures in coda position for obstruents in Korean. The glottis and TT gestures are the active articulators involved in /s, s'/ and they co-articulate together in onset position for /s, s'/ as shown in (17). However, glottal gestures are absent in coda position. Therefore, gesturally, there is no peak of glottal gestures synchronized with the [critical] CD of TT gestures for /s, s'/ in coda position.

The lack of active glottal gestures, in turn, create difficult conditions for creating turbulent noise in coda position. Therefore, the main source for fricatives, turbulent airflow, is not present or is weakened significantly in coda position. As a consequence, the [critical] CD of TT gestures cannot be maintained because there is no air to be controlled to maintain continuous frication noise. Hudson (1995:662) states that syllable-final consonants are likely to be neutralized because syllable-final consonants are not salient acoustically. Therefore, phonetic implementation conditions for underlying /s, s'/ are weakened or impoverished in coda position. Furthermore, the lack of air escaping through the glottis is likely to promote silence corresponding to oral closure, which is a critical property of stops in coda position (Dorman et al. 1980), resulting in neutralization of /s, s' h/ to [t˺].

The question raised is why the [critical] CD of TT gestures for /s, s'/ is adjusted to the [closed] CD of TT gestures, resulting in [t˺] instead of [p˺, k˺]. I claim that the adjustment of the [critical] CD of TT gestures to the [closed] CD results from an effort to minimize phonological adjustments. Consider the fact that the tongue tip as an articulator for /s, s'/ is specified with the [alveolar] CL and [critical] CD as shown in (17). In the adjustment of the [critical] CD of TT gestures to the [closed] CD, the articulator and CL are still maintained in coda position.

Discussions on phonetic motivations for /h/ to [t˺] in coda position are divided into two areas: phonetic motivations for the preference of [t˺] over other unreleased stops, [p˺, k˺], and the relationship between the phonetic realization of [t˺] and the style of speech. I will provide phonetic motivations for the preference of [t˺] over other unreleased stops, [p˺, k˺], below. The second point will be discussed in detail in chapter 4.

Neutralization of /h/ in coda position parallels neutralization of /s, s'/. /h/ is the glottal fricative which is specified with the [open] CD of glottal gestures. However, as mentioned earlier, active glottal gestures are absent in syllable-final position in Korean, as shown in (19). Any of [p˺, t˺, k˺] for /h/ in coda position seems an equally reasonable candidate to appear in coda position. The lips for [p˺], TT for [t˺] or TB for [k˺] are absent in the input for the glottal fricative /h/. Therefore, any adjustments using any of these articulators incurs violations of IDEN-IO(Gesture), which demands that corresponding input-output segments be identical in gestures.

However, I believe that the adjustment of /h/ to [t˺] rather than to [p˺, k˺] occurs because of the following articulatory implementation conditions for [t˺] in coda position: First, the TT movement is quicker than the TB movement for [k˺] or lip movement for [p˺]. Second, the tongue tip is more pliable than the tongue blade and lips. Third, during /h/, there is a tendency for the tongue tip to rest on the floor of the mouth (Byrd 1996). Thus, it will take more time or efforts for the tongue or the lips to travel to make [k˺] or [p˺] (Byrd 1996). All thisngs being equal, speakers tend to use gestures distributed in a given context (J. Jun 1995, Kirchner 1998 and 2000). Therefore, a segment with the tongue tip articulator, namely [t˺], rather than segments with tongue body or lip articulators, namely [p˺, k˺], is produced as in [not̲˺ . k̲ʰːo] from /noh + ko/.

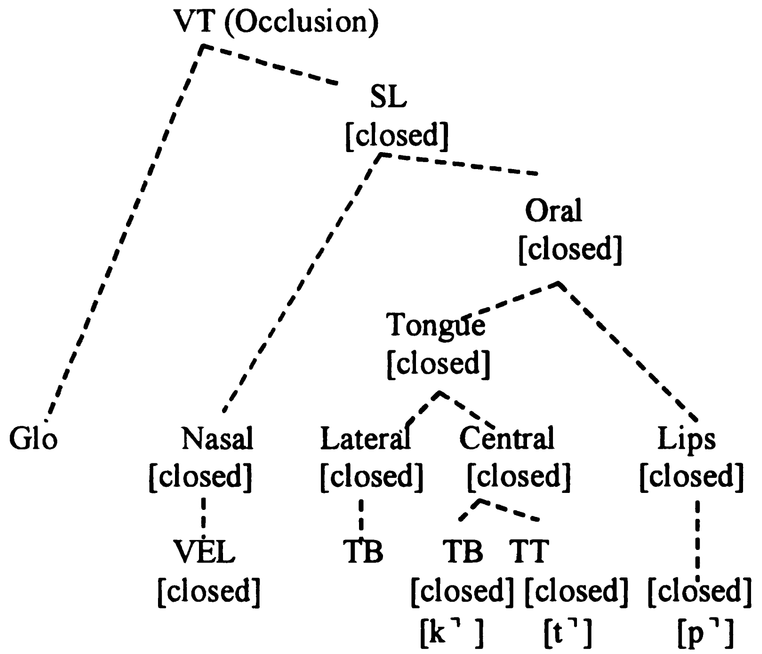
Thus far, it has been discussed that the absence of active glottal gestures and lack of air escaping through the oral cavity for obstruents in coda position create articulatorily and acoustically unfavorable conditions to maintain [open] CD of glottal gestures for /h/ and [critical] CD of TT gestures for /s, s'/. Thus CN in Korean emerges as a by-product of phonetic implementational conditions in a given context (Steriade 1997).

2.1.3.2.5 The gesture-based account of fricatives in coda position

A task at hand is to establish a link between phonetic implementational conditions for fricatives in coda position and fricative neutralization in coda position. Output constraints suggested for fricative neutralization must be sensitive to releasedness of fricatives in coda position. This is because fricative neutralization in coda position is motivated by the lack of active glottal gestures, as stop neutralization in coda position is motivated by the lack of active glottal gestures. In addition, output constraints should be sensitive to the fact that the [critical] CD of TT gestures is not maintained due to the lack of synchronized gestures of the glottis and the TT and the absence of airflow escaping though the oral cavity to maintain [critical] CD of TT.

Before proposing output constraints for fricative neutralization in coda position, it is necessary to examine output CDHs for oral stops ((10) in section 2.1.3.1.3) and an output CDH for fricatives shown in (19). These CDHs can be united as in (20) below.

(20) Output CDHs for three types of oral stops and fricatives in _ {#, C}



A generalization drawn from (20) is that only occlusion, which is specified with [closed] CD at the SL level, can appear in coda position. Occlusion is specified for either [closed] CD of glottal gestures or [closed] CD at the SL level. However, the [closed] CD of glottal gestures of occlusion is not active due to the lack of active glottal gestures in coda position. Therefore the [closed] CD at the SL level plays an important role in

Korean. To have the [closed] CD at the SL level, the TB, TT, or Lips have to be [closed]. Therefore, there are no contrastive CDs of articulator gestures in coda position for fricatives and stops regardless of their target gestures. For example, contrastive CDs of glottal gestures for stops and fricatives are absent or weakened and the [critical] CD of TT gestures for /s, s'/ are absent in the output, as shown in (15b). The absence of contrastive CDs at the articulators, in turn, influences other higher levels, resulting in occlusion at the highest level VT, as shown in (20).

Based on the generalization above, the output constraint *CCD$_{\text{GLOTTIS}}$ /_{#, C}, which is responsible for neutralization of three types of Korean stops in coda position, is expanded and modified as in (21) to incorporate neutralization of stops and fricatives in coda position.

(21) *Contrastive Constriction Degrees (CCD)/ _ {# ,C}

> Contrastive CD at the glottis and at the SL level for obstruents is not allowed when obstruents appear in word-final position or before a consonant.

The constraint (21) requires that obstruents not be contrastive in terms of the CD at the glottis and at the SL level before a consonant or in word-final position.

Two points must be mentioned related to the constraint (21). First, CCD in (21) is subdivided into [open], [mid], [critical], and [closed][7] (Browman and Goldstein 1989: 209). Languages use different CDs of an articulator depending on obstruents involved. For example, Korean uses [open], [mid] and [closed] CDs of the glottis for obstruents,

[7] According to Browman and Goldstein (1989), [narrow] CD comes between [critical] and [mid] and they say that [narrow] is useful in differentiating vowels.

resulting in aspirated, lax, and tensed obstruents respectively. Contrary to Korean, English uses [mid] and [critical] CDs of the glottis for obstruents, resulting in voiceless and voiced obstruents respectively. In addition, an articulator cannot have two CD values simultaneously. Therefore, stops cannot be aspirated and tensed at the same time because the glottis cannot have [open] and [closed] CDs simultaneously.

Second, the comparison of (18) to (19) indicates that within a language there is preference for one CD over another in a given context. Take an example from [critical] CD of TT gestures for fricatives. The [critical] CD of TT gestures for /s/ is contrastive with the [closed] CD of TT gestures for /t/ in onset position in English and Korean. However, in Korean, only the [closed] CD of TT gestures is allowed in coda position. In English, both [critical] and [closed] CDs of TT gestures for /s, t/ are allowed in coda position.

I modify (21) to include language difference and CD preference in a given context as in (22).

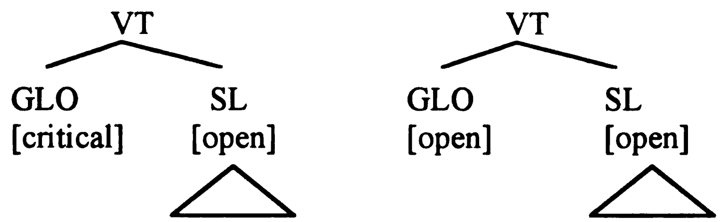
(22) *Contrastive Constriction Degrees (CCD)/ _ {#, C}

Contrastive CDs at the glottis and at the SL level for obstruents are not allowed when obstruents appear in word-final position or before a consonant.

[open] /_{#, C} >>[mid] /_{#, C} >>*[critical] /_{#, C} >> *[closed] /_{#, C}

The fact that the [closed] CD of TT gestures is allowed instead of the [critical] CD of TT gestures in coda position ranks the constraint *[closed] /_{#, C} to be the lowest in the ranking hierarchy. The fact that /h/ is not allowed but a sonorant is allowed in coda position in Korean and English justifies the ranking of *[open]/_{#, C} over [critical]/_{#, C}. As shown in (23), CDs at the SL level for /h/ and a sonorant are [open] but CDs of glottal gestures are [critical] for a sonorant and [open] for /h/.

(23) a. sonorants b. /h/



However, English and Korean do not allow [h] at word-final position or before a consonant. Therefore, the [critical] CD at the glottis is preferred over the [open] CD of glottal gestures in coda position. Therefore, *[open]/_{#, C} dominates *[critical]/_{#, C} in the ranking hierarchy. In English, /h/ is not allowed in coda position but voiceless obstruents appear in coda position. Therefore, *[mid]/_{#, C} is located between *[open]/_{#, C} and *[critical]/_{#, C}.

The phonetic motivation for CN and phonetic based constraints having been introduced above, it is now possible to apply the constraints and their rankings to actual data and evaluate possible candidates.

Languages differ from each other by the ranking of IDENT-IO(Gestures) ((12) in section 2.1.3.1.3) related to *CCD/_{#, C} (22). If IDENT-IO(Gestures) is ranked higher than *[mid]/ _{#. C} in a language, the language would allow fricatives such as [f, v, s, z, θ, ð ʃ, ʒ] and plain stops such as [p, t, k] but not [h] in coda position as in English.

I propose that IDENT-IO(Gestures) is ranked lower than *[closed] /_{#, C} in Korean as in (24) because there are no fricatives or stops with contrastive CDs in coda position. I will show below that CN in Korean results from the effort to satisfy output constraints (24) most optimally.

(24) *[open] /_{#, C} >>*[mid] /_{#, C} >>*[critical] /_{#, C} >>
*[closed] /_{#, C}>> IDENT-IO(G)

(25) shows evaluation of candidates from a lexical entry ending with the fricative /s/. In (25), *CCD/_{#, C} is violated if a consonant in coda position has contrastive CDs either at the glottis or at the SL level. This is because the output airflow of VT is determined by CDs at the glottis or at the SL level when the right amount of airflow from the lungs is assumed.

(25) /nas̲/ 'sickle'

GLO [mid], SL [critical], Oral [critical], TT [critical]

/nas̲/	*[open]/ _{#, C}	*[mid]/ _{#, C}	*[critical]/ _{#, C}	*[closed]/ _{#, C}	IDENT-IO (G)
a. [nas]		*!(GLO)	*(SL)		
b. [nas']			*!(SL)	*(GLO)	* GLO: [closed]
➢c. [na]					
d [nat]		*! (GLO)		*(SL)	*GLO: [mid] *TT: [closed]
e. $[nat^h]$	*! (GLO)			*(SL)	*GLO: [open] *TT: [closed]
f. [nat']				*!(GLO) *(SL)	*GLO: [closed] *TT: [closed]
☞g.[nat˺]				*(SL)	*TT: [closed]

➢ indicates to the most optimal candidate with respect only to constraints given.

Any output candidate that has CCDs of glottal gestures is not the most optimal candidate because of the lack of active glottal gestures in coda position, as discussed in neutralization of three types of stops in coda position. Contrastive glottal gestures are impoverished or not observable in coda position. Thus, (25a), (25b), (25d), (25e), and (25f), which have contrastive [open], [mid] and [closed] of glottal gestures, are not optimal candidates. In addition, candidates with [critical] CD of TT gestures in coda position as in (25a) and (25b) are not desirable to be optimal candidates. The lack of active glottal gestures in coda position creates unfavorable conditions for completing [critical] CD of TT gestures and creating continuous airflow for fricatives. Therefore, among output candidates, only (25c➢) and (25g☞) are possibilities to be the most optimal candidate. (25c➢) deletes the underlying consonant /s/ in coda position. In (25g ☞), [critical] CD of TT gestures and [mid] CD of glottal gestures in the input are adjusted to [closed] CD of TT gestures without any active glottal gestures, resulting in the unreleased stop [t˺].

According to the constraint hierarchy suggested in (22), the candidate (25c➢) satisfies the constraint ranking most optimally. The constraint IDENT-IO(G) is satisfied vacuously because there is no corresponding segment for input /s/ in (25c➢). However, no consonants in the input are deleted in Korean unless there are two consonants in coda position, as will be shown in Coda Consonant Cluster Simplification (section 2.2). Therefore, there is a constraint that prevents an input segment from being deleted.

In Correspondence Theory, a constraint that prevents a segment from being deleted is Max-IO$_{seg}$ in (26), which requires every segment of S_1 have a correspondent in S_2. The comparison of (25c➢) and (25g☞) indicates tMax-IO$_{seg}$ is higher than *CCD/_{#, C} as shown in (26) because no segment is deleted to avoid contrastive CDs in the vocal tract.

(26) Max-IO_{seg}: Every segment of the input has a correspondent in the output. (From McCarthy and Prince 1995:16)
Max-IO_{seg} >> *CCD /_{#, C} >> IDENT-IO(G)

/nas̲/ 'sickle'
GLO [mid], SL [critical], Oral [critical], TT [critical]

/nas̲/	Max-IO_{seg}	*CCD /_{#, C}	IDENT-IO(G)
a. [na]	*!		
☞b. [nat˺]		*(SL)	*TT: [closed]

The most optimal candidate in (26) has [closed] CD of TT gestures, resulting in the unreleased stop [t˺], as shown in (26b). The adjustment of [critical] CD of TT gestures to [closed] CD of TT gestures also changes CDs in higher levels, creating [closed] CD at the SL level. Therefore, the constraint hierarchy of Max-IO_{seg} above IDENT-IO(G) is responsible for gestural disparity (or phonological adjustment of a segement) between the input and the output, rather than deletion of a segment.

The next step is to determine if the constraints suggested in (26) can correctly predict neutralization of /h/ in coda position in Korean. (27) illustrates a lexical item with /h/ before a consonant.

(27) /nohko/ 'and place (verb)'

/h/: GLO [open], SL [open], Oral [open]
/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/no<u>h</u>+ko/	Max-IO$_{seg}$	*CCD/_{#, C}				IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]	
a. no<u>h</u>.ko		*!(GLO)				
b. no<u>t</u>'.k^{h}o					*!(GLO) * (SL)	* (TT)
c. no<u>t</u>.k^{h}o			*!(GLO)		* (SL)	*(TT)
d. no<u>t</u>$^{h·}$k^{h}o		*!(GLO)			* (SL)	*(TT)
e. no.ko	*!				* (SL)	
⇨ f. no<u>t</u>˺.k^{h}o					* (SL)	*(TT)
☞g. no.k^{h}o						

⇨ indicates free variation with the output depending on the style of speech.

Although the output candidate (27a) maintains all input segments, it violates a relatively high *[open]/_{#, C} constraint because it has the [open] CD at the glottis in coda position. Candidates (27b), (27c), (27d), (27e), and (27f ⇨) violate one of *CCD/_{#, C} because they have either contrastive CDs of the glottis or [closed] CDs at the SL level in coda position. In addition, candidates (27b), (27c), (27d), (27e), and (27f ⇨) violate IDENT-IO[G] because these candidates have TT gestures that are absent in the input. I mark insertion of TT gestures as one violation with respect to IDENT-IO[G].

Candidates (27b) and (27f ⇨) violate a relatively low *[closed]/_{#,C} constraint. However (27b) violates *[closed]/_{#,C} twice and (27f ⇨) violates *[closed]/_{#,C} once. [not˺k^{h}o] (27f⇨) is considered as a free variant of (27g) depending on the rate or style of speech in Korean. Considering that gestures are spatio-temporal linguistic units, the rate or style of speech will influence how gestures are co-articulated or co-produced at a given time. Constraints related to these free variations are discussed in detail in Chapter 4.

Candidate (27e) is far from being an optimal candidate because there is no correspondence for [h] in output. The comparison of candidate (27g☞) to candidate (27f⇨) shows that (27g☞), in which /h/ and /k/ are coalesced into [k^h], is the most optimal candidate because both gestures of /h/ and /k/ are maintained in the output.

In order to include neutralization of stops and fricatives, constraints and the constraint hierarchy in (22) are expanded and modified from (11) in section 2.1.3.1.3. Therefore, constraints (22) are examined below for three types of Korean stops to see if constraints and their hierarchy in (22) select the output correctly.

Lexical entries in (28) have aspirated and lax bilabial stops at word-final position.

(28) A. /ip^h/ 'leaf' From (13)

GLO [open], SL [closed], Oral [closed], Lips [closed]

/ip^h/	Max-IO_{seg}	*Contrastive CD/_{#, C}				IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]	
a. ip^h		*!(GLO)			* (SL)	
b.ip'					*!(GLO) * (SL)	* (GLO)
c.ip			*!(GLO)		* (SL)	* (GLO)
☞d.ip˺					* (SL)	* (GLO)

B. /ip/ 'mouth' From (13)

GLO [mid], SL [closed], Oral [closed], Lips [closed]

/ip/	Max-IO_{seg}	*Contrastive CD / _{# , C}				IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]	
a. ip^h		*!(GLO)			*(SL)	* (GLO)
b.ip'					*!(GLO) *(SL)	* (GLO)
c.ip			*!(GLO)		*(SL)	
☞d.ip˺					*(SL)	* (GLO)

Any candidates with segment deletion are winnowed from being most optimal because they violate a relatively high constraint MAX-IO_{seg}. Any candidates with CCDs of the glottis violate *CCD/_{#, C} because glottal gestures cannot be contrastive in coda position due to the lack of glottal gestures. In candidates (28Ad) and (28Bd), contrastive CDs of the glottis are absent in coda position. Compared to (28Ab) and (28Bb), candidates in (28Ad) and (28Bd) violate *CCD/_{#, C} only once because of the [closed] CD at the SL level in coda position. In other candidates such as (28Aa), (28Ba), (28Ac), and (28Bc), relatively higher constraints within *CCD/_{#, C} constraints are violated. Therefore, (28Ad) and (28Bd) are the most optimal candidates.

Up to this point I have shown that CN of stops and fricatives can be analyzed systematically in terms of CD, which is closely related to manner of articulation.

In previous studies of Korean phonology, CN of stops and fricatives was described as delinking of different features such as [spread glottis], [constricted glottis] and [+continuant]. As a consequence, it has been difficult to analyze neutralization of stops and fricatives in a unified and systematic way. The previous analyses based on traditional Feature Geometry Theories at times hinder linguists in finding regularities, generalizations or parallels among different phonological phenomena. This is because it has been difficult to find phonetic reasons why features such as [spread glottis], [constricted glottis] and [+continuant] are involved in CN together in Feature Geometry theories.

2.1.3.3 Patterns of affricates in coda position

2.1.3.3.1 Introduction

Data (29) shows neutralization of affricates /c, c^h/ to the unreleased [t˺] in coda position. No words end with the tensed /c'/ in Korean.

(29) a. Word final position

/na<u>c</u>/	→	[na<u>t</u>˺]	'day'
/na<u>c</u>^{h}/	→	[na<u>t</u>˺]	'face'

b. Before a consonant

/na<u>c</u>c'am/	→	[na<u>t</u>˺. c'am]	'nap'
/na<u>c</u>^{h} kalim/	→	[na<u>t</u>˺. k'a.rim][8]	'shyness of children'

c. Between two vowels

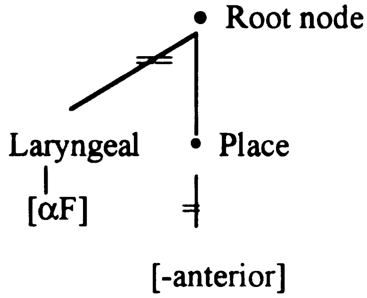
/na<u>c</u>+ɛ/	→	[na<u>c</u>ɛ]	'in the daytime'
/ na<u>c</u>^{h} +ɛ/	→	[na<u>c</u>^{h} ɛ]	'in the face'

According to previous studies (Cho 1990, Sohn 1987 and Kim-Renaud 1974), the delinking of [+constricted glottis], [+spread glottis] and [-anterior] as in (30) is responsible for neutralization of affricates /c, c^h/ as unreleased [t˺] in coda position.

[8] /l/ becomes /r/ between two vowels in Korean.

(30) Patterns of affricates in coda position

Cho (1990:106)



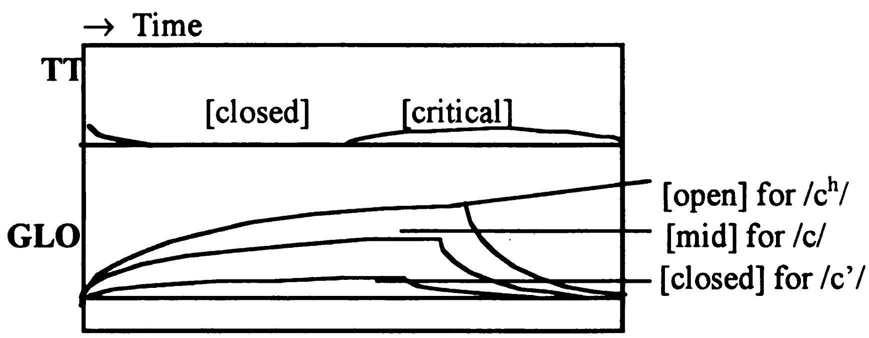
In this section, I will argue two points. First, there is no need for delinking two separate features for patterns of affricates in coda position, as show in (30). I claim that because CN is neutralization in manners of articulation in coda position, CN should be analyzed without reference to a place feature such as [-anterior].

Second, neutralization of /c, c', c^h / as unreleased [t˺] in coda position is in parallel with neutralization of stops and fricatives in coda position. Neutralization of affricates results from the most optimal satisfaction of output constraints in (22), as does neutralization of stops and fricatives.

2.1.3.3.2 Gestural characteristics of affricates

In order to understand patterns of affricates in Korean phonology, gestural characteristics of affricates must be understood first. According to Kehrein (1999), affricates /c, c^h, c'/ result from promoting acoustic transparency by changing the manner of stop /t/. Kim (1997) claims that Korean affricates are characterized as [-continuant, +strident] in the alveolar location. Based on these studies, I assume that TT gestures for affricates are specified with two different CDs: [closed] and [critical] at the TT level, as shown schematically in (31).

(31) Gestural Score of affricates

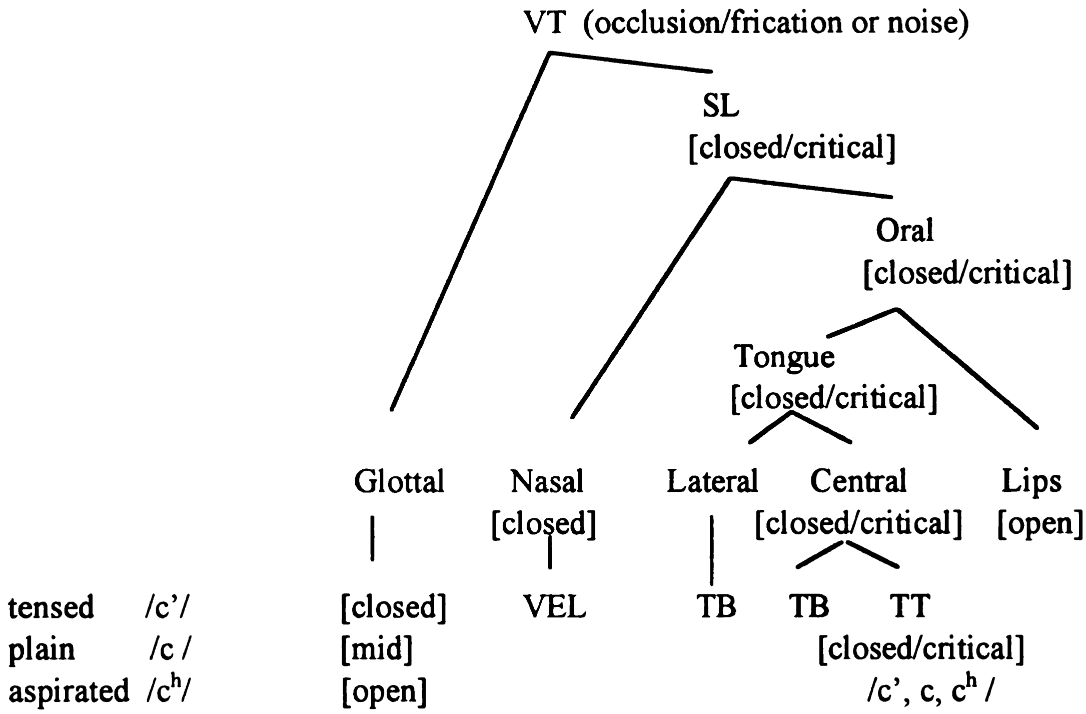


The two different CDs of the TT are co-articulated with three different CDs of the glottis depending on types of affricates: [open] CD of the glottis for /c^h/, [mid] CD of the glottis for /c/ and [closed] CD of the glottis for /c'/.

Affricates begin with oral closure as do stops, as shown in (31). However, the collected air behind an oral closure escapes through the oral cavity in various ways. In the case of stops, the collected air behind an oral closure escapes through the glottis right after oral-closure release. In the case of affricates, the collected air behind the TT closure is held continuously by the [critical] CD of TT gestures in order to create intense frication for the latter part of affricates.

[closed] and [critical] CDs of TT gestures and constrastive CDs of glottal gestures for affricates create the CDH in (32).

(32) CDHs for affricates /c, c', c^h/



In (32), at the highest level, VT, the overall characteristic of output airflow is either occlusion or frication depending on which CDs of TT gestures are counted. This may be understood by reference to controversial issues concerning the representation of affricates discussed by Sagey (1986), Lombardi (1990), Rubach (1994), and Steriade (1989).

2. 1. 3. 3. 3 The gesture-based account of affricates in coda position

In this section, I will discuss adjustments of target gestures of the TT and the glottis for affricates in coda position. In addition, phonetic motivations for gestural adjustments of affricates in coda position are discussed. Gestural characteristics of affricates mentioned above allow us to understand why affricates in coda position behave as they do in Korean.

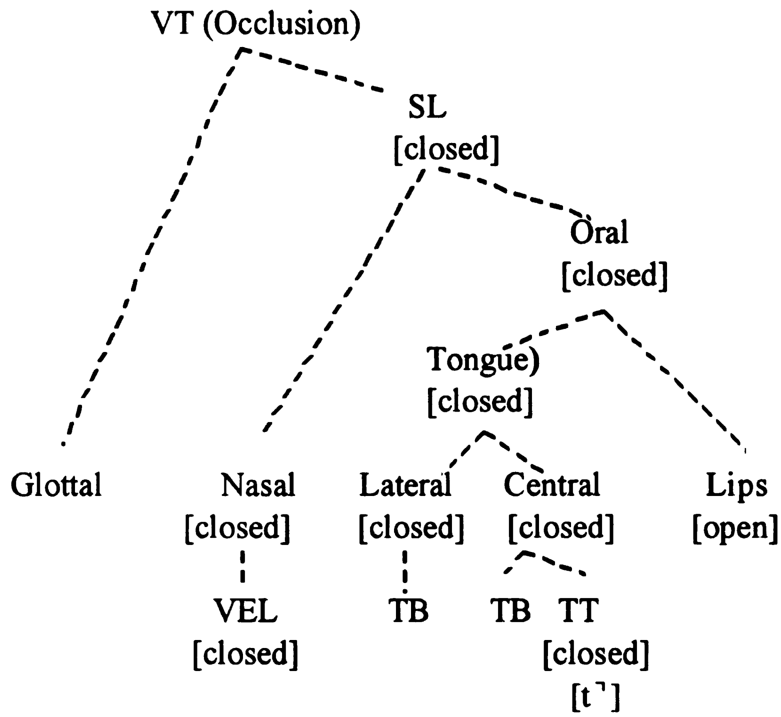
As stops and fricatives in coda position are faced with adverse conditions for completing release gestures, affricates in coda position are also faced with adverse conditions for completing release gestures.

One of the disadvantages of affricates in coda position is that there are no observable glottal gestures at oral-closure release or at the time of [critical] CD of TT gestures. The absence of glottal gestures at the time of TT gestures for affricates creates unfavorable conditions for distinguishing three types of affricates.

In addition, the lack of glottal gestures in coda position decreases implementational conditions for achieving the [critical] CD of TT gestures that is associated with the latter part of affricates. During the latter part of [critical] CD of TT gestures, there should be a fairly large amount of air escaping through the oral cavity in order to create the acoustic characteristics of frication. However, the aerodynamic conditions for frication are not met for affricates in coda position due to the lack of airflow escaping through the glottis. When there is no airflow after the [closed] CD of TT gestures is formed, [closed] CD of TT gestures for affricates in coda position are maintained. Therefore, there is no need for delinking [-anterior] as in (30).

Therefore, neutralization of affricates as the unreleased alveolar stop [t˺] in coda position emerges from phonetic implementational conditions, which result from adjustments of target gestures of affricates in coda positoin. (33) represents the output CDH that reflects adjustments of target gestures of affricates in coda position.

(33) An output CDH for underlying affricates /c', c, c^h/ in __ {#, C}



As shown in (33), there is parallelism in the behavior of stops, fricatives and affricates in coda position. These obstruents are neutralized as unreleased stops in coda position due to the lack of critical gestures such as contrastive CDs of glottal gestures and the [critial] CD of TT gestures. Stops in coda position lack contrastive CDs of glottal gestures. Fricatives in coda position lack contrastive glottal gestures, which are synchronized with TT gestures. In addition, it is difficult for fricatives to maintain the static [critical] CD of TT gestures due to the lack of air escaping through the glottis.

Considering that gestures of affricates are a combination of gestures of stops and fricatives, parallelism in patterns of stops, fricatives, and affricates in coda position is expected in a gestural approach. Affricates in coda position also lack contrastive glottal gestures as well as TT gestures for the same phonetic reasons that stops and fricatives in coda position do.

If affricates in coda position pattern together with stops and fricatives for the same phonetic reasons that stops and fricatives in coda position do, constraints suggested in (26) should correctly select the most optimal candidate for affricates in coda position. Constraints and their hierarchy suggested in (26) are evaluated below in (34) for affricates in coda position to see if they can correctly predict the output.

(34) /c'o$\underline{c}^h$/ 'flower'

GLO [open], SL [closed/critical], Oral [closed/critical], TT [closed/critical]

/ c'o$\underline{c}^h$ /	Max-IO$_{seg}$	*CCD/ _{# or C}				IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]	
a. c'o$\underline{c}^h$		*! (GLO)		* (SL)		
b. c'o$\underline{t}$'					*! (GLO) *(SL)	* GLO:[closed] * TT:[critical]
c. c'o$\underline{t}$			*! (GLO)		*(SL)	* GLO:[mid] * TT:[critical]
d. c'o$\underline{t}^h$		*!(GLO)			*(SL)	* TT:[critical]
e. c'o	*!					
☞f. c'o$\underline{t}$˺					* (SL)	* TT:[critical]

Candidate (34a) is not the most optimal candidate because it has the [open] CD of glottal gestures and the [critical] CDs at the SL level. The [critical] value at the SL level is predicted from [critical] CD of TT gestures. IDENT-IO[G] is satisfied best in (34a) because it does not change input gestures. Candidate (34b) is not an optimal candidate, as it has the contrastive [closed] CD of glottal gestures. It also has the contrastive [closed] CD at the SL level, violating *CCD/_{#, C}. Candidate (34c) is not an optimal candidate because it has the contrastive [mid] CD of glottal gestures. (34d) is not an optimal candidate because of the contrastive [open] CD at the glottis and the [closed] CD at the SL level. Candidate (34e) is the least optimal candidate because it deletes /c^h/. (34f) violates *CCD /_{#, C} because of the [closed] CD at the SL level. However, violation of *[closed]/_{#, C} is preferred to violation of Max-IO_{seg} because Max-IO_{seg} is higher ranked than *[closed]/_{#, C}. Therefore, constraints and their hierarchy in (26) correctly select the most optimal candidate for affricates in coda position.

2.1.4 Summary

Hudson (1995) and Steriade (1997) claim that some phonological phenomena are understood better when phonetic characteristics of a segment in a context rather than prosodic units such as the syllable are taken into account in phonological descriptions. Especially, Hudson (1995:660) claims that "as a phonological feature with generally recognizable phonetic characteristics, [released] may explanatorily replace the analytical syllable boundary in phonological rules." The analysis of CN in this study has provided one more example to strengthen Hudson's claim.

In this study, based on experimental studies in perception and production, releasedness of obstruents is defined in terms of gestural and acoustic properties. Gesturally, [+/- release] refers to the presence or absence of active glottal gestures at oral-closure release. Acoustically, [+/- release] refers to the presence or absence of airflow.

Based on the fact that consonants are likely be unreleased in word-word final position or before a consonant (Hudson 1995) and experimental studies of Korean and English obstruents in word-final position (Kim-Jongman 1996, Dorman et al. 1980), I propose the constraint *CCD/_{#, C} in (22), which is sensitive to context and releasedness of obstruents. In the constraint *CCD/_{#, C}, the role of releaseness is expressed in terms of CDs. This is because [+/-release] is closely associated with active CDs of glottal gestures at the time of oral-closure release. For example, in Korean there are no active glottal gestures at the time of oral-closure release, thus resulting in neutralization of three types of stops as unreleased stops [p˺, t˺, k˺] in coda position. The unreleased stops are characterized by oral-closure gestures only, as shown in (10).

In addition, the presence or absence of active CDs of glottal gestures at the time of oral-closure release consequently influences gestures of other articulators that are co-articulated with glottal gestures, as explained in section 2.1.3.2.4. Therefore, by suggesting the constraint *CCD/_{#, C}, which is sensitive to CDs in the VT, I have shown that neutralization of obstruents in coda position, namely CN, can be analyzed in a unified way.

In addition, I have claimed that CN is neutralization in manners of articulation, which is closely related to the CD of the vocal tract. Therefore,as discussed in 2.1.2, there is no need of suggesting different rules for stops, fricatives and affricates that delete different features. Furthermore, deleting of [+anterior] is not relevant to CN because CN as neutralization of manners of articulation is related to CDs not CLs.

I have claimed that interaction of *CCD/_{#, C}, Max-IO$_{seg}$, and IDENT-IO[G] is responsible for CN in Korean. If obstruents are in coda position, only the [closed] CD at the SL level is allowed in Korean due to the lack of active glottal gestures. The lack of active glottal gestures in coda position forces IDENT-IO[G] to be violated. However, having the [closed] CD at the SL level is preferred to deletion of a segment as long as Korean syllable structure in (19) of section 1.3.1 is maintained. Therefore, satisfaction of Max-IO$_{seg}$ takes precedence over satisfaction of *CCD /_{#, C}, as shown in (26).

In Korean literature, the analyses of CN can be divided into two types of approaches according to features used. In the first approach, features used in the analysis of CN are distinctive features used in Chomsky and Halle (1968) or Jackobson et al (1952), as in Sohn (1987) and Cho (1990). In the second approach, phonetic features such as [release] and A_o are used in the analyses of CN, as in Kim-Renaud (1974) and

Lee (1994). A_o refers to zero aperture of the oral cavity that stands for oral closure in Steriade (1991).

The analyses of CN based on releasedness of obstruents have been attacked for the reason that no sounds are contrastive in terms of releasedness in languages. However, Hudson (1995:661) suggests that [+/-unreleased] is contrastive in Hindi. In addition, when releasedness is defined in terms of CDs of articulatory gestures, especially CDs of glottal gestures, as in this study, the attack on the analyses of CN based on releasedness of obstruents can be avoided. This is because, in Articulatory Phonology, CDs of articulator gestures function like distinctive features of previous phonological theories. Therefore, languages are distinctive in terms of the presence or absence of CDs in articulatory gestures or the degree of constriction, as shown in (5).

In addition, representation of releasedness of obstruents in terms of CDs offers simplicity in phonological descriptions. For example, Kim-Renaud (1974) describes CN as in (35a):

(35) Kim-Renaud (1974: 116)

a. [+consonant, -sonorant] → [-release] /_ {$, [-release] } : $ syllable boundary
   (one or more obstruents are unreleased in syllable-final position)

b. [-release] → [-aspiration, -tense, -delayed release, -continuant]
   (An unreleased segment is unaspirated, non-tensed, non-fricated and non-affricated.)

c. [+coronal, -anterior] → [+anterior]
   (An unreleased coronal segment is dental)

(35a) is suggested for unreleased obstruents in coda position. In addition to (35a), Kim-Renaud suggests (35b) and (35c) to take care of residues that cannot be fully explained by (35a) only. Basically, (35b) defines what the characteristics of non-released obstruents are. (35c) is suggested for non-occurrence of /c, c', c^h/ in coda position. However, like CN analyses based on distinctive features, it is difficult to see phonetic reasons why [-release] of obstruents is related to [-aspiration, -tense, -delayed release, -continuant] and [+anterior].

In this study, unreleased stops in coda position are closely related to the absence of contrastive glottal gestures in coda position due to the lack of active glottal gestures in coda position. The absence of contrastive CDs in coda position is also closely related to [-aspiration, -tense, -delayed release, -continuant] in coda position because these features are associated with CDs in the vocal tract. Therefore there is no need for (35a) and (35b).

In addition, non-occurrence of /c, c', c^h/ in coda position is closely related to the lack of airflow escaping through the oral cavity at the time of the [closed] CD of TT gestures, which is the first part of TT gestures for affricates. The [critical] CD of TT gestures for the latter part of affricates is not achieved due to the lack of airflow needed to create turbulent noise, thus the [closed] CD of TT gestures is maintained. However, CL of TT gestures for affricates are not altered in coda position in this study. Therefore, there is no need to suggest (35c) in Articulatory Phonology.

2.2 Coda Consonant Cluster Simplification (CCCS)

2.2.1 Introduction

Input morphemes can have two consonants in Korean. If output forms in (36a) are assumed to be input forms, there is no way to explain why [s', s c', p^h] are inserted before a vowel suffix, as shown in (36c). However, if input forms have two consonants, as in input forms in (36a), output forms in (36a) are explained as deletion of a consonant in syllable-final position while output forms in (36c) maintain input segments [s', s c', p^h]. Because input morphemes ending with two consonants can explain output forms in both (36a) and (36c), input morphemes should end with two consonants as in (36).

When an input morpheme ends with two consonants, only one of them is maintained in syllable-final position, as shown in output forms of (36a) and (36b).

(36)					
		Input		Output	
	a.	/nəks/		[nək˺]	'soul'
		/kaps/		[kap˺]	'price'
		/wɛkols/		[wɛ.gol]	'stubborn'
	b.	Input		Output	
		/nəks+kwa/		[nək˺ . k'wa]	'soul + and'
		/anc /$_{\text{Verb Stem}}$ +/ta/$_{\text{declarative}}$		[an.t'a]	'to sit down + declarative'
		/ilp^h/$_{\text{Verb Stem}}$ +/ta/ $_{\text{declarative}}$		[ip˺.t'a]	'to recite + declarative
	c.	Input		Output	
		/nəks/ +	/i/$_{\text{Subject Marker}}$	[nək˺ .s'i]	'soul'
		/kaps/ +	/i/$_{\text{Subject Marker}}$	[kap˺ . s'i]	'price'
		/wɛkolsu/		[wɛ.gol. su]	'stubborn'
		/anc/$_{\text{Verb Stem}}$ +	/a/$_{\text{Command Marker}}$ *	[an.c'a]	'sit down'
		/ilp^h/ $_{\text{Verb Stem}}$ +	/ə/$_{\text{Command Marker}}$	[ip˺.p^hə]	'recite '

*Either /a/ or /ə/ is selected depending on the vowel in the verb stem.

If morphemes ending with a consonant cluster are followed by morphemes beginning with a consonant, a sequence of $V_1C_{n-2}C_{n-1}C_nV_2$ is created, as shown in (36b). In the sequence of $V_1C_{n-2}C_{n-1}C_nV_2$, the first consonant C_n before V_2 always appears as an onset consonant of V_2 in output forms, as shown in (36b). However, only one of C_{n-2} and C_{n-1} appears as a coda consonant of V_1, as shown in (36b). The choice between C_{n-2} and C_{n-1} after V_1 depends on gestural characteristics of C_{n-2} or C_{n-1} and dialects.

Data in (37) illustrates patterns of Coda Consonant Cluster Simplification (CCCS) in Standard Korean (SK), known as Seoul Korean.

(37) Patterns of CCCS in SK

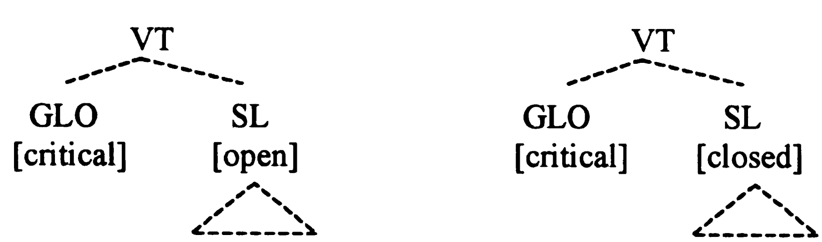
		Input	Output	
a.	ks	/nə<u>ks</u>/	[nə<u>k</u>˺]	'soul'
	ps	/ka<u>ps</u>/	[ka<u>p</u>˺]	'price'
	nc	/a<u>nc</u>+ta/	[a<u>n</u>.t'a]	'to sit down + declarative'
	nh	/a<u>nh</u>+ko/	[a<u>n</u>.kʰo]	'not to do + and'
		/ma<u>nh</u>+so/	[ma<u>n</u>.s'o]	be a lot + statement'
	lh	/o<u>lh</u>+ko/	[o<u>l</u>.kʰo]	'be right + and'
		/o<u>lh</u>+so/	[o<u>l</u>.s'o]	'be right + statement'
	ls	/wɛko<u>ls</u>/	[wɛ.ko<u>l</u>]	'stubborn'
b.	lpʰ	/ɨ<u>lpʰ</u>+ta/	[ɨ<u>p</u>˺.t'a]	'recite + declarative'
	lp	/nə<u>lp</u>+ta/	[nə<u>p</u>˺.t'a]	'be wide + declarative'
	lk	/i<u>lk</u>+ta/	[i<u>k</u>˺.t'a]	'to read + declarative'
c.	lm	/sa<u>lm</u>/	[sa<u>m</u>]	'life'
		/talm+ ta/	[tam.t'a]	'to resemble + declarative'
d.	ltʰ	/ha<u>ltʰ</u>+ta/	[ha<u>l</u>.t'a]	'lick + declarative'

When fricatives and affricates compete for a coda position with stops, nasals, and /l/, fricatives never appear in coda position, as shown in (37a). Either an unreleased stop or a sonorant appears in coda position. (37b) shows that when the lateral /l/ and stops except /t^h/ compete for the coda position, unreleased stops appear in coda position instead of [l]. When /l/ and /m/ compete for the coda position, /m/ is preferred over the lateral /l/ as shown in (37c). Note that in Korean, there are no input morphemes ending with /ln/, /nl/, /lŋ/, or /ŋl/, which further verifies a preference for nasals over the lateral /l/ in coda position. (37d) shows that in a /l/-/t^h/ cluster, the lateral [l] appears in coda position instead of the unreleased stop [t˺]. When (37d) is compared with (37b), (37d) seems to be an exception to the generalization that unreleased stops are preferred over the lateral [l], as in (37b). However, the analysis of CCCS in this study will show that the preference for the lateral [l] over the unreleased stop [t˺] from a /l/-/t^h/ cluster is the expected pattern when gestures involved in /l/ and /t^h/ are taken into account. One point to be mentioned regarding (37) is that all consonant clusters include a consonant whose articulator is the TT. Consonants with the TT articulator are /s, n, l, c, t^h/.

There are two facts observed in CCCS regardless of dialect. First, consonants in word-final position or before a consonant are either sonorants [m, n, ŋ, l], or occlusions [p˺, t˺, k˺], as mentioned in section 2.1. Therefore, consonants in coda position are characterized with the following CDHs in output forms:

(38) Consonant CDHs in coda position in Korean.

a. Sonorant [m, n, ŋ, l] b. Occlusion [p˺, t˺, k˺]



As shown in (38), Korean consonants in coda position have either [open] or [closed] CDs at the SL level. (38a), in fact, is ambiguous whether the [critical] CD of the glottis refers to the default CD of the glottis or the active [critical] CD of the glottis for sonorants. If the [critical] CD of the glottis refers to the default CD of the glottis in coda position, sonorants [m, n, ŋ, l] could be represented with [m˺, n˺, ŋ˺, l˺]. This is because [-release], which is represented by [˺], is closely associated with the lack of active glottal gestures while targeted oral gestures are completed. If the [critical] CD of the glottis refers to the active [critical] CD of the glottis, sonorants [m, n, ŋ, l] are represented with [m, n, ŋ, l]. No matter whether the [critical] CD of the glottis in coda position is the default CD or the active CD for sonorants, the fact is that the CD of the glottis for sonorants is [critical].

Recall that in Articulatory Phonology, the default CD of the glottis for obstruents is [critical]. As mentioned in 2.1.3.1.3, unreleased stops in coda position have the [critical] or narrow CD of the glottis by default, which is similar to the [critical] CD of voiced obstruents. However, unreleased stops in coda position tend to be voiceless because of heightened sub-glottal pressure and the lack of sufficient airflow, which is required for obstruents to be voiced (Ohala 1983).

The second fact observed in CCCS, regardless of dialect, is that the syllable structure in (39) is strictly maintained in output forms.

(39) Korean syllable structure

$$\sigma$$

(C) (G) V (C) G = Glides

If morphemes ending with a consonant cluster appear in word-final position or before a consonant, as shown in (36), the need to fulfill the syllable structure (39) creates competition between two consonants for the coda position.

As mentioned in the previous section, no consonants in the input are deleted unless there are two consonants in coda position. Max-IO$_{seg}$, which demands that every segment of the input has a correspondent in the output, is responsible for maintaining of input segments in output forms. However, the constraint Max-IO$_{seg}$ is violated when a morpheme ends with a consonant cluster or when a morpheme ending with a consonant cluster is followed by a morpheme beginning with a consonant, as shown in (36). The violation of Max-IO$_{seg}$ stems from conflicting demands between Korean lexical representation and Korean syllable structure in (39).

The following section 2.2.2 investigates how these conflicts are resolved in Korean grammar and how SK and Kyung-Sang Korean (KSK) differ from each other. Section 2.2.3 examines how a consonant that fails to appear in coda position influences the following consonants.

2.2.2 The gesture-based account of Coda Consonant Cluster Simplification

2.2.2.1 The gesture-based account of CCCS in SK

As a start, (40) evaluates output forms from a lexical entry ending with a stop-fricative cluster against constraints suggested in (26), because both stops and fricatives are obstruents. Recall that the constraint *CCD/_{# or C} is suggested primarily for obstruents in coda position. Therefore, it is expected that constraints and their hierarchy in (26) select correct output forms in an obstruent-obstruent cluster because two obstruents compete for the coda position. Due to space, hereafter, target gestures of consonants in a consonant cluster are given above tableaux, as in (40).

(40) Max-IO$_{seg}$ >> *CCD/_{# or C} >> IDENT-IO[G] (from (26))

/kaps/ 'price'

/p/: GLO [mid], SL [closed], Oral [closed], Lips [closed]
/s/: GLO [mid], SL [critical], Oral [critical], TT [critical]

/kaps/	Max-IO$_{seg}$	*CCD/_{# or C}				IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]	
➤a. kaps			**!(GLO)	*(SL)	*(SL)	
☞b. kap˺	*				*(SL)	*GLO
c. kas	*		*!(GLO)	*(SL)		
d. kap	*		*!(GLO)		*(SL)	
e. ka	**!/p,s/					
f. kat˺	*				*(SL)	*!TT(closed) *GLO

/p/ is specified with GLO [mid] and SL [closed]. The [closed] CD at the SL level for /p/ is predicted from the [closed] CD of Lip gestures. /s/ is specified with GLO [mid] and SL [critical]. The [critical] CD at the SL level for /s/ is predicted from the [critical] CD of TT gestures.

Candidate (40a➢) satisfies the highest ranked constraint, Max-IO_{seg} given in (40). However, (40a) is not the actual output. The actual output is (40b☞), which violates Max-IO_{seg}.

According to constraints and their hierarchy suggested in (26), (40b), (40c), (40d), (40e), and (40f) should not be selected as the most optimal candidate. They violate the highest constraint Max-IO_{seg}. One of two consonants in a consonant cluster does not have a correspondence in (40b), (40c), (40d), and (40f). Candidate (40e) is the worst candidate because it violates the undominated constraint, Max-IO_{seg} twice.

In the case of (40f), it is hard to determine if the unreleased [t˺] corresponds to either /p/ or /s/. If [t˺] in (40f) corresponds to /s/, instead of /p/, (40f) violates IDENT-IO[G] twice. Most importantly, the [critical] CD of TT gestures for /s/ is adjusted to the [closed] CD of TT gestures. In (40), I considered the unreleased [t˺] as a correspondence of /s/. However, if the unreleased [t˺] corresponds to /p/, (40f) would incur serious violations of IDENT-IO[G] because Lip gestures as a whole are adjusted to TT gestures.

Candidates (40b), (40c), (40d), and (40f) are tied in violations of Max-IO_{seg}. Because candidates (40b), (40c), (40d), and (40f) all violate Max-IO_{seg} once, (40b) and (40f) are possibilities to be the most optimal candidate. (40b) and (40f) satisfy *CCD/ _{#, C} most optimally, tying in violation of *CCD/ _{#, C}. However, (40b☞) is the actual output, even though constraint Max-IO$_{seg}$ is violated by (40b☞). The selection of (40b) over (40f) indicates a preference of minimizing gestural adjustments from the input. In the case of (40f), the [critical] CD of TT gestures are adjusted to the [closed] CD, resulting in violations of IDENT-IO[G].

When /s/ alone appears in word-final position before a consonant as in /nas/→[nat˺], the adjustment of the [critical] to the [closed] CD of TT gestures is preferred over deletion of /s/, as shown in (25). The constraint Max-IO$_{seg}$ is responsible for gestural adjustment in [nat˺] from /nas/, instead of deletion.

The fact that the actual output is (40b☞), even though it violates Max-IO$_{seg}$, implies that there is a higher constraint than Max-IO$_{seg}$. A higher constraint than Max-IO$_{seg}$ is *COMPLEX that bans a consonant cluster in coda position, as shown in (41).

(41) *COMPLEX (*COMP, hereafter): a consonant cluster is not allowed in coda position.

*COMPLEX >> Max-IO$_{seg}$ >>*CCD/_{# or C}>> IDENT-IO[G]

/nəks/ 'soul'

/k/: GLO: [mid], SL: [closed], TB [closed]
/s/: GLO: [mid], SL: [critical], TT [critical]

/nəks/	*COMP	Max-IO$_{seg}$	*CCD/_{# or C} *[open]	*[mid]	*[critical]	*[closed]	IDENT-IO[G]
a. nəks	*!			**!(GLO)	*(SL)	*(SL)	
☞b. nək˺		*				*(SL)	*(GLO)
c. nəs		*		*!(GLO)	*(SL)		
d. nək		*		*!(GLO)		*(SL)	
e. nə		**!/k,s/					
f. nət˺		*				*(SL)	*(GLO) *TT CD

(41) evaluates /nə<u>ks</u>/ against *COMPLEX and other constraints in (40). (41a) is far from being the most optimal candidate because it violates the highest constraint, *COMPLEX. Candidates (41b), (41c), (41d), (41e), and (41f) violate Max-IO$_{seg}$. In particular, (41e) violates Max-IO$_{seg}$ twice and is excluded from being the most optimal candidate. One of two consonants in a consonant cluster does not have a correspondence in candidates (41b), (41c), (41d), (41e), and (41f).

As mentioned in the analysis of CN, glottal gestures for obstruents are impoverished or weakened to function as contrastive units in coda position. Therefore, candidates with contrastive glottal CDs, such as (41c) and (41d), are excluded from being the most optimal candidate. Compared to (41f), violation of IDENT-IO[G] is minimal in (41b). Therefore, in an obstruent-obstruent cluster, an unreleased stop wins the competition for the coda position, as shown in (41b).

In morphemes ending with a stop-fricative cluster, as in (40) and (41), the constraint *CCD_/{#, C}, which is responsible for CN, plays a crucial role in preventing the occurrence of fricatives in coda position.

Constraints and their hierarchy suggested in (41) correctly select the output form (41b) in an obstruent-obstruent cluster. Therefore, it is worthwhile to investigate morphemes ending with a sonorant-obstruent cluster to see if constraints and their hierarchy in (41) correctly select output forms in a sonorant-obstruent cluster. Note that sonorants involved in sonorant-obstruent and sonorant-sonorant clusters are always either /n/ or /l/, as shown in (37).

(42) evaluates the /l/-/t^h/ cluster, a sonorant-obstruent cluster. Because *COMPLEX is undominated in the constraint hierarchy, hereafter, unless necessary, candidates

violating *COMPLEX are excluded from candidate evaluation. Hereafter, candidates violating Max-IO$_{seg}$ twice are also excluded from candidate evaluation, because the most optimal candidates never delete two consonants in a consonant cluster, as shown in (41e).

(42) /ha$\underline{l}\underline{t}^h$+ta/: 'to lick + declarative'

/l/: GLO[critical], SL[open], Oral [open], TB[open], TT[closed]
/t^h/ : GLO[open], SL[closed], Oral [closed], TT [closed]

/ha$\underline{l}\underline{t}^h$+ta/	Max-IO$_{seg}$	*CCD/_{#, C}				IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]	
☞a. ha$\underline{l}$.t'a	*					
b. ha$\underline{t}^h$.t'a	*	*! (GLO)			*(SL)	
c. ha$\underline{t}^{\urcorner}$ t'a	*				*!(SL)	*(GLO)

As Korean allows either a sonorant or an occlusion in coda position, as shown in (38), candidates ending with [l] or [t$^{\urcorner}$] are possible optimal candidates. All candidates in (42) violate Max-IO$_{seg}$. (42a) satisfies *CCD/_{#, C} vacuously because *CCD/_{#,C} is a constraint for obstruents in coda position. Candidate (42b) is excluded from being the most optimal candidate because the coda consonant has contrastive CDs at the glottis and at the SL level. In (42c), if [t$^{\urcorner}$] corresponds to/t^h/, gestures of /t^h/ are adjusted to [t$^{\urcorner}$] in order to optimally satisfy *CCD/_{#, C} at the expense of violating faithfulness constraint IDENT-IO[G]. Therefore, a candidate ending with /l/, (42a), is selected as the most optimal candidate. Constraints in (41) correctly select the most optimal candidate in a sonorant-obstruent cluster, as shown in (42). Therefore, in a sonorant-obstruent cluster, a candidate with a sonorant in coda position is selected as the most optimal candidate.

However, the conclusion drawn in (42) poses problems for morphemes ending with sonorant-bilabial stop and sonorant-velar stop clusters (see (37b)). (43) evaluates output forms from a morpheme ending with a /l/-/$\underline{p}^h$/ cluster against constraints and their hierarchy in (41).

(43) /ɨl$\underline{p}^h$+ ta/: 'to recite+ declarative'

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/p^h/: GLO [open], SL [closed], Oral [closed], Lips [closed]

/ɨl$\underline{p}^h$+ ta/	Max-IO_{seg}	*CCD/_{#, C} *[open]	*[mid]	*[critical]	*[closed]	IDENT-IO[G]
➤ a. ɨl̲.t'a	*					
b. ɨ$\underline{p}^h$.t'a	*	*!(GLO)			*(GLO)	
☞ c. ɨp̲˺.t'a	*				*!(SL)	*(GLO)

Candidate (43b) is excluded from being the most optimal candidate because it violates *[open]/_{#, C}, which is the highest constraint within *CCD/_{#, C}. Candidate (43c) violates *[closed]/_{#, C}, which is the lowest constraint within *CCD/_{#, C}. The faithfulness constraint IDENT-IO[G] is also violated in (43c).

As in (42a), candidate (43a) satisfies *CCD/_{#, C} most optimally without violation of IDENT-IO[G]. Therefore, according to constraints and their hierarchy in (41), (43a➤) is the most optimal candidate. However, (43a➤) is not the actual output. The actual output is (43c☞), which violates *[closed]/_{#, C} and IDENT-IO[G]. The actual output (43c☞) is not consistent with the conclusion drawn in (42): in a sonorant-obstruent cluster, a candidate with a sonorant in coda position is selected as the most optimal candidate. The actual output (43c ☞) has the unreleased stop [p˺] in coda position.

To investigate sources of inconsistency in selecting output forms between (42) and (43), gestures involved in /p^h/ and /t^h/ are compared in (44).

(44) /p^h/: VT (occlusion), GLO [open], SL [closed], Oral [closed], Lips [closed]
/t^h/: VT (occlusion), GLO [open], SL [closed], Oral [closed], TT [closed]

The overall output characteristics at the VT for /p^h/ and /t^h/ are occlusion. CDs at the glottis are [open] for /p^h/ and /t^h/. CDs at the SL level are [closed] for /p^h/ and /t^h/. CDs of oral articulators for /p^h/ and /t^h/ are [closed]. However, /p^h/ and /t^h/ differ from each other in the oral articulator used. The active articulator for /p^h/ is the lips and the active articulator for /t^h/ is the tongue tip.

Therefore, I assume that the reason that constraints and their hierarchy in (41) select (42a) and (43c) as the most optimal candidates is closely related to the oral articulator being used. In (42), the consonant cluster is composed of the lateral /l/ and /t^h/ whose articulator is the TT. In (43), a consonant cluster is composed of the lateral /l/ and /p^h/ whose articulator is the lips. When everything is equal, the preference is given to the lip articulator, as shown in the comparison of [ɨp̚.t'a] from /ɨl$\underline{p^h}$ + ta/ in (43) and [hal.t'a] from /ha$\underline{lt^h}$+ta/ in (42). Therefore, the lip articulator is preferred over the TT articulator in SK.

The evaluation of /talk/ in (45) also illustrates an asymmetrical pattern of CCCS according to the oral articulators involved.

(45) /talk/: 'chicken'

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/k/: VT (occlusion), GLO [mid], SL [closed], Oral [closed], TB [closed]

/talk/	Max-IO_{seg}	*CCD/ {#, C} *[open]	*[mid]	*[critical]	*[closed]	IDENT-IO[G]
➢ a. tal	*					
b. .tak	*		*!(GLO)		*(SL)	
☞ c . tak˺	*				*!(SL)	*(GLO)

(45a➢) satisfies constraints and their hierarchy in (41) most optimally but it is not the actual output. Although (43c) violates *[closed]/_{#, C} and IDENT-IO[G], (43c☞) is the actual output. Therefore, in a /l/-/k/ cluster, the actual output has in coda position the unreleased [k˺], whose oral articulator is the TB. Thus, in a sonorant-obstruent cluster, candidates with TB and Lip articulators in coda position are selected as the output. In addition, in a /l/-/m/ cluster, although both /l/ and /m/ have the [open] CD at the SL level, [m], whose active articulator is the Lips, is preferred over the lateral [l], as shown in [sam] from /salm/ (37c).

Therefore, in competition for the coda position between two consonants, a consonant with the TB or Lip articulators appears in coda position, as shown in (43c) and (45c). I suggest a hierarchy of constraints that are sensitive to the oral articulators used for a consonant as in (46).

(46a) requires that the oral articulator of an input segment be maintained in its output correspondent. According to the oral articulators, IDENT-IO_{Art} is subdivided into IDENT-TB_{Art}, IDENT-$Lips_{Art}$, and IDENT-TT_{Art}. Therefore, IDENT-TB_{Art}, IDENT-$Lips_{Art}$, and IDENT-TT_{Art} require that any correspondent of an input segment specified with the TB, Lips, or TT maintain the TB, Lips, or TT respectively. The constraint hierarchy

(46b) is responsible for the preference of a consonant with the TB or Lip articulator over a consonant with the TT articulator. (46b) indicates that a consonant with the TB or Lip articulator is preferred over a consonant with the TT articulator when two consonants are in competition for the coda position.

(46) a. IDENT-IO$_{Art}$ ($_{Art}$ - Articulator):

Let α be a segment in the input, and β be a correspondent of α in the output.
If α is [γ articulator], then β is [γ articulator].

(IDENT-TB$_{Art}$, IDENT-Lips$_{Art}$, IDENT-TT$_{Art}$)
(TB$_{Art}$, Lips$_{Art}$, and TT$_{Art}$ respectively hereafter)

b. TB$_{Art}$/Lips$_{Art}$ >> TT$_{Art}$

Before establishing rankings between TB$_{Art}$/Lips$_{Art}$ >> TT$_{Art}$ in relation to other constraints in (41), there are two important points to be considered. First, an evaluation standard for the lateral [l] with respect to TB$_{Art}$ and TT$_{Art}$ has to be set up because the lateral /l/ is specified with TB [open] and TT [closed] in the input, as shown in (43) and (45). Consequently, candidates with the lateral [l] in coda position either violate or satisfy TB$_{Art}$ and TT$_{Art}$ simultaneously, depending on how constraints TB$_{Art}$ and TT$_{Art}$ are interpreted in a grammar. If constraints TB$_{Art}$, Lips$_{Art}$, and TT$_{Art}$ are interpreted as constraints that only allow consonants with TB, Lip, or TT articulators, candidates with the lateral [l] in coda position violate TB$_{Art}$ and TT$_{Art}$ simultaneously because both the TB and TT are active articulators for the lateral [l]. If constraints TB$_{Art}$, Lips$_{Art}$ and TT$_{Art}$ are interpreted as constraints that allow any consonant that involves TB, Lip and

TT articulators, candidates with the lateral [l] in coda position always satisfy both TB_{Art} and TT_{Art} simultaneously.

Based on the assumption that gestures are adjusted according to context, I suggest that the distribution of [l] in a given context determines satisfaction or violation of TB_{Art} and TT_{Art}. Sproat and Fujimura (1993: 306) observe that 'In syllable-final /l/s, the (vocalic) dorsal gesture is attracted to the nucleus of the syllable, whereas the (consonantal) apical gesture is attracted to the (right) margin of the syllable...In syllable-initial cases, the reverse prediction is made'. In addition, Browman and Goldstein (1992:166-67) state that for the lateral /l/, the peak of TB gestures occurs significantly earlier than the peak for TT gestures in word-final position.

Based on Sproat and Fujimura (1993) and Browman and Goldstein (1992), I assume that when the lateral [l] appears in word-final position or before a consonant, constraint TT_{Art} is satisfied because the TT gestures of [l] are active in coda position. When the lateral [l] appears in word-initial position or before a vowel, constraints TB_{Art} and TT_{Art} are satisfied simultaneously because both TB and TT gestures occur synchronously and are active in word-initial position or before a vowel.

The second important point to be noted is that constraints TB_{Art}, $Lips_{Art}$ and TT_{Art} evaluate for sonorants and obstruents. Therefore, satisfaction of TT_{Art} in a given context means that consonants such as [n, l, t s, c] are allowed in the context. In Articulatory Phonology, consonants such as [n, l, t s, c] form a natural class by sharing the TT articulator. Therefore, CDs within the TT articulator such as [close] or [mid], and CLs of the TT such as [alveolar] or [palatal] are not considered in evaluation of TT_{Art}. What matters most is if the TT articulator in an input segment is maintained in its output correspondent. As mentioned in 1.2.4.2, one way of grouping sounds into natural classes is based solely on the moving articulators. Therefore, the TT articulator itself plays a role in a grammar, as suggested in (46).

Having introduced an evaluation standard for the lateral /l/, I evaluate /talk/ below in order to establish ranking between TB_{Art}/ $Lips_{Art}$ >> TT_{Art} with respect to other constraints in (41). Recall (45) first. Without constraints TB_{Art}, $Lips_{Art}$, TT_{Art} and their hierarchy suggested in (46b), a candidate ending with the lateral [l] was considered as the most optimal candidate because it satisfied *CCD/_{#, C} most optimally, as shown in (45a➢). However, (45a➢) was not the actual output in SK. The actual output was (45c☞), which violated both *CCD/_{#, C} and IDENT-IO[G]. This indicates that violation of these constraints is tolerated in SK. When two consonants compete for the coda position, maintaining the TB articulator in the output takes precedence over satisfaction of *CCD/_{#, C} and IDENT-IO[G] in SK, as shown in (37b). Therefore, TB_{Art}/$Lips_{Art}$>> TT_{Art} is ranked higher than *CCD/_{#, C}, as shown in (47).

(47) *Max-IO_{seg} >> **TB_{Art}/$Lips_{Art}$** >> **TT_{Art}** >>*CCD/_{#, C} >> IDENT-IO[G]

/ta<u>lk</u>/: 'chicken'

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]

/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/ta<u>lk</u>/	Max-IO_{seg}	TB_{Art}/ $Lips_{Art}$	TT_{Art}	*CCD/_{#, C}				IDENT-IO[G]
				*[open]	*[mid]	*[critical]	*[closed]	
a. ta<u>l</u>	*	*!						
b. ta<u>k</u>	*		*		*!(GLO)		*(SL)	
☞ c . ta<u>k</u>˺	*		*				*(SL)	*(GLO)

Candidate (47a) satisfies *CCD/_{#, C} most optimally but violates TB_{Art} and $Lips_{Art}$, which are higher than *CCD/_{#, C}. The lateral [l] in coda position as in (47a) violates TB_{Art} because the TB gestures of the lateral /l/ is not maintained or is weakened significantly in coda position (Sproat and Fujimura 1993 and Browman and Goldstein 1992). However, satisfaction of TB_{Art}/$Lips_{Art}$ and TT_{Art} take precedence over satisfaction of *CCD/_{#, C} and IDENT-IO[G] in competition between two consonants for the coda position. The TT articulator is significantly active when the latral [l] appears in coda position.

Candidate (47b) is not an optimal output because it has the contrastive [mid] CD at the glottis and the [closed] CD at the SL level in coda position. Although candidate (47c) violates *[closed]/_{#, C} and IDENT-IO[G], it is the most optimal candidate because it satisfies the relatively higher constraint TB_{Art}.

In order to see if TT_{Art} should be ranked lower than *CCD/_{#, C}, (48) evaluates candidates from /ha<u>lt</u>^{h}+ta/. In a /l/-/t^h/ cluster of /ha<u>lt</u>^{h}+ta/, the TT articulator is involved in both /l/ and /t^h/. Therefore, for the correct output to be selected from candidates of

/ha$\underline{\text{lt}}^{h}$+ta/, it would be unnecessary to rank TT_{Art} below *CCD/_{#, C} until it is proven to be otherwise.

(48) /ha$\underline{\text{lt}}^{h}$+ta/ : 'to lick + declarative'

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/t^h/: GLO [closed], SL [closed], Oral [closed], TT [closed]

/ha$\underline{\text{lt}}^{h}$+ta/	Max-IO_{seg}	TB_{Art}/$Lips_{Art}$	TT_{Art}	*CCD/_{#, C}				IDENT-IO[G]
				*[open]	*[mid]	*[critical]	*[closed]	
☞a. ha$\underline{\text{l}}$.t'a	*	*						
b. ha$\underline{\text{t}}^{h}$.t'a	*	*		*!(GLO)			*(SL)	
c ha$\underline{\text{t}}$˺.t'a	*	*					*!(SL)	*(GLO)
d. ha$\underline{\text{t}}$.t'a					*!(GLO)		*(SL)	*(GLO)

Candidates with [l] or coronal stops in coda position violate TB_{Art} and satisfy TT_{Art} equally, as shown in (48). Therefore, candidates with /l/ or stops with the TT articulator in coda position are evaluated against *CCD/_{#, C}. However, because /l/ is not an obstruent, effects of *CCD/_{#, C} do not occur in candidates with the lateral [l] in coda position, as shown in (48a). Candidates (48b) and (48d) with [t^h] and [t˺] in coda position violate *CCD/_{#, C} twice. There are contrastive CDs at the glottis and [closed] CDs at the SL level. Although candidate (48c) violates *[closed]/_{#, C} at the SL level and the faithfulness constraint, IDENT-IO[G], it is a less optimal candidate than (48a). Candidate (48a) does not violate both *[closed]/_{#, C} at the SL level and the faithfulness constraint, IDENT-IO[G]. Therefore, candidate (48a) with [l] in coda position is selected as the most optimal candidate because it satisfies output constraints most optimally. Therefore, constraints and their hierarchy in (47) select the correct output form as the most optimal candidate when /l/ and /t^h/ compete for the coda position.

Based on (48), it is predicted that when a sonorant and an obstruent compete for the coda position and the TT articulator is used for both the sonorant and the obstruent, output forms preserve the sonorant in coda position. This is because both sonorant and obstruent satisfy TT_{Art}, and a candidate with the sonorant in coda position satisfies *CCD/_{#, C} most optimally, as shown in (48a). (37a) and (37d) illustrate that the prediction is correct. For example, in (37a) and (37d), /n, l/ compete with /c, s, t^h/ for the coda position and /n, l, c, s, t^h/ are specified with the TT articulator. Thus, output forms have either [n] or [l] in coda position because they satisfy constraints (47) most optimally.

[hal.t'a] from /halt^h+ta/ in (37d) appears to be an exception, compared to [tak˺] from /talk/ in (37b). [hal.t'a] from /halt^h+ta/ is not an exception, but can be analized as a result of satisfying constraints in (47) most optimally, as shown in (48). As the ranking of TT_{Art} above *CCD/_{#, C} correctly selects the output when two TT consonants form a consonant cluster as shown in (48), TT_{Art} is ranked below TB_{Art}/$Lips_{Art}$ and above *CCD/_{#, C} until proven otherwise.

I conclude that constraints and their hierarchy in (49) are responsible for CCCS in SK:

(49) *COMPLEX>>*Max-IO$_{seg}$>>TB_{Art}/$Lips_{Art}$>>TT_{Art}>> *CCD/_{#, C}>> IDENT-IO[G]

Before discussing KSK, (50) examines constraints and their hierarchy in (49). A /n/-/h/ cluster is evaluated in (50) to see if (49) selects correct output forms given other input consonant clusters.

(50) /anh+ta/ 'don't do'

/n/: GLO [critical], SL [open], Oral [open], TT [closed]
/h/: GLO [open], SL [open], Oral [open]

/anh+ta/	*COMP	Max-IO$_{seg}$	TB$_{Art}$/ Lips$_{Art}$	TT$_{Art}$	*CCD/_{#, C}				IDENT-IO[G]
					*[open]	*[mid]	*[critical]	*[closed]	
a. anh.t'a	**!				*(GLO) *(SL)				
☞b. an.t^{h}a		*							
c. an.t'a		*							*!(GLO)
d. at˺.t'a		*						*!(SL)	*(GLO) *(SL)
e. at.t'a		*				*! (GLO)		*(SL)	*(GLO) *(SL)
f. ah.ta		*		*!	*(GLO) *(SL)				
g. a.ta		**!							

In (50), because *COMPLEX is an undominated constraint, candidates that violate *COMPLEX, as in (50a), are not the most optimal. Candidate (50g) is not the most optimal candidate because it deletes two consonants in the input, violating Max-IO$_{seg}$ twice. (50b), (50c), (50d), (50e), and (50f) are tied in violation of Max-IO$_{seg}$. Candidate (50f), with [h] in coda position, satisfies TB$_{Art}$. There is no TB articulator in the input, which is preferred in consonant competition for the coda position in a consonant cluster. However, (50f) is excluded from being the most optimal candidate. In (50f), a consonant with the TT articulator in the input, namely /n/, is not maintained in competition between two consonants for the coda position. Instead, a consonant with the glottal articulator in the input, /h/, is preferred over a consonant with the TT articulator, /n/. (50b), (50c), (50d), and (50e) satisfy TT$_{Art}$ because the TT articulator in the input is maintained. However, (50e) is not the most optimal candidate because of violation of *[mid]/_{#, C} and *[closed]/_{#, C}. In addition, if [t] corresponds to /h/, [open] CDs at the glottis and at the SL level in the input are not maintained in [t]. Hence, (50e) violates the faithfulness constraint IDENT-IO[G] at the glottis and at the SL level. (50d) violates *[closed]/_{#, C} and the faithfulness constraint IDENT-IO[G]. [open] CDs at the glottis and at the SL level in the input are not maintained in (50d). Candidates (50b) and (50c) satisfy *CCD /_{#, C} most optimally because both (50b) and (50c) end with the sonorant [n]. However, constraints given in (49) select (50b) as the most optimal candidate. This is because the glottal gestures in the input are maintained in (50b) by coalescing /h/ and the following /t/ into [tʰ]. Therefore, constraints and their hierarchy in (49) select the output form correctly in other combinations of coda consonant clusters. Thus, in SK, constraints sensitive to oral articulators are ranked higher than constraints sensitive to CDs in the VT.

2.2.2.2 The gesture-based account of CCCS in Kyung-Sang Korean

Patterns of CCCS in KSK are not much different from those in SK except for the sonorant-stop clusters of (37b), as shown in (51):

(51) Patterns of CCCS in KSK and SK in sonorant-stop clusters

		KSK	SK	
	Input	Output	Output	
lp	/nəl̲p̲+ta/	[nəl.t'a]	[nəp̲˺.t'a]	'be wide + declarative'
lk	/il̲k̲+ta/	[il̲.t'a]	[ik̲˺.t'a]	'to read + declarative'
ltʰ	/hal̲t̲ʰ+ta/	[hal̲.t'a]	[hal̲.t'a]	'lick + declarative'

When competition for the coda position occurs in a sonorant-obstruent cluster in SK, a candidate with an unreleased stop in coda position is selected as the most optimal candidate if the articulators for obstruents are either the TB or the Lips. If the TT is the articulator for an obstruent in a sonorant-obstruent cluster, the sonorant appears in coda position, as shown in (48). However, sonorants appear in coda position as a result of satisfying constraints in (49) most optimally.

However, in KSK, when competition for the coda position occurs in a sonorant-obstruent cluster, a candidate ending with a sonorant is selected as the most optimal candidate regardless of articulators of obstruents. Recall that the sonorant in a sonorant-obstruent cluster is either /n/ or /l/, whose articulators are the TT in coda position.

When there are no constraints sensitive to oral articulators as in TB_{Art}, $Lips_{Art}$, and TT_{Art}, the most optimal candidates selected in sonorant-obstruent clusters have sonorants in coda position, as shown in (43) and (45), and as in KSK in (51). Therefore, one may speculate that there are no constraints such as TB_{Art}, $Lips_{Art}$, TT_{Art} in KSK. However, this speculation is not valid in OT because in OT, constraints are universal and language differences stem from different rankings of universal constraints. If language differences stem from different rankings of universal constraints, I assume that Korean also shares the same constraints regardless of dialect, and dialect differences stem from different rankings of the same constraints.

I argue that differences in CCCS patterns between SK and KSK stem from different rankings of the same constraints. In support of constraint rankings in KSK, recall (45). Before constraints sensitive to the articulators of consonants such as TB_{Art}, $Lips_{Art}$, and TT_{Art} were considered, the most optimal candidate selected was a candidate ending with a sonorant, regardless of the articulators of obstruents, as shown in (52a) below.

(52) Max-IO$_{seg}$ >> *CCD/_{#, C} >> IDENT-IO[G]

/ilkta/ 'to read'

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/k/: VT (occlusion), GLO [mid], SL [closed], Oral [closed], TB [closed]

/ilkta/	Max-IO$_{seg}$	*CCD/_{#, C}				IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]	
☞a. il.t'a (KSK)	*					
b. ik.t'a	*		*!(GLO)		*(SL)	
c. ik˺.t'a (SK)	*				*!(SL)	*(GLO)

When *CCD/_{#, C} is not dominated by TB$_{Art}$, Lips$_{Art}$ and TT$_{Art}$ as shown in (52), constraints in (52) select a candidate with the sonorant [l] in syllable-final position, (52a☞), as the most optimal candidate. In SK, candidate (52a) is not the actual output. (52c) is the actual output in SK. Constraints such as TB$_{Art}$, Lips$_{Art}$ and TT$_{Art}$, and their ranking above *CCD/_{#, C} are responsible for the selection of (52c) over (52a) in SK, as shown in (47).

Contrary to SK, (52a) is the actual output in KSK. Thus, effects of TB$_{Art}$, Lips$_{Art}$ and TT$_{Art}$ are minimal. Therefore, I suggest that TB$_{Art}$/Lips$_{Art}$ >> TT$_{Art}$ is ranked lower than *CCD/_{#, C} in KSK, as shown in (53). Based on the fact that when two consonants are in competition for the coda position, output forms always have a consonant with TB, Lip, or TT articulators in coda position regardless of gestural changes, I rank TB$_{Art}$/Lips$_{Art}$ >> TT$_{Art}$ above IDENT-IO[G] in KSK, as shown in (53).

A morpheme ending with a /l/-/k/ cluster is evaluated in (53).

(53) *COMPLEX>> Max-IO_{seg}>>*CCD/_{#, C}>>TB_{Art}/$Lips_{Art}$ >>TT_{Art} >>IDENT-IO[G]

/ilkta/ 'to read'

/l/: GLO[critical], SL[open], Oral [open], TB[open], TT[closed]
/k/: VT (occlusion), GLO[mid], SL[closed], Oral [closed], TB[closed]

/ilkta/	Max-IO_{seg}	*CCD/_{#, C}				TB_{Art}/ $Lips_{Art}$	TT_{Art}	IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]			
☞ a. il.t'a	*					*		
b. .ik.t'a	*		*!(GLO)		*(SL)		*	
c . ik˺.t'a	*				*!(SL)		*	*(GLO)

In (53), TB_{Art}/$Lips_{Art}$ and TT_{Art}, which are sensitive to oral articulators, are ranked lower than *CCD/_{#, C} and higher than IDENT-IO[G]. (53a), (53b) and (53c) are tied in Max-IO_{seg} because of segment deletion in order to fit into Korean syllable structure. Violation of Max-IO_{seg} is tolerated to a certain degree because Korean syllable structure allows at least one coda consonant. Thus candidates with [l], [k], or [k˺] in coda position are evaluated against *CCD/_{#, C} in (53). (53b) violates a relatively higher constraint within *CCD/_{#, C} because of the [mid] CD at the glottis. (53c) violates the lowest constraint within *CCD/_{#, C} but (53c) is less optimal than (53a). Candidates with sonorants in coda position always satisfy *CCD/_{#, C} most optimally because /n/ or /l/ is not an obstruent.

Note that *CCD/_{#, C} affects obstruents only and TB_{Art}, $Lips_{Art}$ and TT_{Art} affect sonorants and obstruents together. Therefore, when *CCD/_{#, C} is ranked higher than TB_{Art}/$Lips_{Art}$ >> TT_{Art}, as in (53), all candidates with obstruents in coda position, as in (53b) and (53c), are excluded from being the most optimal in a sonorant-obstruent cluster.

When $TB_{Art}/Lips_{Art}$ is evaluated, candidates with sonorants satisfy *CCD/_{#, C} most optimally, as shown in (53a). Therefore, in KSK, when sonorants and obstruents compete for the coda position, output forms always have either [l] or [n] in coda position because [l] and [n] satisfy *CCD/_{#, C}. Candidates (53b) and (53c) satisfy TB_{Art} but satisfaction of *CCD/_{#, C} takes precedence over satisfaction of TB_{Art}, and $Lips_{Art}$ in KSK.

However, when /l/ and /m/ compete for the coda position, candidates with [l] or [m] in coda position satisfy *CCD/_{#, C} most optimally, regardless of the ranking of *CCD/_{#, C} in the constraint hierarchy. Therefore, in KSK and SK, constraints TB_{Art}, $Lips_{Art}$ and TT_{Art}, and the ranking of $TB_{Art}/Lips_{Art}$ >> TT_{Art}, play crucial roles in selecting the output, as shown in (54).

(54) /sa<u>lm</u>/ 'life'

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/m/: GLO [critical], SL [open], Oral [open], Lips [closed]

/sa<u>lm</u>/	Max-IO_{seg}	*CCD/_{#, C}				TB_{Art}/$Lips_{Art}$	TT_{Art}	IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]			
☞ a. sa<u>m</u> (KSK, SK)	*						*	
b. sa<u>l</u>	*					*!		

When /l/ and /m/ compete for the coda position, KSK and SK have output with [m]. Candidates with [l] or [m] in coda position tie in satisfaction of the constraint

$*CCD/\_\{\#, C\}$. Therefore, as shown above, in a sonorant-sonorant cluster the most optimal candidate is selected by the constraints $TB_{Art}/Lips_{Art}$ in both KSK and SK.

A previous study (Lee, 1999) claimed that the preference of nasals over the lateral /l/ is responsible for [sam] from /salm/ in a sonorant-sonorant cluster. However, there are no other sonorant-sonorant clusters other than the /l/-/m/ cluster in Korean. Therefore, there is no evidence for the preference of nasals over the lateral /l/ in a sonorant-sonorant cluster. However, there is abundant evidence for the preference of $TB_{Art}/Lips_{Art}$ over TT_{Art} in both KSK and SK.

(55) examines a morpheme ending with a /p/-/s/ cluster, an obstruent-obstruent cluster, to see whether the constraint hierarchy suggested in (53) for KSK selects correct output forms.

(55) /kaps/: 'price'

/p/: GLO [mid], SL [closed], Oral [closed], Lips [closed]
/s/: GLO [mid], SL [critical], Oral [critical], TT [critical]

/kaps/	Max-IO_{seg}	*CCD/_{#, C}				TB_{Art}/ $Lips_{Art}$	TT_{Art}	IDENT-IO[G]
		*[open]	*[mid]	*[critical]	*[closed]			
a. kap	*		*!(GLO)		*(SL)		*	
☞ b. .kap˺	*				*(SL)		*	*(GLO)
c. kas˺	*		*(GLO)	*!(SL)		*		
d. kat˺	*				*(SL)	*!		*TTCD *(GLO)

(55a) and (55c) are not the most optimal candidates because they violate relatively higher ranking constraints within *CCD/_{#. C}. (55b) and (55d) also violate [closed]/_{#, C}. If [t˺] in (55d) corresponds to /s/ in the input, it violates IDENT-IO[G] because of the [closed] CD of TT gestures from the [critical] CD of TT gestures for /s/.

However, (55b) is preferred over (55d) because (55b) has the lip articulator in the coda position, instead of the TT articulator (55d). Thus the constraints and their hierarchy suggested in (53) for KSK correctly select the output given different consonant clusters. Therefore, the constraint ranking *CCD/_{#, C} >> TB_{Art}/$Lips_{Art}$ >> TT_{Art} is responsible for patterns of CCCS in KSK.

2.2.3 Influences of non-surfaced consonants

In this section, I discuss two points with respect to consonants that failed in competition for the coda position in a consonant cluster. First, when C_{n-1} in $V1C_{n-2}C_{n-1}C_nV2$ does not surface in the output due to Korean syllable structure or phonetic implementational conditions in a given context, gestures of non-surfaced C_{n-1} influence phonetic realizations of C_n, as shown in (56).

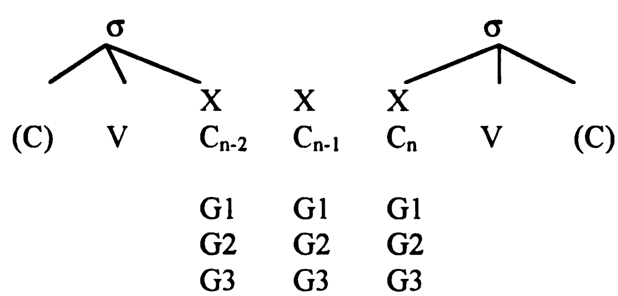
(56) Phonetic realizations of C_n from $V1C_{n-2}C_{n-1}C_nV2$

a. Tensification	/il<u>k</u> + ta/	[ilt'a]	'to read'(KSK)
	/ɨl<u>p^h</u> + ta/	[ɨl<u>t</u>'a]	'to recite' (KSK)
	/nəl<u>p</u> + ta/	[nəl<u>t</u>'a]	'be wide' (KSK)
b. Aspiration	/ol<u>h</u> + ta/	[ol<u>t</u>^{h}a]	' to be right'
	/an<u>h</u> + ta/	[an<u>t</u>^{h}o]	'don't do'
	/an<u>h</u> + ta/	[an<u>t</u>^{h}a]	'not do + declarative'
c.	/man<u>h</u> + so/	[man<u>s</u>'o]	'be plenty + statement'
	/ol<u>h</u> + so/	[ol<u>s</u>'o]	'be right + statement'

The comparison of (56a) to (56b) illustrates that phonetic realizations of C_n are influenced by gestures belonging to non-surfaced C_{n-1}. In (56a), when gestures of non-surfaced consonants are specified with occlusion (/k, p^h, p/), C_n is tensed in the output, as in [ilt'a] from /ilk + ta/ 'to read'. In (56b), when gestures of non-surfaced consonants are specified with the glottal fricative /h/, C_n is aspirated in the output, as in [olt^{h}a] from /olh + ta/ 'to be right'.

The gestural interactions between non-surfaced C_{n-1} and C_n occur while maintaining Korean syllable structure, as shown in (57).

(57)



I suggest that Korean CCCS be viewed as the overlapping of timing as assumed in Browman and Goldstein (1989 and 1990a), Byrd (1996) and Cho (1998a and 1998b), instead of as deletion the entire timing and gestures associated with C_{n-1}. The overlapping of timing does not incur doubly linked timing slots in onset and coda positions, thus, satisfying *COMPLEX (*σ[XX__] or *σ[__XX]). Although C_{n-1} in the output does not occupy a timing slot, some gestures associated with C_{n-1} are reassociated to C_n, resulting in tensification of C_n, as in [halt'a] from /halt^{h}ta/ or aspiration of C_n, as in [ant^{h}a] from /anh+ta/. Which gestures of C_{n-1} can be reassociated to C_n follows phasing principles of gestures that will be discussed in detail in chapter 4 (see the last page of section 1.2.4.2 for a brief summary of phasing principles).

Data in (56a) presents another argument for the influence of gestures associated with non-surfaced C_{n-1}. For example, in Korean verbal morphology, lax stops are tensed after obstruents and nasals, as in [ipt̲'a] from /ip + ta/ 'to wear' and [ant̲'a] from /an + ta/ 'to hug'. Lax stops are not tensed after the lateral /l/, as in [kalda] from /kal +ta/ 'to cultivate'. Instead, lax stops are voiced between two [+voice] features, as in [kald̲a] from /kal + ta/ 'to cultivate'. However, the lax stop /t/ is tensed in the environment where the lax stop /t/ should be voiced in (56a). If we assume influences of non-surfaced consonant gestures on /t/ in (56a), the tense [t'] after [l] in (56a) is not an exception to obstruent tensification in Korean Verbal Morphology. /t/ is tensed in the output because of non-surfaced consonant gestures related to /k, p^h/.

Second, gestures of C_n themselves play a role in phonetic realizations of C_n in $V1C_{n-2}C_{n-1}C_nV2$. In other words, gestures of C_n and gestures of non-surfaced consonants, namely C_{n-1}, interact together in forming phonetic realizations of C_n.

For example, when the glottal fricative /h/ is followed by lax stops, lax stops are aspirated, as in [ol.k^ho] from /olh+ko/. However, in (56c), when the glottal fricative /h/ is followed by /s/, /s/ is tensed, as in [ol.s'o] from /olhso/, instead of aspirated, as in (56b). The reason that /s/ is not aspirated after /h/ as in (56b) stems from gestural characteristics of /s/, which forms a natural class with /h/ as frication at the VT. As mentioned in the analysis of fricatives in coda position, having the [critical] CD of TT gestures is one of the important gestures for /s/. Considering that targeted gestures of onset consonants are more likely to be maintained than targeted gestures of coda consonants (Byrd 1996 and

Cho 1998b), gestures of /s/ are likely to be maintained in (56c). However, the large amount of airflow escaping from the glottis for /h/ increases pharyngeal pressure behind the [critical] CD of TT gestures and increases turbulent frication, resulting in tense /s'/ after /h/. Therefore, gestures of C_n and gestures of non-surfaced C_{n-1} interact together in phonetic realizations of C_n.

According to gestural characteristics of C_{n-1}, phonetic realizations of C_n are divided into two patterns: tensification and aspiration of C_n:

(58)	Tensification				Aspiration	
	a. /ha$\underline{lt^h}$ta/ →[ha$\underline{l}$.$\underline{t}$'a]		b. /a$\underline{nc}$ta/ → [a$\underline{n}$.$\underline{t}$'a]		c. /a$\underline{nh}$ta/ → [a$\underline{n}$.$\underline{t}^h$a]	
	C_{n-1}	C_n	C_{n-1}	C_n	C_{n-1}	C_n
	/t^h, p^h, p /	/t/	/c, s/	/t/	/h/	/t/
SL	[closed]	[closed]	[critical]	[closed]	[open]	[closed]
Oral	[closed]	[closed]	[critical]	[closed]	[open]	[closed]

Tensification of C_n occurs when C_{n-1} does not have the [open] CD at both the SL and Oral levels, as shown in (58a) and (58b). The aspiration of C_n occurs when C_{n-1} has the [open] CD at the SL and Oral levels, as shown in (58c). Therefore, I conclude that there are influences from gestural characteristics of non-surfaced C_{n-1} to C_n. In addition, phonetic realizations of C_n depend on gestural characteristics of C_n, as shown in the comparison of (57a) and (57c), and gestural characteristics of C_{n-1}, as shown in (58).

2.2.4 Summary

In the analysis of this study, I have first shown that there is a close relationship between CN and CCCS. Primary constraints that are responsible for CN such as *CCD/_{#, C} and IDENT-IO[G], and their basic rankings (*[open]>>*[mid] >>*[critical] >>*[closed]>>...>> IDENT-IO[G]) are still maintained in CCCS of SK and KSK. In addition, *CCD/_{#, C} and IDENT-IO[G] also play a role in CCCS of SK and KSK, especially when two obstruents compete for the coda position, as shown in (41) and (55).

Second, the ranking of $\mathrm{TB}_{\mathrm{Art}}$/$\mathrm{Lips}_{\mathrm{Art}}$ >> $\mathrm{TT}_{\mathrm{Art}}$ with respect to *CCD/_{#. C} is responsible for different patterns in CCCS between SK and KSK, as shown in (47) and (53). Therefore, there is no need for separate rules or constraints for SK and KSK. In SK, constraints sensitive to articulators such as $\mathrm{TB}_{\mathrm{Art}}$, $\mathrm{Lips}_{\mathrm{Art}}$, $\mathrm{TT}_{\mathrm{Art}}$ are ranked higher than the constraint *CCD/_{#. C}, which is sensitive to manner of articulation, as shown in (47). In KSK, constraints sensitive to articulators are ranked lower than the constraint *CCD/_{#. C}, as shown in (53).

Third, I have demonstrated influences of non-surfaced consonants on the following consonants and predicted phonetic realizations of the following consonants based on gestural characteristics of non-surfaced consonants, as shown in (58).

Fourth, in (48), output forms that appear to be exceptions in CCCS are found not to be exceptional. For example, in SK, [ha<u>l</u>.t'a] from /ha<u>lt</u>ʰ+ta/ (37d) appears to be an exception to [i<u>k</u>˺.t'a] from /i<u>lk</u>+ta/ and [nə<u>p</u>˺.t'a] from /nə<u>lp</u>+ta/ (37b). In the former, the lateral /l/ surfaces in the output. In the latter examples, the lateral /l/ does not surface in the output. Traditionally, (37d) is considered as an exception but (48) illustrates that (37d) results from satisfying output constraints most optimally. Therefore, in this study, CCCS in Korean is explained in a systematic and unified way, regardless of dialect.

Therefore, I conclude that CN and CCCS are related because both phonological phenomena are motivated to fit into Korean syllable structure and phonetic implementational conditions in a given context.

Previous analyses (Ahn 1985, Cho 1990, and Kim-Renaud 1974) fail to connect CN and CCCS and to explain dialect differences between SK and KSK in a systematic and unified way. Separate rules or principles are suggested for CN and CCCS. For example, Ahn (1985) proposes CN and CCCS as follows:

(59) A. CN (Ahn 1985:171)

σ

C

$$\begin{bmatrix}+\text{obstruent}\\ \alpha\ \text{coronal}\end{bmatrix} \rightarrow \begin{bmatrix}-\text{tense}\\ -\text{aspirated}\\ \alpha\ \text{coronal}\end{bmatrix}$$

B. CCCS

Ahn (1985:168)

a. [-continuant, -coronal] > [+lateral]

b. $C_1 > C_2$ (a) is applied before (b)

CN in (59A) is proposed to prevent tense and aspirated obstruents from occurring in coda position but obstruents maintain their place of articulation by maintaining [+/-coronal]. However, (59A) cannot explain non-occurrence of the affricate [c] in coda position because /c/ is specified with [+coronal, -anterior]. According to (59A), the affricate [c] is allowed in coda position.

In (59B), preference laws are proposed for CCCS. Non-continuant and non-coronal segments such as [p, k, m] are preferred over the lateral /l/ because of (59Ba), when two consonants compete for the coda position. Otherwise, the first of the two consonants appears in coda position according to (59Bb). However, there is no connection between CN and CCCS in Ahn's (1985) proposals although both (59A) and (59B) are motivated to fit into Korean syllable structure.

Chapter 3 Post-Obstruent Tensification

3. 1. Introduction

Before discussing Post-Obstruent Tensification (POT), the term 'Obstruent Tensification' (ObsT) is first introduced for subsequent discussions on the phonetic realization of O_2 in the sequences $V_1O_1O_2V_2$ (O: obstruents), $V_1NO_2V_2$ (N: nasals), and $V_1LO_2V_2$ (L: the lateral /l/). In this study, ObsT refers to a phonological phenomena in Korean in which a syllable initial lax obstruent /p, t, k, s, c/ is tensed after an obstruent, a nasal, or the lateral /l/, resulting in [p', t', k', s', c'] respectively. ObsT is subdivided into POT, Post-Nasal Tensification (PNT), and Post-Lateral Tensification (PLT) according to the consonant before the lax obstruent. Instead of 'Obstruent Tensification', often the term 'Obstruent Glottalization' is used in the Korean linguistics literature. In this study, the term ObsT is used because the term 'Obstruent Glottalization' is likely to be associated with glottal gestures only. However, ObsT is characterized by minimal glottal opening, long oral-closure duration, heightened subglottal pressure, stiffness, and muscular tension of the vocal tract walls and the pharynx (Kim-Renaud 1974, Lee 1994 and Rhee 1997).

This chapter mainly investigates cases in which a lax obstruent /p, t, k, s, c/ is tensed to [p', t', k', s', c'] respectively after an obstruent, as shown in (1).

(1) a. /i$\underline{k}\underline{s}$al/$_{noun}$ ‘funny act or sayings’ → [i$\underline{k}$˺.$\underline{s}$’al]

b. /p^{h}u$\underline{t}$/$_{prefix}$ + /$\underline{s}$akwa/$_{noun}$ → [p^{h}u$\underline{t}$˺.$\underline{s}$’a.kwa]
‘unripe’ ‘apple’ ‘unripe apple’

/co$\underline{h}$/$_{verb\ stem}$ + /$\underline{s}$o/$_{declarative\ marker}$ → [co$\underline{t}$˺.$\underline{s}$’o]
‘be good’ ‘It is good’

c. /sa$\underline{p}$/$_{noun}$ + /$\underline{c}$il/$_{bound\ noun\ morpheme}$ → [sa$\underline{p}$˺.$\underline{c}$’il]
‘shovel’ ‘repeated action of something’ ‘shoveling’

d. /ku$\underline{k}$/$_{noun}$ +/t or ʔ/$_{sub\text{-}compound\ morpheme}$ + /$\underline{p}$ap/$_{noun}$→ [ku$\underline{k}$˺.$\underline{p}$’ap˺]
‘soup’ ‘rice’ ‘a kind of food’

POT refers to tensification of lax obstruents after obstruents, as in (1). POT appears within non-derived words, as in (1a), within words with bound morphemes, as in (1b) and (1c), and across two nouns that form sub-compound nouns, as in (1d).

Whenever two nouns form sub-compound nouns as in (2a), [d] or [t˺] appears between two nouns in the output.

(2) a. /u/ ‘upper’ + /əlin/ ‘elders’ → [u$\underline{d}$ərin] ‘seniors or elders’
/c^{h}o/ ‘candle’ + /pul/ ‘fire’ → [c^{h}o$\underline{t}$˺.$\underline{p}$’ul] ‘candle light’
/ko/ ‘nose’ + /tiŋ/ ‘bridege’ → [kot˺ t’iŋ] ‘nose bridge’
b. /pom/ ‘spring’ + /pi/ ‘rain’ → [pom.p’i] ‘spring rain’

In (2a) and (2b), POT occurs obligatorily even though the first nouns end with a vowel or a nasal. Therefore, it has been assumed that there is a lexical sub-compound morpheme, known as [t] or [ʔ], between two nouns that forms sub-compound nouns (Sohn 1987 and Kim-Renaud 1974). Whether the sub-compound morpheme is [t] or [ʔ]

is not relevant to this study. What is important in this study is that the characteristic of the sub-compound morpheme is occlusion, which is specified with either the [closed] CD at the glottis or the [closed] CD at the SL level.

The Korean linguistic literature (Jun 1995 and Lee 1996) suggests that ObsT occurs within an accentual phrase but not across accentual phrases, as shown in (3a).

(3) a. /cʰoka/$_{\text{noun}}$ + /cip̟/$_{\text{noun}}$ + /k̲ocʰi/$_{\text{verb stem}}$ +/ki/
'straw' 'house' 'to fix' nominal suffix
→ [cʰogacip̟˺]$_{\text{Accentual Phrase}}$ [k̲ocʰigi]$_{\text{Accentual Phrase}}$ 'to fix a straw thatched roof'

b. /cip̟/$_{\text{noun}}$ 'house'+ /c̲ip/$_{\text{noun}}$ 'house' → [cip̟˺. c̲ip˺] 'every house'
/kak̲˺/$_{\text{noun}}$ 'each'+ /k̲ak˺/$_{\text{noun}}$ 'each' → [kak̲˺. k̲ak˺] 'each person'
/ap̟ʰ /$_{\text{noun}}$ 'front' /t̟wiɛ/$_{\text{noun}}$ 'back' → [ap̟˺. t̟wi] 'front and back'

In (3a), the lax stop [k] in the third word is not tensed after the unreleased stop [p˺], as shown in [cʰogacip̟˺][k̲ocʰigi]. This is because [k] in [k̲ocʰigi] is not located within the same accentual phrase with [p˺] in [cʰogacip̟˺].

In addition, ObsT does not occur when two nouns form co-compound nouns, as shown in (3b). The [c, k, t] in the second word appears without being tensed after the unreleased stop [p˺, k˺, p˺] respectively. Lax obstruents [c, k, t] are in a condition where POT occurs but they are not tensed in (3b) after unreleased stops [p˺, k˺, p˺]. Thus, POT is under-applied in (3b).

Kang (1992) and Sohn (1987) attribute the under-application of POT in (3b) to the different morpho-syntactic structures of sub-compound and co-compound nouns, as shown in (4).

(4) a. sub-compound nouns (1d) b. co-compound nouns (3b)

NP

N N
modifier head
/c^ho/ /t/ /pul/
'candle' 'fire'

b. NP

N N
head head
/cip/ (and) /cip/
'house' 'house'

(4a) and (4b) represent morpho-syntactic structures of the sub-compound noun (1d) and the co-compound noun (3b) respectively. When the sub-compound morpheme /t/ appears before a noun beginning with a lax obstruent as in (4a), the lax obstruent in the second noun is tensed due to the sub-compound morpheme /t/, as shown in [$c^ho\underline{t}^{\urcorner}.\underline{p}$'ul] 'candle light' from /c^ho/ 'candle' + /t/$_{\text{Sub-compound morpheme}}$ +/pul/ 'fire', even though the first noun does not have /t/. The morpho-syntactic structure of co-compound noun (4b) has an invisible 'and' branch, as represented by a broken line, which does not cause tensification.

Data (5) shows cases in which POT does not occur.

(5)	a.	/naktʰa/$_{noun}$			→	[nak̚.tʰa] 'camel'
		/təs/$_{prefix}$	+	/pʰan/$_{noun}$	→	[tət̚.pʰan]
		'added'		'layer'		'added layer'
	b.	/t'ək/$_{noun}$	+	/s'al/$_{noun}$	→	[t'ək̚.s'al]
		'rice cake'		'pattern'		'a mold for rice cake'
		/pak/$_{noun}$	+	/s'i/$_{noun}$	→	[pak̚.s'i]
		'pumpkin'		'seed'		'seed of pumpkin'

(5a) shows that aspirate obstruents are not tensed after unreleased stops (S̚). It is not clear in (5b) whether tense obstruents are tensed after unreleased stops (S̚) or not.

A comparison of (6a) to (6b) indicates that unreleased stops [S̚] in syllable-final position trigger tensification of the following lax obstruents.

(6)	a.	/maktæ/	→ [mak̚.t'æ]	'stick'
		/mac+saŋ/	→ [mat̚.s'aŋ]	'a kind of table setting for two people'
	b.	/pintæ/	→ [pin.dæ]	'bedbug'
		/kɨmpaŋ/	→ [kɨm.baŋ]	'soon'
	c.	/polki/	→ [pol.gi]	'hip'

In (6a), /t/ and /s/ are tensed to [t'] and [s'] after unreleased stops [k̚] and [t̚] respectively. In general, as shown in (6b) and (6c), /t/, /p/, and /k/ are not tensed after sonorants such as nasals or the lateral /l/, except for two cases shown in (7) and (8). Instead, /t/, /p/ and /k/ are voiced between two [+voice] sounds, resulting in [d], [b] and [g] respectively. Thus, having an unreleased stop in syllable-final position is a critical condition for ObsT.

However, there are two cases in which obstruents are tensed after nasals or the lateral /l/.

(7) a. /us/$_{\text{verb stem}}$ + /ki/[1]$_{\text{gerundial suffix}}$ → [ut̚.k̲'i] 'laughing'
/us/$_{\text{verb stem}}$ + /ta/$_{\text{declarative marker}}$ → [ut̚.t̲'a] 'laugh'

b. /an̲/$_{\text{verb stem}}$ + /k̲i/$_{\text{gerundial suffix}}$ → [an̲.k̲'i] 'to hug'
/an̲/$_{\text{verb stem}}$ + /k̲o/$_{\text{conjunction marker}}$ → [an̲.k̲'o] 'to hug and'
/an̲/$_{\text{verb stem}}$ + /c̲a/$_{\text{verb ending for indirect command}}$ → [an̲ c̲'a] 'let's hug'
/an̲/$_{\text{verb stem}}$ + /s̲o/$_{\text{verb ending for indirect command}}$ → [an̲.s̲'a] 'please hug'

c. /mul̲/$_{\text{verb stem}}$ + /k̲i/$_{\text{noun derivational suffix}}$ → [mul̲.gi] 'biting'
/nol̲/$_{\text{verb stem}}$ + /t̲a/$_{\text{declarative marker}}$ → [nol̲.d̲a] 'play'

First, obstruents are tensed after nasals if nasals end verb stems, as shown in (7b). (7c) indicates that within the verbal morphology, obstruents are not tensed after the lateral /l/. Thus, in the verbal morphology, triggers of ObsT are obstruents, which are unreleased in syllable-final position, and nasals, as shown in (7a) and (7b) respectively.

Second, in Sino-Korean words, /t, c, s/ after the lateral /l/ are tensed, as shown in (8).

(8) Sino-Korean words

a.	/kal̲c̲iŋ/	→	[kal̲.c̲'iŋ]	'thirsty'
	/pal̲t̲al/	→	[pal̲.t̲'al]	'development'
	/il̲s̲a ŋ /	→	[il̲.s̲'aŋ]	'everyday'
b.	/mal̲k̲i/	→	[mal̲.g̲i]	'the end period'
	/pul̲p̲ok/	→	[pul̲.b̲ok]	'disobedience'

[1] If /ki/ is a passive suffix, instead of a gerundial suffix, [k] is not tensed after nasals within the verbal morphology, as shown in [an.g̲i.ta] from /an+ki+ta/.

In data (8), /t, s, c/ are tensed after the lateral /l/ in Sino-Korean words, presumably because /t, s, c/ share the tongue tip articulator with /l/. The phonetic motivations behind PNT in (7b) and PLT in (8a) are discussed in detail in chapter 4.

3.2 The gesture-based account of Post-Obstruent Tensification

3.2.1 Introduction

In section 2.1, I have shown that CN in Korean is motivated by the lack of contrastive CD gestures, which distinguish different types of obstruents in syllable-final position. For example, three types of Korean stops are neutralized in syllable-final position due to the lack of contrastive glottal gestures.

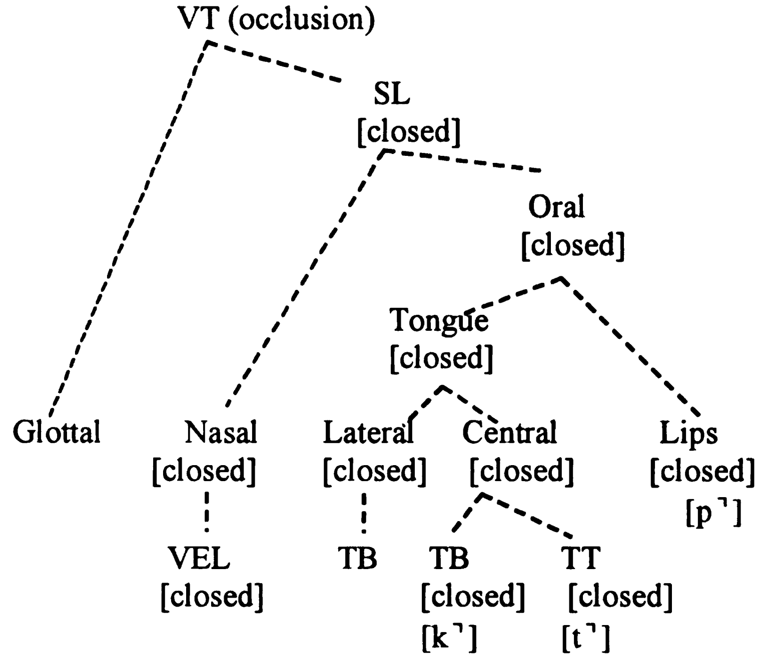
This section argues for the following three points: First, occurrence of ObsT is predictable based on CDs of C_2 in the sequence of $V_1O_1C_2V_2$ (O: obstruents hereafter). Second, contrary to CN, POT results from enriched tense gestures at the oral-closure release of O_2 in the sequence of $V_1O_1O_2V_2$, where O_2 is a lax obstruent. Third, there is a close relationship between distribution of tense gestures in the sequence of $V_1C_1C_2V_2$ and morphological conditions of ObsT.

3.2.2 Occurrence of Obstruent Tensification

The gesture-based account of POT begins with what gestural characteristics of O_1 are in the sequence of $V_1O_1O_2V_2$. As will be illustrated in section 3.2.3, ObsT is sensitive to CDs at the SL level for C_1 and C_2 in the sequence of VC_1C_2V.

In the discussion of CN, the output CDH for stops, affricates, and fricatives in syllable-final position is represented as in (9).

(9) The output CDH for stops, affricates, and fricatives in _{#, C}.



O_1 in $V_1O_1O_2V_2$ is always an unreleased stop, which is characterized by [closed] CDs at the SL and all levels below the SL level, as shown in (9). In addition, recall that the CD of glottal gestures of an unreleased stop is as narrow as that of voicing by default (Browman and Goldstein 1989). Sawashima et al. (1980) also characterize unreleased stops in word-final position as having a small degree of glottal opening.

The following table displays what happens to C_2 after an unreleased stop when C_2 ranges from stop to the lateral /l/ in the sequence of $V_1O_1C_2V_2$.

(10) Phonetic realizations of C2 after unreleased stops.

O1	C2				
Output	Input				Output
	GLO	SL	ORAL	**Stops**	
[closed]$_{SL}$ [closed]$_{Oral}$	[mid]	[closed]	[closed]	lax	**C2 Tensification**
	[closed]	[closed]	[closed]	tense	tense
	[open]	[closed]	[closed]	aspirate	aspirate
				Affricates	
	[mid]	[closed]/ [critical]	[closed]/ [critical]	lax	**C2 Tensification**
	[closed]	[closed]/ [critical]	[closed]/ [critical]	tense	tense
	[open]	[closed]/ [critical]	[closed]/ [critical]	aspirate	aspirate
				Fricatives	
	[mid]	[critical]	[critical]	lax	**C2 Tensification**
	[closed]	[critical]	[critical]	tense	tense
	[open]	[open]	[open]	/h/	**C1 Aspiration**
	[critical]	[open]	[closed]	**nasals**	**C1 Nasalization**
	[critical]	[open]	[open]	/l/	**C1 Nasalization**

(10) illustrates two important points about POT in Korean. First, it reveals a clear gestural condition for POT. In VO1C2V2, when C2 does not have the [open] CD at the SL level, C2 participates in POT. When C2 has the [open] CD at the SL level (shaded areas in (10)), C2 does not participate in POT except for certain cases that will be discussed later in chapter 4. Therefore, POT is sensitive to CDs at the SL level, which are predicted from CDs of the nasal and oral levels.

Based on (10), I suggest that one of the most important gestural conditions for tensification of lax-C2 is that the CD of C2 should not be the [open] CD at the SL level. Therefore, ObsT is a phonological phenomenon captured at the SL level, as illustrated in (11).

(11) Tensification of C2 | O1 Nasalization

	a.			b.	
	O1	C2		O1	C2
Input	/ip	ku/ 'entrance'		/ak	ma/ 'devil'
SL	closed	**closed**		closed	**open**
Oral	closed	closed		closed	closed
Output	[ip	k'u]		[aŋ	ma]

In (11a) and (11b), O1s have identical CDs at the SL and oral levels. However, (11a) and (11b) differ from each other at the SL levels. C2 of (11a) has the [closed] CD at the SL level and C2 of (11b) has the [open] CD at the SL level. When the CD of C2 is [open] at the SL level, O1 is assimilated to C2 according to gestural characteristics of C2, as shown in (11b). When CD of C2 is [closed] at the SL level, C2 is tensed. Therefore, in Korean, ObsT occurs when CD of C2 is not [open] at the SL level, as shown in (10).

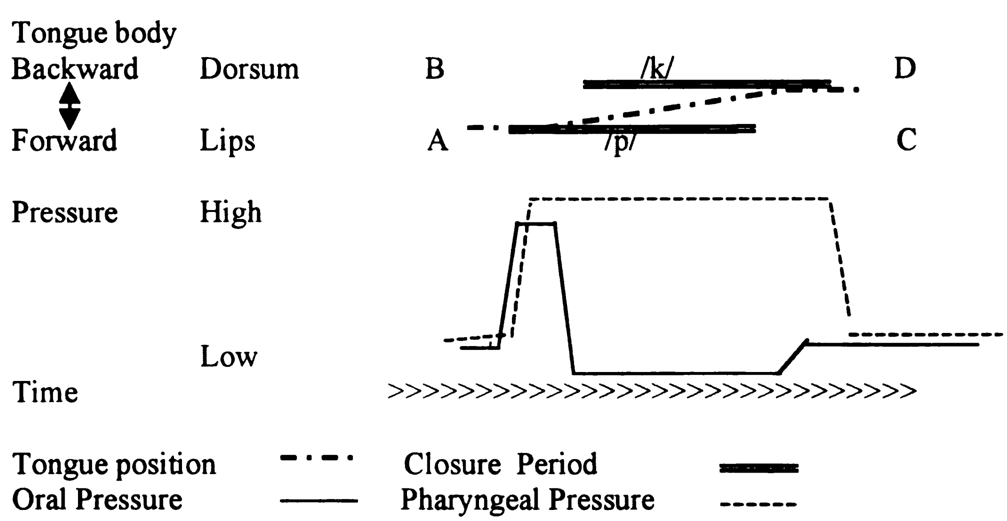
The second important point that (10) displays about POT is that only lax-O2s are tensed in the sequence of VO1O2V2. Therefore, lax and tense O2s are neutralized to tense obstruents while aspirate O2s are maintained. I suggest that neutralization of lax and tense O2s in the sequence of VO1O2V2 is closely associated with distribution of tense gestures at the oral-closure release of O2.

3. 2. 3 Distribution of tense gestures and Post-Obstruent Tensification

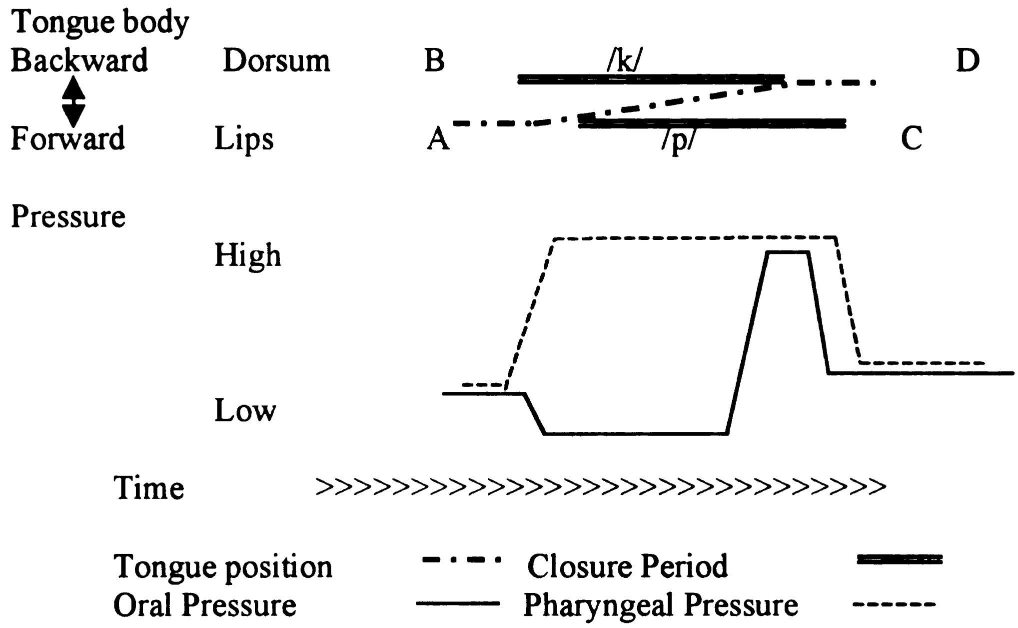
As the condition for occurrence of ObsT has been introduced, it is now necessary to find out what tense gestures are distributed in the sequence of $V_1O_1O_2V_2$, where O_2 is a lax obstruent.

To further understand POT, it would be helpful to look at some experimental studies that examine the sequence of $V_1O_1O_2V_2$ in Korean. Silverman and Jun (1994) measure oral flow, SL pressure, and pharyngeal pressure in order to investigate co-articulation effects in the sequence of $V_1O_1O_2V_2$. Their study provides some answers to what happens to O_1O_2 in the sequence of $V_1O_1O_2V_2$, as shown in (12a) and (12b).

(12) a. /ipku/ (Silverman and Jun 1994:215)



b. /ikpu/ (Silverman and Jun 1994:217)



In (12a), point A represents the beginning of the oral closure for /p/. Point B represents the beginning of the oral closure for /k/ in /ipku/. As the closure gesture of /p/ starts, the oral pressure and the pharyngeal pressure are increased. After the [closed] CD of the TB for /k/ is formed, the increased pharyngeal pressure is still maintained because of the [closed] CD of the TB. Contrary to the increased pharyngeal pressure, the oral pressure is rarefied after the [closed] CD of the TB for /k/, due to the oral cavity expansion. The TB is moved from the front vowel /i/ to the back vowel /u/ while keeping [closed] gestures for /p/ and /k/.

In (12b), as the [closed] gesture of /k/ starts, the pharyngeal pressure is increased but the oral pressure is rarefied due to the expanded oral cavity. After the [closed] CD of the lips for /p/ is formed, the oral pressure stays low until the end of the oral burst for /k/. However, the pharyngeal pressure is sustained because of the [closed] CD of the lips for /p/.

Note that the increased pharyngeal pressure is maintained for an extensive period as long as the oral closure exists in the oral cavity, as shown in both (12a) and (12b). However, the oral pressure varies according to oral gestures, as shown in the comparison of (12a) and (12b).

(12) illustrates two important points relevant to POT. The first important point is the long closure duration between two vowels in $V_1O_1O_2V_2$, as shown in the first diagrams in (12a) and (12b). I assume that long closure duration between two vowels in $V_1O_1O_2V_2$ acoustically and articulatorily promote tensification of lax-O_2s.

According to Han (1996), closure duration is a primary perceptual cue that distinguishes tense consonants from lax consonants between two vowels. In addition, Oh's study (1998) illustrates that closure duration of tense obstruents between two vowels is always longer than that of lax consonants regardless of speech style, as shown in (13). Oh's observation is also consistent with Kim (1965 and 1970).

(13) The overall closure duration of consonant clusters between two vowels.

(Oh 1998: 319 and 320)

Careful Speech		**Normal Speech**
$V_1C_1V_2$	shortest↑	$V_1C_1V_2$
$V_1C'_1V_2$		$V_1C'_1V_2$ / $V_1C_1C'_2V_2$
$V_1RC'_2V_2$ / $V_1C_1C'_2V_2$		
$V_1X_1C'_2V_2$/	longest↓	$V_1RC'_2V_2$ / $V_1X_1C'_2V_2$

R=sonorant. C_1 and X_1= homorganic and non-homorganic with C'_2 respectively.

Note that C's in $V_1RC'_2V_2$, $V_1C_1C'_2V_2$, and $V_1X_1C'_2V_2$ are from lax or tense obstruents. Closure durations of consonant clusters in $V_1RC'_2V_2$, $V_1C_1C'_2V_2$, and $V_1X_1C'_2V_2$ are either longer than that of $V_1C'_1V_2$ or are similar to that of $V_1C'_1V_2$

regardless of styles of speech. Therefore, I assume that lax-O2s in the sequence of V1O1O2V2 are tensed because one of important gestures of tense obstruents, namely long closure duration, is distributed between two vowels.

The second important point that (12) illustrates related to POT is the increased pharyngeal pressure between two vowels in the sequence of V1O1O2V2. The increased pharyngeal pressure is maintained in (12) until the end of the oral-closure release of O2 in V1O1O2V2, regardless of O1and O2's places of articulation. The heightened pharyngeal pressure, which is maintained for a long period, is closely associated with stiffness in the vocal tract, according to Dart (1987).

Dart (1987) states the heightened vocal tract pressure results from the stiffened vocal tract wall tension, as shown in (14). Namely, as the vocal tract tension is increased, the vocal tract pressure is increased as well.

(14) From Dart (1984:143)

> The pressure increase can be understood as a result of stiffening the walls, which is effectively the same as decreasing supra-glottal cavity volume, since it calls for a reduction in the possibility of passive vocal tract expansion. This decrease in elasticity of the cavity wall also contributes to a lower peak flow by decreasing the amount of elastic recoil of the walls and thereby slowing down the initial flow velocity at release.

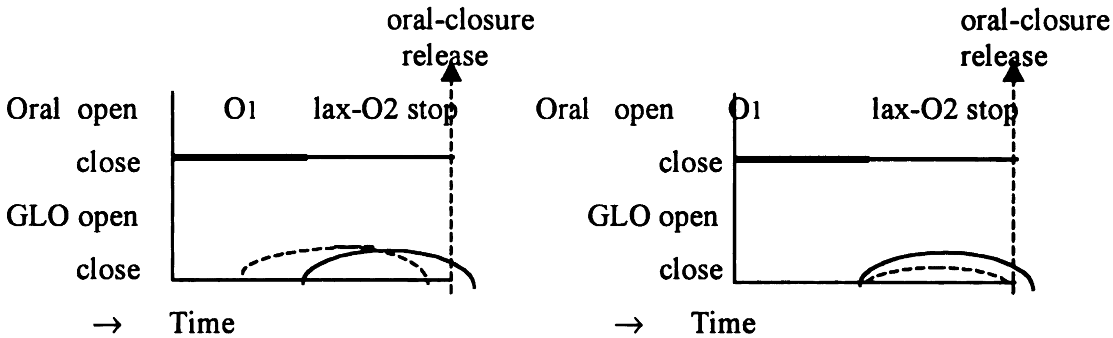
According to Dart (1987), Kim (1965, 1970) and Hardcastle (1973), the heightened pharyngeal pressure and the greater muscular tension in the vocal tract wall are important properties of tense obstruents. Therefore, I assume that the heightened pharyngeal pressure and stiffness in the vocal tract during oral closure of O1O2 in V1O1O2V2 are also responsible for tensification of lax O2s.

Sawashima et al. (1980)'s study also provides insight for glottal gestures between two vowels in the sequence of $V_1O_1O_2V_2$. According to their fiberscopic observation of laryngeal gestures, glottal gestures of O_1 are assimilated by glottal gestures of O_2 regardless of O_2's places of articulation. In Sawashima et al.'s study, glottal gestures between two vowels are divided into three groups.

First, when O_2s are lax or tense stops, Sawashima et al. (1980:129) observe that "the degree of glottal opening for the consonant sequences of the syllable-final applosives followed by the lax and forced stops is almost the same as that of the syllable-initial forced stop." Second, when O_2s are lax fricatives, "there is a fairly large glottal opening for both the lax and forced [tense] fricatives" (Sawashima et al. 1980:129). However, there is no significant difference between tense and lax O_2 fricatives in terms of glottal opening. Third, when O_2s are aspirate stops, the glottal opening at the oral-closure release of O_2 is as wide as that of syllable-initial aspirate stops.

I provide two reasons for the fact that lax and tense stops of O_2 pattern together in terms of glottal opening in $V_1O_1O_2V_2$. The first reason may be closely related to the fact that glottal gestures of O_1 are assimilated by those of O_2 in $V_1O_1O_2V_2$. This means that glottal gestures of lax-O2 stops may begin while oral closure of unreleased stops of O_1 is maintained, as schematically shown in (15a) and (15b). In (15) and hereafter, the curved-broken line on the glottal tier represents the actual glottal gestures in $V_1O_1O_2V_2$. The curved-solid line on the glottal tier represents the targeted glottal gestures for lax stops in the input, which are contrastive in Korean.

(15) a. b.



As shown in (15a), the glottal opening for lax-O_2 stops may have reached and completed its targeted CD significantly earlier than that of lax stops in the input. Therefore, by the time lax-O_2 stops are released, the CD at the glottis is already as closed as that of tense stops. Recall that the glottal opening of tense obstruents comes to nearly complete closure before oral-closure release, as mentioned in section 1.3.2.1.

The second reason why lax and tense stops of O_2 pattern together in $V_1O_1O_2V_2$ may be related to the fact that there are no two glottal gestures relevant to O_1 and O_2 respectively. This may mean that the CD of glottal gestures for lax-O_2 stops begins with the glottal opening value of O_1, rather than from a point where lax stops in the input would normally start. Because the CD of glottal gestures for O1 is very narrow, the glottal gestures for lax-O_2 stops do not reach their target gestures (the broken line in (15b)) within a given time and come to near closure before the oral-closure release. Therefore, glottal gestures for lax-O_2 stops undershoot their target gestures, resulting in the [closed] CD at the glottis before oral-closure release for O_2 (Browman and Goldstein 1990).

In summary, when O2s are lax stops in V1O1O2V2, the phonetic implementational conditions promote tensification of lax-O2 stops because of long closure duration and the minimal glottal opening at oral-closure release for O2, which are coupled with heightened oral pressure and tension in the vocal tract. The similarities between lax-O2s in V1O1O2V2 and tense obstruents are summarized in (16) based on Han (1997), Dart (1987), Kim (1965 and 1970), Hardcastle (1973), Oh (1998), and Sawashima et al. (1980).

(16) Phonetic implementational conditions between two vowels in V1O1O2V2.

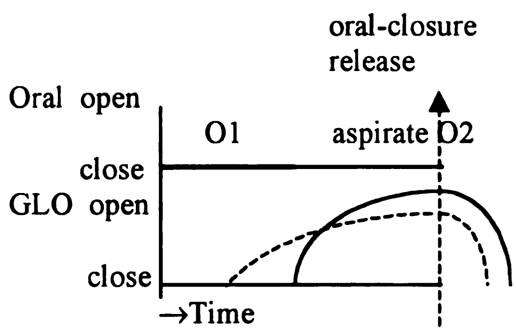
phonetic implementational conditions	V1O1O2V2	VO'V
oral-closure duration	as long or longer than C's	long
pharyngeal pressure	heightened	heightened
vocal tract tension	high muscular tension in the vocal tract	high muscular tension
glottal opening at oral-closure release	as narrow as that of tense	narrow

Sawashima et al. (1980) observed that lax-O2 fricatives in the sequence of V1O1O2V2 are phonetically realized as tensed fricatives although the glottal opening for the lax fricative /s/ tends to be slightly large. This observation indicates that in addition to the glottal opening at oral-closure release of O2, other factors such as the heightened pharyngeal pressure and tension in the vocal tract are also responsible for tensification of lax-O2 as long as the CD at the SL level is not [open], as discussed in Rhee (1997), Kim-Renaud (1974), and Sohn (1987).

If the CD at the SL level is [open], there is no heightened pharyngeal pressure and tension in the vocal tract because air flows freely through either the oral or nasal cavity. When O2s are fricatives in V1O1O2V2, although the glottal opening is slightly large, the heightened pharyngeal pressure and tension in the vocal tract are expected because CDs at the SL level are [closed] for O1 and [critical] for O2. Therefore, narrow CDs at the SL level for O1 and O2 in V1O1O2V2 promote tensification of the lax fricative /s/.

Now is an appropriate time to explain why lax-O2s in V1O1O2V2 are not aspirated. One of the answers to this question is that contrary to lax and tense obstruents, the glottal opening for aspirate O2 stays wide open at the time of oral-closure release, as shown in (17).

(17) Gestural score for aspirate O2 in V1O1O2V2



When O2s are aspirate obstruents in V1O1O2V2, no phonetic implementational conditions for aspirate obstruents are altered. Relative long oral-closure duration may cause heightened pharyngeal pressure and tension in the vocal tract. As mentioned in 1.3.2.2, the heightened pharyngeal pressure and tension in the vocal tract are also characteristics of aspirate obstruents. However, the wide glottal opening at oral-closure release distinguishes aspirate obstruents from lax and tense obstruents.

As mentioned above, when O2s are lax obstruents in V1O1O2V2, phonetic implementational conditions promote tensification of lax O2s because of the relatively long oral-closure duration and [closed] glottal opening before or at oral-closure release, which increases the heightened oral pressure and tension in the vocal tract. Therefore, to have the [open] CD at the glottis at the time of oral-closure release for lax-O_2s in $V_1O_1O_2V_2$ would require an extra effort from speakers. According to Flemming (1995) and Kirchner (2000), speakers tend to minimize articulatory effort. This means that speakers tend to use gestures that are distributed in $V_1O_1O_2V_2$. Therefore, lax-O_2s in $V_1O_1O_2V_2$ are not aspirated because there is no [open] CD at the glottis at the time of oral-closure release for lax O_2s.

Based on (16) and Steriade's (1997:7) claim that relative poverty or opulence of cues induces neutralization or contrasts of a relevant feature, I propose a constraint sensitive to distribution of tense gestures in $V_1O_1O_2V_2$, as in (18). As shown in (11) and (16), properties of tense are abundant when CDs of the SL level are not [open] for O_1 and O_2. In other words, gestures for lax obstruents are absent or not abundant in $V_1O_1O_2V_2$. This fact is reflected in (18).

(18) a.

	$-O_1$	O_2-
SL	closed	closed/critical
Oral	closed	closed/critical

b. $*[\text{mid}]_{GLO}/V_1O_1\_\_V_2$

(18a) identifies conditions where gestures to tense are abundant. The constraint $*[\text{mid}]_{GLO}/V_1O_1\_\_V_2$ (18b) prevents lax obstruents from appearing after obstruents because there are no gestures for lax-O_2 obstruents in $V_1O_1O_2V_2$. Examples of such gestures include relatively short oral-closure duration, low air pressure and tension in the vocal tract, and a relatively wider CD at the glottis than that of tense obstruents. The constraint *[mid]$_{GLO}$/V1O1__V2 is based on a suggestion from Steriade (1997) that if there are no cues to a contrast in a given context, the contrast is not maintained, as shown in (19):

(19) *[tense]/ in positions lacking contextual cues
(abbreviated: Context Cues (tense)) (Steriade 1997:70)

Stops cannot be tense ... or ... lax in positions where contextual cues to this contrast are necessarily absent.

3.2.4 Morphological conditions and distribution of tense gestures

As CDs at the SL level are predicted from the nasal and oral levels, any changes in CDs of the velum or oral level in C1 change CDs of the SL level. Because POT is sensitive to CDs of the SL level, as shown in (10) and (11), it would be useful to examine what happens when C1 is a nasal or the lateral /l/ in the sequence of VC1O2V. Nasals are specified with the [open] CD at the SL level because of the velum opening, but have the [closed] CD at the oral level, as shown in (20a). The lateral /l/ is specified with the [open] CD at the SL level and the [open] CD at the oral level, as shown in (20b):

(20) a.

C1 Nasals	O2	SL	oral	Phonological alteration and conditions
[open]$_{SL}$ [closed]$_{oral}$	stops	[closed]$_{SL}$	[closed]$_{oral}$	Post-Nasal Tensification **- after the verb stem**
	affricates	[closed]/ [critical]$_{SL}$	[closed]/ [critical]$_{oral}$	
	fricatives	[critical]$_{SL}$	[critical]$_{oral}$	

b.

C1 /l/	O2	SL	oral	Phonological alternations and conditions
$[\text{open}]_{SL}$ $[\text{open}]_{oral}$	stops	$[\text{closed}]_{SL}$	$[\text{closed}]_{oral}$	Post-Lateral Tensification - when O2 is only /t, s, c/ - in Sino-Korean
	affricates	[closed]/ $[\text{critical}]_{SL}$	[closed]/ $[\text{critical}]_{oral}$	
	fricatives	$[\text{critical}]_{SL}$	$[\text{critical}]_{oral}$	

A comparison of (10) and (20) shows that the more [open] the CD in C1, the more conditions are attached to ObsT. For example, in (10), where C1 is specified with the [closed] CD at the SL and Oral levels, ObsT occurs obligatorily across all lexical categories within an accentual phrase. When C1 is the lateral /l/ specified with [open] CD at the SL and Oral levels, as shown in (20b), ObsT is limited to Sino-Korean nouns and cases where O2 is /t, s, c/.

I assume that the most favorable or strongest phonetic implementational condition for ObsT is when ObsT occurs obligatorily across all lexical categories. Favorable conditions for tensification of lax O2s in VC1O2V are summarized as harmonic scales based on CD of the SL and Oral levels.

(21) Favorable conditions for tensification of lax O2s in VC1O2V

	a. C1	O2		b. C1	O2		c. C1	O2
SL	**closed**	closed	⊃	**open**	closed	⊃	**open**	closed
Oral	**closed**	closed		**closed**	closed		**open**	closed

A ⊃ B: A is more favorable than B for tensification of lax O2s.

When O2s are lax obstruents, the most favorable condition for tensification is when C1 has the [closed] CD at the SL and Oral levels, as shown in (21a). In other words, there are no lax obstruents after unreleased stops. The least favorable condition for tensification of lax O2s is when CD for C1 is [open] at the SL and Oral levels, as shown in (21c). If the SL and Oral levels have [open] CD as in the lateral /l/, ObsT occurs only in limited cases. In general, when C1 has the [open] CD at the SL level or the [open] CD at both SL and Oral levels, lax O2s are voiced rather than tensed, as shown in data (6b) and (6c).

The patterns in ObsT in (10) and (21) also exhibit the close relationship between distribution of tense gestures and patterns of ObsT, as shown in (22).

(22)

	a. O1+O2	b. nasal+O2	c. /l/+O2
oral-closure duration	long	long	short
oral tract closure of coda	close	close	open
CDs at the SL level	[closed][close/critical]	[open]	[open]
airflow during the oral articulator closure	no	yes through nasal cavity	yes, through the oral cavity
air pressure behind the oral closure	strong ◄-------	-----------------	--► weak
tension in the vocal tract	high ◄------- low	-----------------	--► weak
tense properties	more ◄-------	-----------------	--► less
conditions for ObsT	across all lexical categories except co-compounds	after verb stem	only when O2 is /t, s, c/ and in Sino-Korean

(22) illustrates that patterns of ObsT in Korean are closely related to CD at the SL and Oral levels. CD at the SL and Oral levels influences pharyngeal pressure and tension in the vocal tract according to degrees of airflow escaping through the nasal or oral cavity. Therefore, ObsT occurs obligatorily after obstruents across all lexical categories

except co-compounds. This is because favorable phonetic implementational conditions for ObsT are rich in the sequence of $V_1O_1O_2V_2$.

However, lexical and/or phonological exceptions appear in $V_1NO_2V_2$ (22b) and $V_1LO_2V_2$ (22c) (N: nasals and L: the lateral /l/). Especially, the pharyngeal pressure and the vocal tract tension are weak in the sequence of $V_1LO_2V_2$, due to [open] CD at the SL and Oral levels for the lateral /l/. Phonetic implementational conditions for ObsT are weak in (22c). Therefore, lax O2s in $V_1LO_2V_2$ (22c) are tensed only when morphological and additional phonological conditions are attached.

The relationship between conditions for ObsT and distribution of tense gestures in (22) supports Anttila's claim (2000: 28) for the emergence of morphology in Phonology.

(23) The Emergence of Morphology: Extra-phonological (morphological, lexical) conditions emerge in environments where the phonological conditions are at their weakest.

According to Anttila (2000), morphological or lexical conditions are attached to a phonological process when phonological conditions to the process are not strong. Therefore, the less tense gestures are distributed in a given context, the more morphological and/or additional phonological conditions are likely to be attached to ObsT as claimed by Anttila. (24) summarizes basic perspectives discussed in this section.

(24)	$O^{\urcorner}_1$ + O_2 >>	N + O_2 >>	L + O_2 >>	h + O_2
Gestures	Gesture1	Gesture1	Gesture1	•
Of C_1	Gesture2	Gesture2	•	
that promote	Gesture3	•	•	
tensification.	•	•		
of lax O_2s	•			
Influence	strongest ←		→	weakest
Morphonological conditions	NO	Yes	Yes	No ObsT

Gestural characteristics of consonants in syllable-final position influence the following consonants to different degrees, as shown in (24). Thus, unreleased stops in syllable-final position strongly influence the following lax obstruents. As a consequence, POT occurs obligatorily across morphological categories within an accentual phrase.

The lateral [l] in syllable-final position weakly influences the following lax obstruent. As a consequence PLT appears with the morphological and additional phonological conditions, as shown in (20). Thus, different degrees of influence on the following lax obstruents are reflected in terms of morphological and/or additional phonological conditions.

When /h/ specified with the [open] CD in the vocal tract is C_1, as shown in $V_1hO_2V_2$, ObsT does not occur in O_2, instead aspiration occurs. Therefore, ObsT is sensitive to CD in the vocal tract, especially CD at the SL and Oral levels.

3.2.5 The gesture-based account of POT

In this section, based on the harmonic scales in (21), I propose a set of constraints that ban lax obstruents in O2 position in the sequence of V1C1O2V2, as in (25).

(25) Distribution of tense gestures and ObsT

	*[mid]$_{GLO}$/V1O1__V2 >>		*[mid]$_{GLO}$/V1N__V2- >>		*[mid]$_{GLO}$/ V1L__V2	
	O1	O2	nasal	O2	lateral	O2
SL	**closed**	closed	**open**	closed	**open**	closed
Oral	**closed**	closed	**closed**	closed	**open**	closed

A>>B = A is higher than B in a constraint hierarchy.

The enriched tense gestures at oral-closure release of O2 in V1O1O2V2 are closely related to O1 having [closed] CDs at the SL and Oral levels. Thus, *[mid]$_{GLO}$/ V1O1__V2 states that O2 cannot be lax in sequences of V1O1O2V2 because properties of tense, such as long oral-closure duration, [closed] CD at the glottis at the oral-closure release, and heightened air pressure behind the oral closure are abundant in V1O1O2V2, as shown in (22a). *[mid]$_{GLO}$/ V1N__V2 states that lax obstruents are prevented from occurring after nasals due to the [open] CD at the SL level and the [closed] CD at the oral level. Due to the [critical] CD at the glottis and the [open] CD at the SL level of nasals, the amount of air accumulated behind oral closure is relatively weaker in the sequence of V1NO2V2 than that of V1O1O2V2. Therefore, voice gestures, rather than tense gestures, are increased in V1NO2V2 (Kager 1999 and Ito et al. 1995). As a consequence, if ObsT occurs after nasals, it does so with a morphological condition, as will be shown in chapter 4.

*[mid]$_{GLO}$/V1L__V2 prevents lax O2s from occurring after the lateral /l/. The sequence of V1LO2V2 has the least favorable conditions for occurrence of ObsT due to the [open] CD at the SL and Oral levels of the lateral /l/. In other words, ObsT would occur in a more limited way after the lateral [l] than after nasals or obstruents.

Whenever a segment or a gesture in the input is banned from occurring in the output, as in (25), a faithfulness constraint is at risk of being violated. Recall that IDENT-IO[G] requires that gestures in the input be preserved in the output, as shown in (26a).

(26) a. IDENT-IO[G]:
Gestures in the input are maintained in the output.

b. *[mid]$_{GLO}$/V1O1_V2 >>*[mid]$_{GLO}$/V1N__V2 >>
*[mid]$_{GLO}$/V1L__V2 >> IDENT-IO[G]

Tense or aspirate obstruents appear after obstruents, as shown in data (5). Tense, aspirate or voice obstruents appear after nasals or the lateral /l/ as in [palt'al] 'development, [kan.t^{h}oŋ] 'adultery', and [kul.b̲i] 'a kind of fish'. Therefore, actual outputs never have GLO [mid] after obstruents, nasals or the lateral /l/ except in co-compounds as in [cip̲˺. c̲ip˺]$_{co\text{-}compound}$ 'every house' from /cip̲/$_{noun}$ 'house'+ /c̲ip/$_{noun}$ 'house'. As a result, CD of glottal gestures is not maintained in the output, as shown in data (1), (5), and (6) (e.g. [ik̲˺.s̲'al] from /ik̲s̲al/$_{noun}$ 'funny act or saying', /pin̲t̲æ/ → [pin̲.d̲æ] 'bed bug' and [pol.g̲i] from /pol̲k̲i/ 'hip'). Therefore constraints against GLO [mid] after obstruents, nasals or the lateral [l] are ranked higher than IDENT-IO[G], as shown in (26b).

POT occurs obligatorily when an obstruent is preceded by another obstruent within an accentual phrase regardless of morphological category, as shown in (27a), (27b), (27c), and (27d).

(27) a. Nouns

/iksal/	→	[ik˺.s’al]	‘funny act or sayings’
/maktæ/	→	[mak˺.t’æ]	‘stick’

b. Verbs (verb stem +inflectional suffix)

mʌk +t’a$_{\text{declaritive}}$	→	[mʌk˺.t’a]	‘eat’
pis +ko$_{\text{conjunction}}$	→	[pit˺.k’o]	‘to comb + and’
cf. an + ki$_{\text{derivation}}$ +ta	→	[an.gi.da]	‘be hugged’

c. Modifier +noun

yəp $_{\text{modifier}}$ 'next' + cip 'house'→ [yəp˺.c’ip] ‘next house’

d. Prefix + noun

pus ‘first’+ sakwa ‘apple’ → [put˺s’akwa] ‘fresh apple’

e. Nouns with a sonorant in C1 position

/koŋki/	→	[koŋ.gi]	‘air’ or 'rice bowel'
/əlkul/	→	[əl.gul]	'face'

Obstruents that follow obstruents are never voiced, as shown in (27a), (27b), (27c), and (27d). However, in general, obstruents after nasals or the lateral [l] are voiced, as shown in (27e) but tensed in the verbal morphology or in some Sino-Korean nouns, as shown in (7b) and (8a).

In (28), output candidates from lexical entries with different types of obstruents in C2 position are evaluated against constraints and the rankings of constraints suggested in (26).

(28) *[mid]$_{GLO}$/V1O1_V2 >>*[mid]$_{GLO}$/V1N__V2 >> *[mid]$_{GLO}$/V1L__V2 >> IDENT-IO[G]

A. /apc̲'ok/ 'front side' /ap/ 'front' + /c̲'ok/ 'side'

/c'/: GLO [closed], SL [close/critical], Oral [close/critical], TT [close/critical]

/apc̲'ok/	*[mid]$_{GLO}$/ V1O1 _V2	*[mid]$_{GLO}$/ V1N _V2	*[mid]$_{GLO}$/ V1L _V2	IDENT-IO[G]
a. ap˺.c̲ok	*!			*(GLO)
➢☞b.ap˺.c̲'ok				
c. ap˺.c̲^{h}ok				*!(GLO)

B. /pakt̲^{h}al/ 'deprive'

/t^h/: GLO [open], SL [closed], Oral[closed], TT [closed]

/pakt̲^{h}al/	*[mid]$_{GLO}$/ V1O1 _V2	*[mid]$_{GLO}$/ V1N _V2	*[mid]$_{GLO}$/ V1L _V2	IDENT-IO[G]
a. pak˺.t̲al	*!			*(GLO)
b. pak˺.t̲'al				*!(GLO)
☞ c. pak˺.t̲^{h}al				

C. /makt̲æ/ 'stick'

/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/makt̲æ/	*[mid]$_{GLO}$/ V1O1 _V2	*[mid]$_{GLO}$/ V1N _V2	*[mid]$_{GLO}$/ V1L _V2	IDENT-IO[G]
a.mak˺.t̲æ	*!			
➢☞b.mak˺.t̲'æ				*(GLO)
➢ c.mak˺.t̲^{h}æ				*(GLO)

(28A) and (28B) illustrate that when the second consonants are aspirate or tense obstruents, constraints and their ranking suggested in (26) select candidates with aspirate or tense obstruents in C2 position as the most optimal candidate. However, as shown in (28C), when the second consonant is a lax obstruent, constraints and their ranking in (26) select both (28Cb) and (28Cc) as the most optimal candidates. This is because both

(28Cb) and (28Cc) optimally satisfy output constraints in (26). Therefore, there must be a constraint which selects (28Cb) over (28Cc) as the most optimal candidate.

I suggest that the selection of (28Cb) over (28Cc) results from interaction between IDENT-IO[G] and a constraint sensitive to articulatory effort in V1O1O2V2. As mentioned above, when O2s are lax obstruents in the sequence of V1O1O2V2, phonetic implementational conditions promote tensification of lax O2s. This is because gestures of tense are distributed between two vowels in the sequence of V1O1O2V2.

In particular, at the time of oral-closure release for lax O2s, the CD at the glottis for lax O2s is already as closed as that of tense obstruents (Sawashima et al. 1980). Therefore, having the [open] CD at the glottis for lax O2s requires an extra effort from speakers. However, speakers tend to minimize articulatory effort as discussed in Flemming (1995) and Kirchner (1998 and 2000). In other words, speakers tend to use the gestures distributed in the sequence of V1O1O2V2.

Recall that there are no two separate glottal gestures for O1 and O2 respectively in the sequence of V1O1O2V2 according to Sawashima et al. (1980)'s observation. Sawashima et al.'s observation is similar to Browman and Goldstein's (1986) observation of glottal gestures in s+stop clusters such as found in English words 'spin', 'star', and 'skin'.

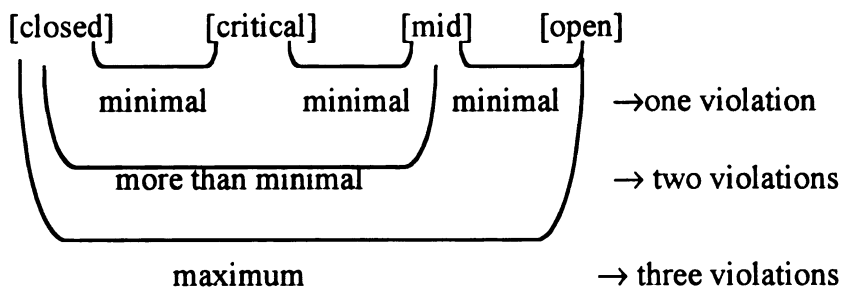
According to Browman and Goldstein (1986), there are no separate glottal gestures for /s/ and stops respectively. Instead, glottal gestures of /s/ influence glottal gestures of /p/, resulting in unaspirate stops (see 2.1.3.2.2). According to Sawashima et al. (1980)'s observation, glottal gestures of O1 are assimilated by glottal gestures of O2 in V1O1O2V2. This means that there is an effort to minimize articulatory gestures between two vowels with respect to glottal gestures. According to Flemming (1995) and Kirchner (2000: 529), the principle of minimization of effort is universal and is computed for each candidate representation.

Based on the principle of minimization of articulatory effort, and the observation of Sawashima et al. (1980) and Browman and Goldstein (1986), I suggest a constraint sensitive to articulatory effort of glottal gestures between two vowels, as shown in (29). Note that constraints sensitive to gestural efforts may be sensitive to articulators involved in a given context (Kirchner 1998, Cho 1998a and 1998b and Byrd 1996).

Constraint (29) promotes reduction of glottal gestures between C_1 and C_2.

(29) Minimization of articulatory effort at the glottis (Mini Eff [GLO]=0):

CDs of glottal gestures for C_1 and C_2 between two vowels should be identical or minimal.



Mini Eff [GLO]=0(hereafter Mini Eff=0) demands no glottal CD changes for C_1 and O2 between two vowels. Therefore, Mini Eff=0 is satisfied when CDs at the glottis for C_1 and C_2 between two vowels are identical, whether they are [closed], [critical], [mid], or [open].

CDs of glottal gestures for C_1 and C_2 between two vowels are minimal when CDs at the glottis for C_1 and C_2 are one degree narrower or wider with respect to each other, as shown in (29). Therefore, GLO [critical] occurs with either GLO [closed] or GLO [mid]. When difference of CD for C_1 and C_2 is minimal, as shown in (35), Mini Eff=0 is violated only once.

CDs of glottal gestures for C_1 and C_2 between two vowels are more than minimal when these are more than one degree narrower or wider with respect to each other, as shown in (29). Therefore, GLO [critical] occurs with GLO [open] or GLO [mid] occurs with GLO [open]. When the CD difference for C_1 and C_2 is more than minimal, as shown in (29), Mini Eff=0 is violated twice.

CDs of glottal gestures for C_1 and C_2 are maximum when opposite ([open] vs. [closed]). Therefore, GLO [closed] occurs with GLO [open]. When CD difference for C_1 and C_2 is maximum, as shown in (29), Mini Eff=0 is violated three times.

A comparison of (28A) and (28C) to (28B) indicates that Mini Eff=0 is lower than IDENT-IO[G], as shown in (30). Especially (28Bc) illustrates that although the CD difference at the glottis between [k˺] and [t^h] in [pa<u>k</u>˺.<u>t</u>^{h}al] is more than minimal, the input [open] CD at the glottis for /t^h/ is preserved.

(30) *[mid]$_{GLO}$/ V_1O1__V_2 >> *[mid]$_{GLO}$/ V_1N__V_2 >> *[mid]$_{GLO}$/ V_1L__V_2 >> IDENT-IO[G] >> Mini Eff=0

A. /apc'ok/ 'front side' /ap/ 'front' + /<u>c</u>'ok/ 'side'

/p/: GLO [mid], SL [closed], Oral[closed], Lips [closed]
/c'/: GLO [closed], SL [close/critical], Oral[close/critical], TT [close/critical]

/ap<u>c</u>'ok/	*[mid]$_{GLO}$/ V_1O_1__V_2	*[mid]$_{GLO}$/ V_1N__V_2	*[mid]$_{GLO}$/ V_1L__V_2	IDENT -IO[G]	Mini Eff=0
a. ap˺.<u>c</u>ok	*!			*(GLO)	*
☞b.ap˺.<u>c</u>'ok					*
c. ap˺.<u>c</u>^{h}ok				*!(GLO)	**

B. $/pak\underline{t}^{h}al/$ ‘deprive’

/k/: GLO [mid], SL [closed], Oral[closed], TB [closed]
$/t^{h}/$: GLO [open], SL [closed], Oral[closed], TT [closed]

$/pak\underline{t}^{h}al/$	$*[mid]_{GLO}/V_1O_1\_V_2$	$*[mid]_{GLO}/V_1N\_V_2$	$*[mid]_{GLO}/V_1L\_V_2$	IDENT -IO[G]	Mini Eff=0
a.pak˺.t̲al	*!			*(GLO)	*
b. pak˺.t̲’al				*!(GLO)	*
☞c. pak˺.$\underline{t}^{h}$al					**

C. /mak t̲æ/ ‘stick’

/k/: GLO [mid], SL [closed], Oral [closed]
/t/: GLO [mid], SL [closed], Oral [closed]

/makt̲æ/	$*[mid]_{GLO}/V_1O_1\_V_2$	$*[mid]_{GLO}/V_1N\_V_2$	$*[mid]_{GLO}/V_1L\_V_2$	IDENT -IO[G]	Mini Eff=0
a. mak˺.t̲æ	*!				*
☞b. mak˺.t̲’æ				*(GLO)	*
c. mak˺.$\underline{t}^{h}$æ				*(GLO)	**!

Candidate (30Aa) violates $*[mid]_{GLO}/V_1O_1\_V_2$, IDENT-IO[G], and Mini Eff=0. Mini Eff is violated once because CDs at the glottis for O1 and O2 are [critical] and [mid] respectively. [c] in [ap˺.cok] has the [mid] CD at the glottis while [p˺] has default [critical] CD or narrower than [critical] CD in syllable-final position. Therefore, effort is required from speakers to change the CD of the glottis from [critical] to [mid] in $V_1\underline{C_1C_2}V_2$. Candidate (30Aa) violates $*[mid]_{GLO}/V_1O_1\_V_2$ because the lax obstruent [c] appears in the position where lax gestures are absent, as mentioned in 3.2.3. (30Aa) also violates IDENT-IO[G] because [c] in [ap˺.cok] does not maintain the input glottal gestures.

(30Ac) violates IDENT-IO[G] because [c^h] in [ap˺.c^hok] does not maintain the input [closed] CD at the glottis. (30Ac) violates Mini Eff=0 twice because CD difference at the glottis is more than minimal, namely from [critical] to [open].

(30Ab) also violates Mini Eff=0 once because the CDs at the glottis for O1and O2 are [critical] and [closed] respectively. However, violation of Mini Eff=0 is minimal compared to (30Ac). Although (30Ab) violates Mini Eff=0 once, it is selected as the most optimal candidate because it does not violate higher ranked constraints *[mid]$_{GLO}$/V1O1__V2 and IDENT-IO[G].

Candidate (30Ba) violates *[mid]$_{GLO}$/V1O1__V2 because the lax obstruent [t] appears in the position where lax gestures are absent. Candidate (30Ba) violates IDENT-IO[G] because [t] in [pak˺.t̠al] does not maintain the input glottal gestures for /t^h/. (30Ba) violates Mini Eff=0 once because CDs at the glottis are [critical] and [mid]. [t] in [pak˺.t̠al] has the [mid] CD at the glottis while [k˺] in [pak˺.t̠al] has the [critical] CD or narrower than [critical] at the glottis.

In (30Bb), IDENT-IO[G] is violated because the [open] CD at the glottis for /t^h/ is not maintained. Mini Eff=0 is violated in (30Bb) once because CDs at the glottis are [critical] and [closed].

(30Bc) violates Mini Eff=0 twice because CD difference between [k˺] and [t^h] in [pak˺.t̠^{h}al] is more than minimal. However, (30Bc) is the most optimal candidate because it satisfies higher constraints, *[mid]$_{GLO}$/V1O1__V2 and IDENT-IO[G].

In (30C), candidate (30Ca) violates *[mid]$_{GLO}$/V1O1__V2 because the lax obstruent [t] appears in the position where lax gestures are absent. (30Ca) satisfies

IDENT-IO[G]. However, satisfaction of *[mid]$_{GLO}$/V1O1__V2 takes precedence over satisfaction of IDENT-IO[G] because *[mid]$_{GLO}$/V1O1__V2 is ranked higher than IDENT-IO[G] in the constraint ranking hierarchy.

Candidates (30Cb) and (30Cc) are tied in *[mid]$_{GLO}$/V1O1__V2 and IDENT-IO[G]. Therefore, Mini Eff=0 plays a role in selecting the most optimal candidate. Candidate (30Cb) violates Mini Eff=0 once because CD difference between [k˺] and [t'] in [mak˺.t̠'æ] is minimal. Candidate (30Cc) violates Mini Eff=0 twice because CD difference between [k˺] and [tʰ] in [mak˺.tʰæ] is more than minimal. Thus, [k˺] and [tʰ] in (30Cc) demand more articulatory effort from speakers than [k˺] and [t'] in (30Bb) do. Therefore, (30Cb) is the most optimal candidate.

As constraints related to ObsT after obstruents, nasals or the lateral /l/ have been introduced, it is now necessary to argue for the ranking of constraints against GLO [mid] with respect to *CCD/_{#, C} and other constraints proposed in chapter 2. (31) illustrates constraints responsible for CN and CCCS.

(31) a. *COMPLEX >> *Max-IO$_{seg}$ >> TB$_{Art}$/Lips$_{Art}$ >> TT$_{Art}$ >> *CCD/__{#, C} >> IDENT-IO[G]

b. *Contrastive Constriction Degrees (CCD)/ __{#, C} (From chapter 2 (21))

Contrastive CD at the glottis and at the SL level for obstruents is not allowed when obstruents appear in word-final position or before a consonant.

[open] /_{#, C} >>[mid] /_{#, C} >>*[critical] /_{#, C} >> *[closed] /_{#, C}

Because constraints against GLO [mid] after obstruents, nasals, or the lateral /l/ are ranked above IDENT-IO[G], as shown in (30), it is first necessary to examine the constraint ranking between *CCD/__{#, C} and constraints against GLO [mid] after obstruents, nasals, or the lateral /l/. As seen in chapter 2, *CCD/__{#, C} is violable but constraints against GLO [mid] after obstruents, nasals or the lateral /l/ are never violated, as shown in (30). Therefore, *CCD/__{#, C}, which is responsible for Korean CN, is ranked lower than constraints against GLO [mid] after obstruents, nasals, or the lateral [l], as shown in (32).

(32) $*[mid]_{GLO}/\ V_1O_1\_\_V_2 >> *[mid]_{GLO}/\ V_1N\_\_V_2 >>$
$*[mid]_{GLO}/\ V_1L\_\_V_2 >> *CCD/\_\{\#, C\} >> IDENT\text{-}IO[G] >> Mini\ Eff{=}0$

/saskas/ 'a type of hat'

/s/: GLO [mid], SL [critical], Oral [critical], TT [critical]
/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/sa<u>s</u><u>k</u>as/	$*[mid]_{GLO}/\ V_1O_1\ \_\ V_2$	*CCD/_{#, C}	IDENT-IO[G]	Mini Eff=0
a. sa<u>s</u>.<u>k</u>at˺	*!	*(GLO) *(SL)		
b. sa<u>t</u>.<u>k</u>at	*!	*(GLO) *(SL)	*(TTCD)	
c. sa<u>t</u>˺.<u>k</u>at˺	*!	*(SL)	*(GLO) *(TTCD)	*
➢☞d. sa<u>t</u>˺.<u>k</u>'at˺		*!(SL)	**(GLO) *(TTCD))	*
➢ e. sa<u>k</u>'at˺			*(GLO)	

In (32), because consonants between two vowels are obstruents, only $*[mid]_{GLO}/V_1O_1\_\_V_2$ is displayed in candidate evaluation. Hereafter, in order to conserve space when evaluating candidates, if a lexical entry does not have obstruents, nasals, or the lateral /l/ in C_1 position, constraints relevant to absent segments will not be illustrated.

Because candidate (32a) maintains target gestures of the input, it satisfies IDENT-IO[G]. However, it violates higher constraints such as *[mid]$_{GLO}$/V1O1__V2 and *CCD/_{#, C}. (32a) violates *[mid]$_{GLO}$/V1O1__V2 because lax [k] appears after [s]. (32a) violates *CCD/_{#, C} twice because of GLO [mid] and TT [critical] for [s] in syllable-final position. (32a) satisfies Mini Eff=0 because [s] and [k] have the identical [mid] CD at the glottis. Although (32a) satisfies IDENT-IO[G] and Mini Eff=0 most optimally, it is not the most optimal candidate because of violations of *[mid]$_{GLO}$/V1O1__V2 and *CCD/_{#, C}, which are ranked higher than IDENT-IO[G] in the constraint hierarchy.

Assuming [t] and [t˺] correspond to /s/, (32b) and (32c) violate *[mid]$_{GLO}$/V1O1__V2 because lax [k] appears after [t] and [t˺] respectively. (32b) violates *CCD/_{#, C} twice because of GLO [mid] and SL [closed] for [t]. (32c) violates *CCD/_{#, C} once because of SL [closed] for [t˺]. (32b) violates IDENT-IO[G] because the input CD at the TT is changed from [critical] to [closed]. (32c) violates IDENT-IO[G] twice because the input CDs for /s/ at the glottis and at the TT are changed. (32b) satisfies Mini Eff=0 because [t] and [k] have the identical [mid] CD at the glottis. (32c) violates Mini Eff=0 because CDs at the glottis for [t˺] and [k] in [sat˺.kat˺] are [critical] and [mid] respectively. Both (32b) and (32c) violate *[mid]$_{GLO}$/V1O1__V2 and *CCD/_{#, C}. Therefore, both (32b) and (32c) are eliminated from being the most optimal candidate because they violate relatively higher constraints.

Candidates (32d☞) and (32e➢) are tied in *[mid]$_{GLO}$/V1O1__V2. Therefore, *CCD/_{#, C} may play a role in selecting the most optimal output. Candidate (32d) has the [closed] CD at the SL level in syllable-final position, resulting in violation of *CCD/_{#, C}. Candidate (32e➢) satisfies *CCD/_{#, C} because there is no obstruent in syllable-final position due to deletion of /s/ in the input. Therefore, according to constraints and their rankings in (32), (32e➢) should be the most optimal candidate. However, the actual output is (32d☞), rather than (32e). The difference between (32d) and (32e➢) is in the alteration or deletion of /s/.

Recall that Max-IO$_{seg}$ is responsible for maintaining of input segments. As shown in the analysis of CCCS, Max-IO$_{seg}$ is ranked higher than *CCD/_{#, C}. In addition, Max-IO$_{seg}$ is violated when satisfaction of *COMPLEX, which bans a consonant cluster in syllable-final position, is at risk. Otherwise, segments in the input are not deleted. *COMPLEX and constraints against GLO [mid] after obstruents, nasals or the lateral /l/ are never violated in output forms in Korean. However, Max-IO$_{seg}$ is violated in some output forms. Therefore, constraints against GLO [mid] after obstruents, nasals or the lateral /l/ are unranked with respect to *COMPLEX and ranked higher than Max-IO$_{seg}$, as shown in (33).

(33) *COMPLEX, *[mid]$_{GLO}$/ V1O1__V2 >> Max-IO$_{seg}$ >> *CCD/_{#, C} >> IDENT-IO[G] >> Mini Eff=0

/koskan/ 'barn'

/s/: GLO [mid], SL [critical], Oral [critical], TT [critical]
/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/koskan/	*COMP	*[mid]$_{GLO}$/ V1O1__V2	Max-IO$_{seg}$	*CCD/_{#, C}	IDENT-IO[G]	Mini Eff=0
a. kos.kan		*!		*(GLO) *(SL)		
b. kos.k'an				*(GLO) *!(SL)	*(GLO)	*
c. kot.kan		*!		*(GLO) *(SL)	*(TTCD)	
d. kot.k'an				*(GLO) *!(SL)!	*(TTCD)	*
e. kot˺.kan		*!		*(SL)	*(TTCD) *(GLO)	*
☞f. kot˺.k'an				*(SL)	*(TTCD) *(GLO)	*
g. ko.k'an			*!			

Candidates (33b), (33d), and (33f) are tied in *COMPLEX and *[mid]$_{GLO}$/ V1O1__V2. However, (33f) satisfies *CCD/_{#, C} most optimally. The comparison of (33f) to (33g) shows that constraints against GLO [mid] after obstruents, nasals, or the lateral /l/ are ranked higher than *Max-IO$_{seg}$. (33g) satisfies *[mid]$_{GLO}$/V1O1__V2, as does (33f), by deleting /s/. (33g) does not violate *CCD/_{#, C}, IDENT-IO[G], or Mini Eff=0, whereas (33f) violates all three constraints. However, (33g) is not selected as the most optimal candidate because it violates Max-IO$_{seg}$.

Constraints against GLO [mid] after obstruents, nasals, or the lateral /l/ are ranked higher than Max-IO$_{seg}$. TB$_{Art}$, Lips$_{Art}$, and TT$_{Art}$, are ranked lower than Max-IO$_{seg}$. By transitivity, TB$_{Art}$, Lips$_{Art}$, and TT$_{Art}$, are ranked lower than constraints against GLO

[mid] after obstruents, nasals, or the lateral /l/, as shown in (34). (34) evaluates candidates from a lexical entry with an obstruent-obstruent cluster.

(34) *COMPLEX, *[mid]$_{GLO}$/ V1O1__V2 >> Max-IO$_{seg}$ >> TB$_{Art}$,/Lips$_{Art}$,>> TT$_{Art}$ >> *CCD/ _{#, C} >> IDENT-IO[G] >> Mini Eff=0

/kapskwa/

/p/: GLO [mid], SL [closed], Oral [closed], Lips [closed]
/s/: GLO [mid], SL [critical], Oral [critical], TT [critical]
/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/kapskwa/	*COMP	*[mid]$_{GLO}$/ V1O1__V2	Max-IO$_{seg}$	TB$_{Art}$,/ Lips$_{Art}$	TT$_{Art}$	*CCD/ _{#, C}	IDENT-IO[G]	Mini Eff=0
a. kaps.kwa	*!	**				**(GLO) **(SL)		
b. kaps'.k'wa	*!					**(GLO) **(SL)	**(GLO)	*
c. kat.kwa		*!	*	*!		*(GLO) *(SL	*(TTCD)	
d. kas.kwa		*!	*	*!		*(GLO) *(SL)		
e. kat˺.kwa		*!	*	*!		*(SL)	*(GLO) *(TTCD)	*
f. kap.kwa		*!	*		*	*(GLO) *(SL)		
g. kap˺.kwa		*!	*		*	*(SL)	*(GLO)	*
h. ka.kwa			**!	*	*			
i. ka.k'wa			**!	*	*			
j. kas.k'wa			*	*!		*(GLO) *(SL)	*(GLO)	*
k. kat.k'wa			*	*!		*(GLO) *(SL	*(GLO) *(TTCD)	*
l. kat˺.k'wa			*	*!		*(SL)	**(GLO) *(TTCD)	*
m. kap.k'wa			*		*	*!(GLO) *(SL)	*(GLO)	*
☞n. kap˺k'wa			*		*	*(SL)	**(GLO)	*

In (34), candidates which violate *COMPLEX and *[mid]$_{GLO}$/ V1O1__V2 are eliminated as possibilities to be the most optimal candidate because both *COMPLEX and *[mid]$_{GLO}$/V1O1__V2 are the highest ranked constrants. Therefore, candidates from (34a) to (34g) are eliminated as possibilities to be the most optimal candidate.

Candidates (34h) and (34i) are not the most optimal candidate because two input segments are deleted, violating Max-IO$_{seg}$ twice. Candidates from (34j) to (34n) are tied in *COMPLEX, *[mid]$_{GLO}$/V1O1__V2, and Max-IO$_{seg}$. Therefore, TB$_{Art}$, Lips$_{Art}$, and TT$_{Art}$ play a role in selecting the most optimal candidate. Because TB$_{Art}$, and Lips$_{Art}$, are ranked higher than TT$_{Art}$, candidates violating TB$_{Art}$, and Lips$_{Art}$ are not possibilities to be the most optimal candidate. Therefore, candidates from (34j) to (34l) are not the most optimal candidates because the Lip articulators in the input are not maintained.

Candidates (34m) and (34n) are tied in *COMPLEX, *[mid]$_{GLO}$/ V1O1__V2, Max-IO$_{seg}$, and TT$_{Art}$. Therefore, *CCD/_{#, C} plays a role in selecting the most optimal candidate. (34m) violates *CCD/_{#, C} twice because of GLO [mid] and SL [closed] in syllable-final position. (34n) violates *CCD/_{#, C} once because of Lips [closed]. Therefore, (34n) is selected as the most optimal candidate.

Constraints and their ranking in (34) correctly select the actual output as the most optimal candidate regardless of whether lexical items finish with a consonant or a consonant cluster, as shown in (33) and (34). In addition, (34) displays that CN and POT result from interaction of output constraints sensitive to phonetic implementational conditions in V1C1C2V2.

Up to this point, discussion has concerned occurrence of ObsT after obstruents. As mentioned above, occurrence or non-occurrence of ObsT is sensitive to gestural characteristics of C1. When C1 is an obstruent, a lax O2 is always tensed in Korean within an accentual phrase. However, when C1 is a nasal or the lateral /l/, a lax-O2 stop is voiced within an accentual phrase except in Korean verbal morphology and some Sino-Korean nouns (Jun 1993 and 1994).

If ObsT results from interaction of output constraints, non-occurrence of ObsT after nasals or the lateral /l/ in (6b) and (6c) should result from interaction of output constraints suggested in (34). In order to see if when O1 is a nasal or the lateral /l/, constraints and their hierarchy in (34) correctly select actual output forms as the most optimal candidates, (35A) evaluates candidates from a lexical entry with N+a lax stop /t/. (35B) evaluates candidates from a lexical entry with L + a lax stop /k/.

(35) *COMPLEX, *[mid]$_{GLO}$/ V1N__V2 >> Max-IO$_{seg}$ >> TB$_{Art}$,/Lips$_{Art}$,>> TT$_{Art}$ >> *CCD/ _{#, C} >> IDENT-IO[G] >> Mini Eff=0

A. /bintæ/ 'bed bug'

/n/: GLO [critical], SL [open], Oral [closed], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/bintæ/	*COMP	*[mid]$_{GLO}$/ V1N__V2	Max-IO$_{seg}$	TB$_{Art}$,/ Lips$_{Art}$	TT$_{Art}$	*CCD/ _{#, C}	IDENT -IO[G]	Mini Eff=0
a. bin.tæ		*!						*
b. bin.t'æ							*[GLO]	*!
c. bin.tʰæ							*[GLO]	**!
☞d. bin.dæ							*[GLO]	

B. *COMPLEX, *[mid]$_{GLO}$/ V1L__V2 >> Max-IO$_{seg}$ >> TB$_{Art}$,/Lips$_{Art}$,>> TT$_{Art}$ >> *CCD/ _{#, C} >> IDENT-IO[G] >> Mini Eff=0

/əlkul/

/l/: GLO [critical], SL [open], Oral [open], TB [open],TT [closed]
/k/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/əlkul/	*COMP	*[mid]$_{GLO}$/ V1L__V2	Max-IO$_{seg}$	TB$_{Art}$/ Lips$_{Art}$	TT$_{Art}$	*CCD/ _{#, C}	IDENT -IO[G]	Mini Eff=0
a. əl.kul		*!						*
b. əl.k'ul							*[GLO]	*!
c. əl.kʰul							*[GLO]	**!
☞ d. əl.gul							*[GLO]	

As shown in (35A) and (35B), constraints *COMPLEX, Max-IO$_{seg}$, TB$_{Art}$, Lips$_{Art}$, and TT$_{Art}$ are not relevant to candidates from /bintæ/ and /əlkul/. This is because both /bintæ/ and /əlkul/ do not have more than two consonants between two vowels. The constraint *CCD/ _{#, C} is not relevant to candidates in (35A) and (35B) because *CCD/ _{#, C} pertains to obstruents in syllable-final position.

Candidates (35Aa) and (35Ba) violate *[mid]$_{GLO}$/ V1C1__V2 because lax obstruents are in the position where gestures to lax obstruents, such as relatively short oral-closure duration, are absent. Both (35Aa) and (35Ba) satisfy IDENT-IO[G] because input target gestures are preserved. However, satisfaction of *[mid]$_{GLO}$/V1C1__V2 is more important than satisfaction of IDENT-IO[G] because the former is ranked higher than the latter in the constraint hierarchy. Therefore (35Aa) and (35Ba) are not desirable as most optimal candidates.

All the candidates in (35A) and (35B) except (35Aa) and (35Ba) violate IDENT-IO[G] once because input target gestures at the glottis are not maintained while maintaining oral gestures. All the candidates in (35A) and (35B) except (35Aa) and (35Ba) are tied with regard to IDENT-IO[G] and higher constraints. Therefore constraints lower than IDENT-IO[G] play a role in selecting the most optimal candidate.

Note that Mini Eff=0 is a gradient constraint, as shown in (29). Identical glottal CDs of O1 and O2 do not violate Mini Eff=0. There is no displacement of CDs at the glottis for O1 and O2. Therefore, the wider the CDs at the glottis for the flanking segments, the greater the displacement (hence effort) required to achieve a given degree of consonantal constriction according to Kirchner (1998:22).

(35Ac) and (35Bc) violate Mini Eff=0 to the greatest degree because glottal gestures move from the [critical] CD for sonorants to the [open] CD for aspirate obstruents, thus violating Mini Eff=0 twice. Candidates (35Ab), and (35Bb) violate Mini Eff=0 once because CDs of glottal gestures for O1 and O2 are one degree narrower with respect to each other.

Candidates (35Ad) and (35Bd) satisfy Mini Eff=0 most optimally because CDs of glottal gestures are identical, being [critical]. Therefore, according to constraints and their ranking in (34), (35Ad) and (35Bd) are the most optimal candidates and they are actual output forms in Korean.

Note that after an obstruent, the lax fricative /s/ and the lax affricative /c/ pattern together with lax stops. However, /s/ and /c/ separate themselves from lax stops in V_1__V_2, V_1N__V_2, and V_1L_V_2. A lax stop is voiced in V_1__V_2, V_1N__V_2, and V_1L_V_2 unless constraints related to morphological conditions are active, as will be shown in section 4.2.2. However, /s/ and /c/ are never voiced in Korean in V_1__V_2,

$V_1N\_V_2$, and $V_1L\_V_2$. In addition, /s/ and /c/ are never tensed unless constraints related to morphological conditions are active, as will be shown in section 4.2.2.

Therefore, a thorough investigation related to phonetic constraints on voicing and tensing in fricatives and affricates is needed. Because the focus of this study is not about phonetic constraints on voicing and tensing in fricatives and affricates, the syllable-initial /s/ or /c/ after the [+voice] feature is not discussed in this study except when morphological conditions are active. A discussion on the syllable-initial /s/ or /c/ after the [+voice] feature would seem to be premature because there are not enough studies about phonetic constraints on voicing and tensing in fricatives and affricates to set up phonetically motivated constraints in a given context (see Ohala 1983:194-01 for phonetic constraints on voicing in fricatives and stops).

As shown in (33), (34), and (35), occurrence of ObsT after obstruents and non-occurrence of ObsT after nasals or the lateral [l] are explained with the same constraints and their rankings. In addition, I have shown that contrast and neutralization of features in a given context result from interaction between constraints sensitive to phonetic implementational conditions, faithfulness constraints, and minimization of articulatory effort. One remaining issue relevant to ObsT is to account for ObsT after nasals in the verbal morphology and after the lateral [l] in some Sino-Korean nouns. The first part of chapter 4 investigates ObsT after nasals or the lateral /l/ with morphological conditions.

3. 3 Discussion

As mentioned in Rhee (1997), there are two types of approaches to POT: the geminate analyses by Han (1992) and Lee (1994) and the non-geminate analyses by Cho and Inkelas (1994), Kang (1992), Kim-Renaud (1974), and others. The main assumption in the geminate analyses is that tense obstruents have two timing slots, as shown in (42a). Lax obstruents have one timing slot, as shown in (42b). POT is represented as insertion of [CG] (constricted glottis) when two timing slots are associated as shown in (42c).

```
(42) a. Tense obstruents        b.   Lax obstruents        c.   POT
        X     X                      X                          X   X
         \   /                       |                           \ /
         [CG]                        •                            •
                                                                  |
                                                                [CG]
```

According to Han's (1992) geminate account of POT, there is a geminate rule that associates two timing slots, as in (43b). After applying the geminate rule to input, [CG] is inserted and lax consonants are tensed, as in (43c). A delinking rule deletes the line associated with the first obstruent, as shown in (43d).

```
(43) a. Input          b. Geminate          c. POT            d. Delinking

     /p/    /k/.       /p/   /k/.           /p/   /k/.         /p/   /k/.
     X      X          →X    X       →      X     X      →     X     X
     |      |            \  /                \   /               \   |
   [-son][-son]         [-son]               [CG]                [CG]
  son: sonorant
```

However, Cho and Inkelas (1994) point out that deletion of [CG] in a geminate structure, as in (43d), violates geminate inalterability (Hayes 1986), which prevents a rule from being applied to only one part of a geminate.

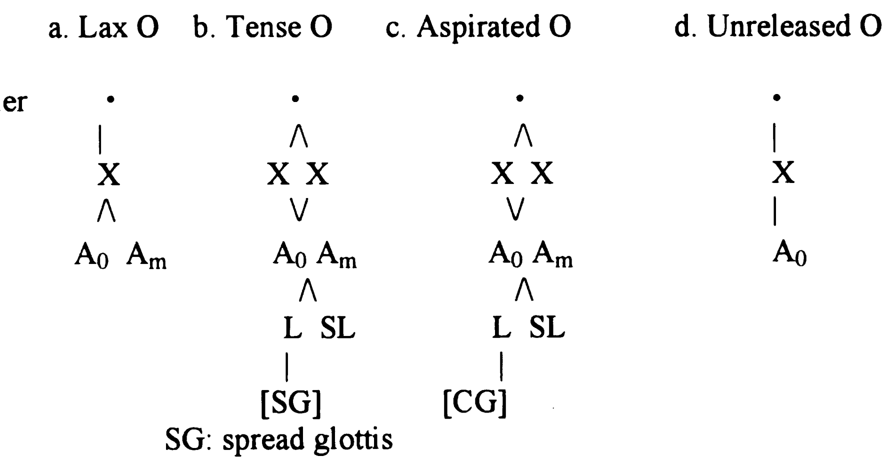
In this study, geminate inalterability problems do not occur because tense and aspirate obstruents are associated with one timing slot. Relative long closure duration is one of the properties of tense and aspirate obstruents.

In addition, the delinking rule (43d) results in shortening of oral-closure duration and deletion of [CG] in C_1. The shortening of oral-closure duration occurs due to the delinking of the line associated with the first obstruent. This means that there are two types of tense obstruents in the output: one associated with two timing slots as in (42a) and the other associated with one timing slot as indicated in (43d). However, there is no conclusive evidence that there are two types of tense obstruents distinguished by different timing slots (Oh 1998).

In the gesture-based account of POT, characteristics of tense gestures, such as minimal glottal opening in C_1C_2, which is closely associated with [CG], and relative long oral-closure duration between two vowels, motivate ObsT. These gestures promote tensification of lax C_2s. Therefore, the minimal glottal opening and long oral-closure duration in C_1C_2 should not be deleted, as implied by (43d).

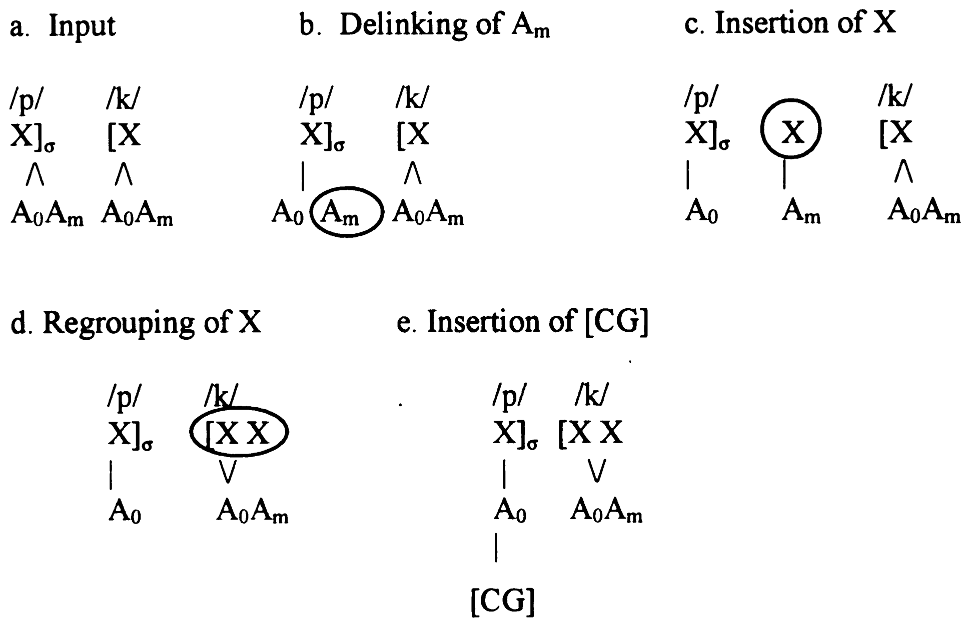
Based on Steriade (1991b), Lee's (1994) geminate analysis represents lax, tense, and aspirate obstruents, as in (44). A_0 stands for zero aperture and represents closure. A_m stands for maximal aperture and represents approximant release. In addition, A_f stands for aperture-cum-friction and represents fricative release.

(44)



Based on the above representations, Lee (1994) explains POT as follows:

(45)



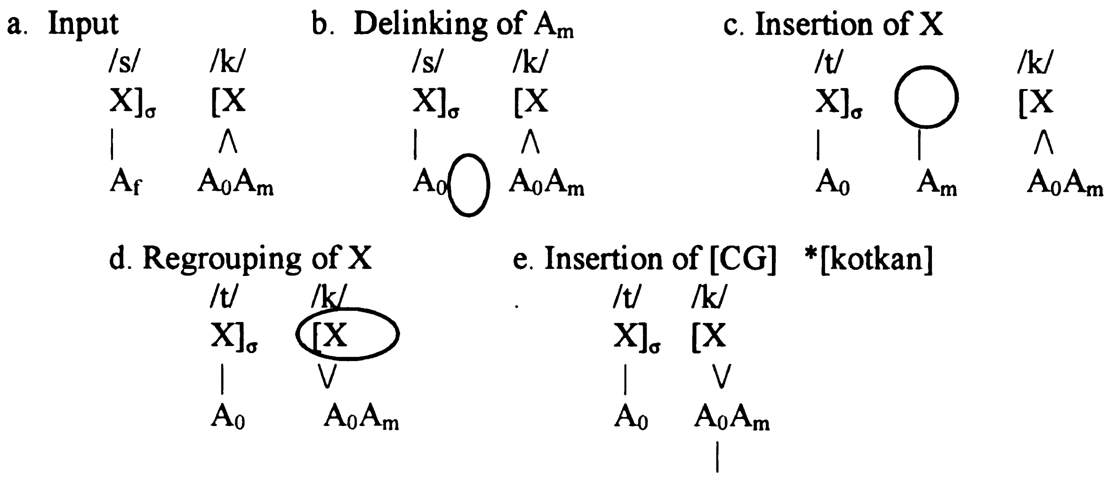
(45b) shows that A_m is delinked from the lax stop timing slot /p/, as indicated with a circle. The delinked A_m is recovered by an extra timing slot X in (45c). The inserted timing slot X is incorporated into the following syllable-initial position, resulting in an onset with two timing slots as in (45d). After incorporating the inserted timing slot X into the following syllable, [CG] is inserted because of the two timing slots in syllable-initial position in (45e).

As pointed out by Rhee (1997), Lee's (1994) analysis of POT fails to provide phonetic or phonological reasons for the following: the inserted timing slot X, incorporation of the inserted X into the following syllable position, and the insertion of [CG] instead of [SG] (spread glottis). If both aspirate and tense consonants are associated with two timing slots, as shown in (44), there is no reason why [SG] could not be inserted in (45e).

In addition, Lee's (1994) analysis of POT needs to be modified when C1s are fricatives.

(46)	A. /s/	/s'/	/h/
Root Tier	•	•	•
	|	|	|
X- tier	X	X	X
	|	|	|
	A_f	A_f	A_m
		/\	/\
		L SL	L SL
		|	|
		[CG]	[SG]

B. /koskan/ ‘barn’



As shown in (46Ba), there is no A_m to be delinked in fricatives. A_f in syllable-final position becomes A_0, as shown in (46Bb). This is supported by data such as [kot˺.k’an] from /koskan/ ‘barn’ and [kat˺.k’o] from /kas’ko/ ‘went and’. As a consequence, there is no delinked A_m to be recovered by an extra-timing slot X, as shown in (46Bc). Thus there is no extra timing slot X to be incorporated into the following syllable-initial position, as shown in (46Bd), and to trigger insertion of [CG], as shown in (46Be). Therefore, obstruents preceded by fricatives should not participate in POT according to Lee (1994). However, obstruents preceded by fricatives participate in POT, as shown in [kot˺k’an] from /koskan/ ‘barn’ and [kat˺k’o] from /kas’ko/ ‘went and’. Therefore Lee’s (1994) analysis of POT needs to be modified further.

As shown in (32), in the gesture-based account of POT, ObsT after fricatives is treated the same way as ObsT after stops or affricates is treated. Therefore, there is no reason to treat ObsT after fricatives differently from ObsT after stops or affricates.

In the non-geminate analyses, tense and aspirate obstruents are represented with one timing slot. Long closure duration is an inherent property of tense and aspirate obstruents. In the non-geminates analyses, POT is generally represented as follows (47).

(47) POT

a. [-sonorant] →[+tense] / [-sonorant] _____ (Ahn 1985)

b. [-sonorant] →[+constrict glottis]/ ([-sonorant] _____)δ (Kang 1992)

δ : An accentual phrase

Compared to the geminate analysis of POT, the non-geminates analyses of POT do not face geminate-inalterability problems. However, regardless of geminate or non-geminate analyses of POT, Han (1992), Lee (1994), and others using rule-based approaches do not explain why the inserted feature is [CG], instead of [SG] or some other feature(s).

The gesture-based account of POT in this study provides phonetic reasons for tensification, rather than aspiration, of lax O2s in the sequence of V1O1O2V2. As discussed in section 3.2.3, tense properties, such as long oral-closure duration, minimal glottal opening at the oral-closure release of O2, and heightened air pressure behind the oral closure, are abundant in V1O1O2V2.

When tense gestures are abundant between two vowels in V1O1O2V2, having [open] CD at the glottis at the oral-closure release of lax O2s, as shown in (17), would require gestural effort from speakers. However, speakers tend to use gestures distributed in a given context in order to minimize articulatory effort. This principle of minimization of articulatory effort plays a role to a degree, in the tensification, rather than aspiration, of lax O2s, as discussed in (29) and (30). Therefore, interaction of constraints sensitive to phonetic implementational conditions in a given context, a constraint sensitive to articulatory effort, and a faithfulness constraint are responsible for tensification of lax O2s in the sequence of VO1O2V, as illustrated in (30).

Many Korean linguists either directly or indirectly accept the fact that there is close relationship between POT and CN (Park 1990, Sohn 1987, Kim-Renaud 1974, Lee 1994, Rhee 1997, and Cho 1990). However, few studies show the close relationship between POT and CN in a systematic and unified way.

Kim-Renaud (1974:130) states that phonological descriptions such as (47a) and (47b) obscure the fact that '"fortition"(ObsT in this study) actually occurs always and only when a lenis obstruent (a lax obstruent in this study) is preceded by an unreleased stop' even though (47a) and (47b) are descriptively correct. Kim-Renaud describes POT in terms of the [-release] feature, as shown in (48a). Therefore, [+tense] is inserted when an obstruent is preceded by an unreleased stop.

(48) a. [+release, -sonorant]→ [+tense]/[-release]__ (Kim-Renaud 1974: 131) - POT

b. [-sonorant] → [+tense]/ [+nasal] & __ (& : verb stem boundary) - PNT
(Kim-Renaud 1974: 175)

c. [-sonorant, +cororanl] → [+tense] /[lateral] ! __
(! Chinese loan word boundary) (Kim-Renaud 1974: 173) - PLT

Kim-Renaud (1974)'s relating of CN and POT is correct. However, ObsT occurs not only after an unreleased stop, but also after a nasal in the verbal morphology, or after the lateral /l/ in Sino-Korean nouns, as shown in (48). However, phonological descriptions such as (48b) and (48c) seem to be as obscure as (47a) and (47b) are. (48b) and (48c) do not show any mechanism behind them as (48a) does.

There are three questions raised related to (48). First, if the [-release] feature of obstruents is closely related to ObsT as shown in (48a), why are [nasal] and [lateral] related to ObsT in (48b) and (48c)? Second, why does morphological information play a role in (48b) and (48c) but not in (48a)? Third, why does C2 have to be [-sonorant, +coronal] in Sino-Korean nouns if C1 is the lateral /l/?

Section 3.2.2 and 3.2.4 in this study provide answers to these questions. I have shown that CDs at the SL and Oral levels are closely related to occurrence or non-occurrence of ObsT and morphological or phonological conditions of ObsT, as shown in (49).

(49) Favorable conditions for tensification of lax O2s

	a. C1	C2		b. C1	C2		c. C1	C2
SL	**closed**	closed	$\supset$	**open**	closed	$\supset$	**open**	closed
Oral	**closed**	closed		**closed**	closed		**open**	closed

$A \supset B$: A is more favorable than B for tensification of lax O2s.

As shown in (49), the narrower the SL and Oral levels are, the more C2 is likely be tensed. This is because gestural and aerodynamic properties of tense are distributed more in (49a) than in (49c), as discussed in 3.2.3 and 3.2.4.

Gestural characteristics of obstruents in syllable-final position influence the following consonants to different degrees. Unreleased obstruents in syllable-final position most strongly influence lax obstruents that follow due to the [closed] CD at the SL and Oral levels. Therefore, POT (48a) occurs obligatorily across morphological categories within an accentual phrase. The lateral /l/ in syllable-final position most weakly influences the following lax obstruents due to the [open] CD at the SL and Oral levels. As a consequence, PLT appears with the most restricted morphological and phonological conditions, as shown in (48c). The morphological condition for PLT is Sino-Korean nouns and the additional phonological condition is that C2 must be /t/, /s/ or /c/. The influence of nasals on the following consonants falls between that of obstruents and the lateral /l/. Therefore, PNT requires the morphological condition. PNT occurs only after a verb stem within an accentual phrase, as shown in (48b). Therefore, morphological conditions for ObsT are sensitive to phonological conditions of ObsT. Interestingly, when phonological conditions for ObsT are weak, as shown in (49c), morphological and additional phonological conditions are attached to ObsT, as shown in (48c).

So far, I have compared the analysis of this study to the analyses of POT within rule-based approaches. It is now necessary to compare the analysis of this study to an analysis within constraint-based approaches because this study adopts the basic concepts of constraint-based approaches, as shown in chapter 1.

Rhee (1997) investigates POT within OT and constraints in Rhee are based on Steriade's (1993 and 1994) aperture geometry. Three types of Korean obstruents are represented with one timing slot in Rhee's study, as shown in (50):

(50) a. Lax C

$$\begin{array}{ccc} & X & \\ / & & \backslash \\ A_0 & & A_m \end{array}$$

b. Aspirated C

$$\begin{array}{ccc} & X & \\ / & & \backslash \\ A_0 & & A_m \\ & & | \\ & & [SG] \end{array}$$

c. Tensed C

$$\begin{array}{ccc} & X & \\ / & & \backslash \\ A_0 & & A_m \\ & & | \\ & & [CG] \end{array}$$

Rhee (1997) states that interaction of constraints and their hierarchy in (51) is responsible for occurrence of tensification of lax O2s after an obstruent and non-occurrence of tensification of lax-O2s after nasals or the lateral /l/.

(51) a. CODA CONDITION
(CODA COND)
X]
|
A_0

b. SHARE–VOICE
(SHA-[voc])
N C
\ /
[voice]

c. Attract-[CG]
(ATT-[CG])
LO ←→[CG] (LO : Long duration of Obstruency, that is A_0 A_0 or A_0 A_f)
X] [X
| |
A_0 A_0
|
[CG]

d. PARSE- A_m
(PAR- A_m)
* <A_m >

e. CODA COND, SHA-[voc] >> ATT-[CG] >> PAR- A_m

CODA CONDITION (51a) prevents the maximal aperture (A_m) from occurring in syllable-final position and allows A_0, which represents closure. SHARE–VOICE (51b) demands the sharing of the [voice] feature in the sequence of NC. Attract-[CG] (51c) suggests that when two A_0s are next to each other, [CG] is attracted to the second segment, as shown in (51c). PARSE-A_m (51d) requires the release phase of an obstruent to be preserved. (51e) shows the ranking of constraints (51a), (51b), (51c), and (51d).

(52) illustrates non-occurrence of ObsT after nasals (Rhee 1997:271).

(52) CODA COND, SHA-[voc] >> ATT-[CG] >> PAR- A_m

/pantæ/ ‘opposition’

/n/: GLO [critical], SL [open], Oral [closed], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/p a n tæ/ A_0A_m A_0 A_m / \ [nasal] [voice]	CODA COND	SHA-[voc]	ATT-[CG]	PAR-A_m	*INS-[CG]
a. pa n˺ t’ æ $A_0{<}A_m{>}$ A_0 A_m / \ | [nasal] [voice] [CG]		*!		*	*
b. pa n˺ t æ $A_0{<}A_m{>}$ A_0 A_m / \ [nasal] [voice]		*!	*	*	
☞c. pa n˺ d æ $A_0{<}A_m{>}$ A_0 A_m / \ / [nasal] [voice]			*	*	
d. pa n˪ t’ æ A_0A_m A_0 A_m / \ | [nasal] [voice] [CG]	*!	*	*		*
e. pa n˪ d æ A_0A_m A_0 A_m / \ [nasal] [voice]	*!				

Candidates (52a), (52b), and (52c) satisfy CODA COND because there is no A_m in syllable-final position. Candidates (52d) and (52e) violate CODA COND due to A_m in syllable-final position. Therefore, (52d) and (52e) are not the most optimal because CODA COND is the highest ranked constraint.

Among (52a), (52b), and (52c), (52c) satisfies SHA-[voc]. (52c) violates ATT-[CG] because there is no insertion of [CG] when two A_os are next to each other.

However, violation of ATT-[CG] in (52c) is not important in selecting the most optimal candidate because (52c) satisfies SHA-[voc], which is a higher ranked constraint than ATT-[CG]. Therefore, (52c), which does not attract [CG] when two A_0s are next to each other, is selected as the most optimal candidate.

Rhee (1997)'s analysis of POT contributes to the understanding of POT and the connection between CN and POT. However, there are some issues that still need to be discussed. Constraints and their ranking suggested in (51) fall short in explaining the non-occurrence of ObsT after the lateral /l/. Constraints and their ranking in (51) predict the wrong output when a lax obstruent is preceded by the lateral /l/, as shown in (53). Take as an example /salku/ 'apricot':

(53) CODA COND, SHA-[voc] >> ATT-[CG] >> PAR- A_m

/salku/ 'apricot'

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/sa l k u/ A_m A_0 A_m | [voice]	CODA COND	SHA -[voc]	ATT- [CG]	PAR-A_m	*INS- [CG]
➢ a. s a l˺ . k' u A_0 A_0 A_m | | [voice] [CG]				*!	*
b. s a l˺ . k u A_0 A_0 A_m | [voice]			*!	*	
☞ c. s a l˺ . g u A_0 A_0 A_m \ / [voice]		*!	*	*	
d. s a l[L]* . k' u A_m A_0 A_m | | [voice] [CG]	*!		*		*

* [L] indicates released consonants.

SHA-[voc] is satisfied vacuously in (53a) because SHA-[voc] demands that the [voice] feature be shared in the NC sequence, rather than the LC sequence. Candidate (53a) violates PAR-A_m because A_m for /l/ is not maintained. According to constraints and their hierarchy in (51), (53a➢) is the most optimal candidate but (53c) is the actual output, even though it violates SHA-[voc].

Regardless of the ranking of constraints in (51), the actual output (53c) is not selected as the most optimal candidate. However, in the gesture-based account of POT in this study, constraints and their hierarchy in (34), which are suggested for tensification of lax O2s after an obstruent, correctly predict non-occurrence of ObsT in lax O2s after nasals or the lateral /l/, as shown in (35A) and (35B).

One may modify SHA-[voc] so that the [voice] feature is shared by NC and LC sequences. However, modification of SHA-[voc] to include a nasal and the lateral /l/ poses problems in the verbal morphology, as will be discussed in chapter 4.

In the verbal morphology, an obstruent preceded by either an obstruent or a nasal is tensed, as in [ut̲˺.t̲' a] from /us̲$_{\text{verb stem}}$ + t̲a$_{\text{inflectional suffix}}$/ 'to smile' and [an̲.t̲'a] from /an$_{\text{verb stem}}$ + ta$_{\text{inflectional suffix}}$/ 'to hug'. However, an obstruent preceded by the lateral /l/ is voiced, instead of tensed, as in [sal̲. d̲a] from /sal̲$_{\text{verb stem}}$ + t̲a$_{\text{inflectional suffix}}$/ 'to live'. Therefore, if SHA-[voc] is modified to include nasals and the lateral /l/, they should pattern together with respect to ObsT in the verbal morphology. However, nasals and the lateral /l/ exhibit different patterns with respect to ObsT, as shown in [an̲.t̲'a] from /an$_{\text{verb stem}}$ + ta$_{\text{inflectional suffix}}$/ 'to hug' and [sal̲.d̲a] from /sal̲$_{\text{verb stem}}$ + t̲a$_{\text{inflectional suffix}}$/ 'to live'. Therefore, modification of SHA-[voc] to include NC and LC sequences is unable to resolve the problem in (53).

3.4 Summary

The gesture-based account of POT in this study offers several advantages that previous studies on POT (Han 1992 and 1997, Lee 1994, Kim-Renaud1974, and Rhee 1997) do not offer. The following generalizations and predictions are made through the gesture-based account of POT:

First, the necessary condition for ObsT is that C2 must not have the [open] CD at the SL level. When C2 has the [open] CD at the SL level, lax obstruents in C2 position do not participate in ObsT, as shown in (10). This generalization is possible through constriction degree hierarchies predicted from gestures of active articulators for segments at a given time, as proposed by Browman and Goldstein (1989 and 1990a and 1992).

Second, the systematic relationship between C1 and C2 with respect to ObsT is illustrated in terms of CDs at the SL and Oral Levels. When CDs at the SL and Oral levels are [closed] for C2, the narrower the opening of C1 is, the more C2 is likely to be tensed, as shown in (20) and (21). Therefore, the morphological condition in the verbal morphology and the additional phonological condition in Sino-Korean nouns emerge when gestural conditions of ObsT are relatively weak, as summarized in (24).

Third, the gesture-based account of POT illustrates the close relationship between phonetic implementational conditions for a feature and neutralization of the feature in a given context. As shown in 3.2.3, when C1 is an obstruent and C2 is a lax obstruent in the sequence of V1C1C2V2, relatively long oral-closure duration and minimal glottal opening, which are coupled by heightened oral pressure and tension, promote tensification of the lax-C2 obstruent. This is because long oral-closure duration, minimal glottal opening, heightened oral pressure, and heightened vocal tract tension between two vowels in V1C1C2V2 are properties of tense obstruents, rather than properties of aspirate or lax obstruents.

In addition, the gesture-based account of POT in this study connects an unreleased stop in syllable-final position to POT as Kim-Renaud (1974), Lee (1996) and Rhee (1997) also do. Unreleased stops in syllable-final position increase tense gestures in V1C1C2V2. This implies that when C1 and C2 are obstruents, candidates with an unreleased stop in syllable-final position are preferred over candidates without an unreleased stop. This implication is illustrated in (54).

(54) *[mid]$_{GLO}$/ V1O1__V2>> Max-IO$_{seg}$ >> *CCD/_{#, C} >> IDENT-IO[G] >> Mini Eff=0

/koskan/ 'barn'

/s/: GLO [mid], SL [critical], Oral [critical], TT [critical]
/k/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/koskan/	*[mid]$_{GLO}$/ V1O1__V2	Max-IO$_{seg}$	*CCD/_{#, C}	IDENT-IO[G]	Mini Eff=0
a. kos.kan	*!		*(GLO) *(SL)		
b. kot.kan	*!		*(GLO) *(SL)	*(TTCD)	
c. kot˺.kan	*!		*(SL)	*(TTCD) *(GLO)	*
d. kos.k'an			*(GLO) *!(SL)	*(GLO)	*
e. kot.k'an			*(GLO) *!(SL)	*(TTCD)	*
☞f. kot˺.k'an			*(SL)	*(TTCD) *(GLO)	*

Candidates from (54a), (54b), and (54c) are eliminated as possibilities to be the most optimal candidate because these candidates violate the highest constraint

$*[mid]_{GLO}$/ V1O1__V2. Candidates from (54d), (54e), and (54f) are tied in satisfying $*[mid]_{GLO}$/ V1O1__V2 and Max-IO_{seg}. Therefore, *CCD/_{#, C} plays a role in selecting the most optimal candidate. (54f) violates *CCD/_{#, C} once while (54d) and (54e) violate *CCD/_{#, C} twice. Thus, (54f) is the most optimal candidate. Therefore, *CCD/_{#, C}, which is responsible for CN, plays an active role in selecting the most optimal candidate for ObsT.

Chapter 4 Obstruent patterns after sonorants and /h/

4.1 Introduction

In chapter 3, it was suggested that patterns of ObsT in Korean are closely related to CDs at the SL and Oral levels for C_1 and C_2 in $V_1C_1C_2V_2$. Because gestures and aerodynamic properties of tense, such as minimal glottal opening, and long oral-closure duration, heightened pharyngeal pressure, and vocal tract tension, are sufficient in $V_1O_1O_2V_2$, lax O_2s are tensed obligatorily within an accentual phrase. In other words, when CDs of C_1s are [closed] CDs at the SL and Oral levels in $V_1O_1O_2V_2$, lax O_2s are tensed obligatorily, as shown in section 2.2.2 (11).

This chapter investigates ObsT after nasals or the lateral /t/(Post-lateral Tensification (PLT)), and coalescence of /h/ and a lax stop (Aspiration). Note that nasals, the lateral /l/ and /h/ have the [open] CD at the SL level, as shown in (1b), (1c) and (1d). Chapter4 adds more examples that illustrate the close relationship between phonetic realization and CD in the vocal tact.

(1) CDs of C_1 in $V_1C_1O_2V_2$

	a. Obstruents	b. Nasals	c. Lateral /l/	d. /h/
GLO	[closed], [mid], [open]	[critical]	[critical]	[open]
SL	[closed]/[critical]	[open]	[open]	[open]
Nasal	[closed]	[open]	[closed]	[open]
Oral	[closed]/[critical]	[closed]	[open]	[open]
Lips/	[closed]	[closed]	[open]	[open]
TB/	[closed]	[closed]	[open]	[open]
TT	[closed]/[critical]	[closed]	[closed]	[open]
Phonetic realization of lax O_2	ObsT	ObsT	ObsT	Aspiration
Conditions for ObsT	No conditions	Yes After a verb stem	Yes Sino-Korean nouns O_2 must be /t, s, c/	

(1) shows a close relationship between CDs of C_1 and (non)-occurrence of ObsT. When C_1 does not have any [closed] or [critical] CD at the vocal tract as in /h/ (shaded area in 1d), C_1's influence to the following O_2 is the weakest with respect to ObsT. This is because there is no long oral-closure duration and/or minimal glottal opening. Therefore, in general, aspiration, instead of tensification, of lax O_2s occurs when C_1 is /h/ in Korean.

The first goal of this chapter is to show that there are phonetic motivations behind the conditions for PNT and PLT. The conditions for ObsT are understood best when the articulatory gestures of nasals or the lateral /l/, and principles of co-articulation between two adjacent gestures are taken into account (Browman and Goldstein 1990a and 1990b, Byrd and Tan 1996, J. Jun 1995, and Cho 1998a and 1998b). The second goal of this chapter is to demonstrate that aspiration of lax stops (Aspiration) to a degree results from the optimal satisfaction of constraints suggested for ObsT. The third goal of this chapter is to show that Post-Nasal Tensification (PNT), Post-Lateral Tensification (PLT), and Aspiration result from interaction of the same constraints sensitive to phonetic implementational conditions in a given context, faithfulness constraints, and minimization of articulatory effort as POT does. Therefore, PNT, PLT, and Aspiration, which are treated as unrelated phenomena, are treated as related phenomena and are explained in a unified way in this chapter.

Contrary to POT, there are few studies that discuss ObsT after nasals (PNT 1b), or after the lateral /l/ (PLT 1c) in a unified way, as in this study. In addition, POT, PNT, PLT, and Aspiration of lax C2s are treated with separate rules without any connection to each other in previous studies (Kim-Renaud 1974, Ahn 1985, and Park 1990).

In section 4.3, I show that patterns of [h] are predictable and regular like patterns of other obstruents in Korean such as stops, fricatives and affricates. The regular patterns of /h/ are also motivated by phonetic implementational conditions in a given context. The phonetic realization of /h/ and lax obstruent sequences are considered to be irregular and exceptions in previous Korean studies (Ahn 1985, Cho 1990, Kim-Renaud 1974, Park 1990 and others).

4.2 Obstruent Tensification after sonorants

4.2.1 Introduction

Syllable-initial lax stops after unreleased stops are never voiced across all lexical categories, as shown in (2). Instead tensification of lax O2s occurs due to the distribution of tense gestures in $V_1O_1O_2V_2$, as discussed in chapter 3. Note that data in this chapter is mainly from verbs or Sino-Korean nouns for subsequent discussions on PNT in the verbal morphology and PLT in Sino-Korean nouns.

(2) Verb Stem (VS) Inflectional suffix(IFS)

/us/	+	/ki/$_{\text{gerundial suffix}}$	→	[ut̲˺.k̲'i]	'laughing'
/us/	+	/ta/$_{\text{declarative marker}}$	→	[ut̲˺.t̲'a]	'laugh'
/mək/	+	/ta/$_{\text{declarative marker}}$	→	[mək̲˺.t̲'a]..	'eat'
/mək/	+	/s̲o/$_{\text{command suffix}}$	→	[mək̲˺.s̲'o]..	'do eat'

Sino-Korean nouns

/kukki/	→	[kuk˺. k'i]	'flag'
/kukcɛ/	→	[kuk̲.c̲'ɛ]	'international'

In general, lax-O2 stops are voiced between two vowels (3a), after the lateral /l/ (3b) or nasals (3c) across lexical categories except for certain cases such as in (4) and (5).

(3) a. Voicing of syllable-initial lax stops after a vowel

Verb Stem		Inflectional suffix			
/ha/	+	/ta/$_{\text{declarative suffix}}$	→	[ha.da]	'do something'
/mək/	+	/ə/$_{\text{command suffix}}$	→	[mə.gə]	'do eat'

Sino-Korean nouns

/kaku/	'furniture'	→	[ka.gu]
/sopi/	'consume'	→	[so.bi]

b. Voicing of syllable-initial lax stops after the lateral /l/

Verb Stem		Inflectional suffix			
/mul/	+	/ki/$_{\text{noun derivational suffix}}$	→	[mul.gi]	'biting'
/nol/	+	/ta/$_{\text{declarative suffix}}$	→	[nol.gi]	'play'

Sino-Korean nouns

/malki/	→	[mal.gi]	'the end period'
/pulpok/	→	[pul.bok]	'disobedience'

c. Voicing of stops between a nasal and a vowel.

Verb Stem		Inflectional suffix			
/əŋki/	+	/nta/ *	→	[əŋ.gin.da]	'harden'
/o/	+	/nta/	→	[on.da]	'come'

*/nta/ is used after an action verb stem ending in a vowel and used for writing essays and reports as simple or plain style statements.

Sino-Korean nouns

/tanki/	'short period'	→	[tan.g i]
/kamtok/	'inspector'	→	[kam.dok]

There are certain cases where lax stops are not voiced after nasals or the lateral /l/ in the verbal morphology and Sino-Korean nouns. Instead, obstruents after verb-stem-ending nasals or /t, s, c/ after the lateral /l/ in Sino-Korean nouns are tensed, as shown in (4) and (5).

The difference between (4a) and (4b) is that nasals in (4a) end verb stems while nasals in (4b) do not end verb stems.

(4) a. ObsT after verb-stem-ending nasals

Verb Stem		Inflectional suffix			
/kam/	+	/so/$_{\text{command suffix}}$	→	[kam$_{\text{VS}}$.s'o]	'do wind'
/an/	+	/ki/$_{\text{gerundial suffix}}$	→	[an$_{\text{VS}}$.k'i]	'hugging'
/an/	+	/ta/$_{\text{declarative marker}}$	→	[an$_{\text{VS}}$.t'a]	'hug'

b. Voicing after nasals

Verb Stem		Inflectional suffix			
/o/	+	/nta/	→	[o$_{\text{VS}}$n.da]	'come'
/əŋki/	+	/ta/ $_{\text{declarative marker}}$	→	[əŋ.gi$_{\text{VS}}$.da]	'harden'

A comparison of (4a) and (4b) reveals that syllable-initial lax-O2 stops are tensed after nasals that end verb stems. Otherwise, syllable-initial lax-O2 stops are voiced in the verbal morphology.

In addition to (4), /t, s, c/ after the lateral /l/ are tensed in Sino-Korean nouns, as shown in (5a). However, /k, p/ after the lateral /l/ are not tensed, instead they are voiced in Sino-Korean nouns.

(5) a. Tensification of /t, s, c/ after the lateral /l/ in Sino-Korean nouns

/kalciŋ/	→	[kal.c'iŋ]	'thirsty'
/paltal/	→	[pal.t'al]	'development'
/ilsa ŋ /	→	[il.s'aŋ]	'everyday'

b. Voicing after the lateral /l/ or nasals in Sino-Korean nouns

/malki/	→	[mal.gi]	'the ending period'
/pulpok/	→	[pul.bok]	'disobedience'
/kamtok/	→	[kam. dok]	'inspector'

4. 2. 2 The gesture-based account of tensification after sonorants

Constraints suggested for POT in chapter 3 play a role to a degree in selecting output forms in (2). (6) evaluates candidates from /mək/$_{\text{verb stem}}$ + /ta/$_{\text{declarative marker}}$ 'to eat' against constraints suggested in chapter 3 (43). Note that /mək+ta/ has the sequence $V_1O_1O_2V_2$.

(6) *COMPLEX, *[mid]$_{\text{GLO}}$/ V_1O_1__V_2 >> *[mid]$_{\text{GLO}}$/ V_1N__V_2 >> *[mid]$_{\text{GLO}}$/ V_1L__V_2 >> Max-IO$_{\text{seg}}$ >> *CCD/_{#, C} >> IDENT-IO[G] >> Mini Eff=0

/mək/$_{\text{VS}}$ + /ta/$_{\text{IFS}}$ 'to eat'

/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/t/: GLO [mid], SL [critical], Oral [critical], TT [critical]

/mək/+ /ta/	*COMP	*[mid]$_{\text{GLO}}$/ V_1O_1 V_2	Max-IO$_{\text{seg}}$	*CCD/_{#, C}	IDENT-IO[G]	Mini Eff=0
a. mək.ta		*!		**(GLO) (SL)		
b. mək˺.ta		*!		*(SL)	*(GLO)	*
c. mək.tʰa				*!*(GLO) (SL)	*(GLO)	*
d. mək.t'a				*!*(GLO) (SL)	*(GLO)	*
e. mək˺.tʰa				*(SL)	** (GLO)	**!
☞f. mək˺.t'a				*(SL)	** (GLO)	*

Candidates (6a) and (6b) violate the highest-ranked constraint *[mid]$_{GLO}$/ V1O1__V2, which prevents GLO [mid] from occurring in a position where gestures related to lax obstruents are lacking or absent. Therefore, (6a) and (6b) are eliminated by *[mid]$_{GLO}$/ V1O1__V2.

Candidates (6c), (6d), (6e), and (6f) violate *CCD/_{#, C}, which does not allow contrastive CDs in syllable-final position. However, violations in (6e) and (6f) are less critical than violations in (6c) and (6d) because (6e) and (6f) violate *CCD/_{#, C} only once. (6e) and (6f) are tied in violations of IDENT-IO[G] because the input glottal gestures for /k/ and /t/ are not preserved in [mək̲˺.t̲'a] (6e) and [mək̲˺.t̲ʰa] (6f).

Therefore, the next lower-ranked constraint Mini Eff=0 plays a role in selecting the most optimal candidate. (6e) violates Mini Eff=0 twice because CDs at the glottis for C1 and C2 are [critical] and [open] respectively. (6f) violates Mini Eff=0 once because CDs at the glottis for C1 and C2 are [critical] and [mid] respectively. Therefore, (6f) satisfies constraints in (6) best, and is the most optimal candidate and the actual output.

However, in certain cases actual output forms are not selected as the most optimal candidates according to constraints in (6), as shown in (7) and (8). (7A) and (7B) evaluate candidates from /o/$_{VS}$ + /n̲ta/$_{IFS}$ 'to com' and /an̲/$_{VS}$+ /t̲a/$_{IFS}$ 'hug' respectively. Note that in /o/$_{VS}$ + /n̲ta/$_{IFS}$ 'come', the nasal /n/ does not end the verb stem, as shown in data (4b), while in /an̲/$_{VS}$ + /t̲a/$_{IFS}$ 'hug', the nasal /n/ ends the verb stem, as shown in data (4a).

(7) *COMPLEX, *[mid]$_{GLO}$/ V1N__V2 >> Max-IO$_{seg}$ >> *CCD/_{#, C} >> IDENT-IO[G] >> Mini Eff=0

A. /o/$_{VS}$ + /nta/$_{IFS}$‘come’

/n/: GLO [critical], SL [open], Oral [closed], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

o$_{VS}$ + n̲t̲a $_{IFS}$	*COMP	*[mid]$_{GLO}$/ V1N__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	IDENT -IO[G]	Mini Eff=0
a. on.t̲a		*!				*
b. on.t̲’a					*[GLO]	*!
c. on.t̲ʰa					*[GLO]	**!
☞d. on̲.d̲a					*[GLO]	

B. /an/$_{VS}$+/ta/$_{IFS}$ ‘hug’

/n/: GLO [critical], SL [open], Oral [closed], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

an̲$_{VS}$+t̲a$_{IFS}$	*COMP	*[mid]$_{GLO}$/ V1N__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	IDENT -IO[G]	Mini Eff=0
a. an.t̲æ		*!				*
☞ b. an.t̲’æ					*	*
c. an.t̲ʰæ					*	**!
➢ d. an.d̲a					*	

Candidates (7Aa) and (7Ba) violate *[mid]$_{GLO}$/V1N__V2 because [t] is in the position where gestures to lax obstruents are not abundant. As mentioned in Rhee (1997) and Kim-Renaud (1974), in V1N O1V2, heightened pharyngeal pressure and tension may be relatively low due to the [open] CD at the SL level for nasals. However, there is a long oral-closure duration in V1NO1V2, which is one of the important properties of tense obstruents, as shown in Han (1997). According to Ohala (1983), longer oral-closure duration is likely to create unfavorable phonetic implementational conditions for voicing.

Candidates in (7A) and (7B) except (7Aa) and (7Ba) are tied in IDENT-IO[G] because they do not maintain the input glottal gestures. Therefore constraints lower than IDENT-IO[G] play a role in selecting the most optimal candidate.

(7Ac) and (7Bc) violate Mini Eff=0 to the greatest degree because glottal gestures move from the [critical] CD for sonorants to the [open] CD for aspirated obstruents, thus violating Mini Eff=0 twice. Candidates (7Ab), and (7Bb) violate Mini Eff=0 once because CDs of glottal gestures for C1 and O2 are one degree narrower with respect to each other. Candidates (7Ad) and (7Bd) satisfy Mini Eff=0 most optimally because CDs of glottal gestures are identical, being [critical]. Therefore, according to constraints and their ranking in (6), (7Ad☞) and (7Bd➢) are the most optimal candidates.

However in (7B), the actual output is (7Bb☞), not the most optimal candidate (7Bd➢) selected by (6). Candidate evaluation from /paltal/ in Sino-Korean nouns reaches the same conclusion. The most optimal candidate (7Bd➢) selected by constraints in (6) is not the actual output, as shown in (8).

(8) *COMPLEX, *[mid]$_{GLO}$/ V1L__V2 >> Max-IO$_{seg}$ >> *CCD/_{#, C} >> IDENT-IO[G] >> Mini Eff=0

/paltal/$_{SinoK}$ 'development' ($_{SinoK}$: Sino-Korean nouns)

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/paltal/ $_{Sino\text{-}K}$	*COMP	*[mid]$_{GLO}$/ V1L__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	IDENT-IO[G]	Mini Eff=0
a. pal.tal		*!				*
☞ b. pal.t'al					*	*
c. pal.tʰal					*	**!
➢ d. pal.dal					*	

(8a) is not the most optimal candidate because it violates *[mid]$_{GLO}$/ V1L__V2, which is ranked relatively high in the constraint hierarchy. Candidates (8b), (8c) and (8d) are tied in violation of IDENT-IO[G]. Therefore, Mini Eff=0 selects the most optimal candidate. Candidate (8d➢) is the most optimal candidate according to (6) because [l] and [d] have identical [critical] CDs at the glottis, and therefore no displacement of the glottis. Recall that the CD value of the glottis for [+voice] feature is [critical] (Browman and Goldstein 1989: 225). The most optimal candidate (8d➢) selected by constraints in (6) is not the actual output (8b☞).

(9) compares the most optimal candidates selected by (6) and actual outputs, using (8Bb☞) and (8Bd➢).

(9) /paltal/$_{SinoK}$ 'development' ($_{SinoK}$: Sino-Korean nouns)

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/paltal/$_{SinoK}$	*COMP	*[mid]$_{GLO}$/ V1N__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	IDENT-IO[G]	Mini Eff=0
a. pal.t'al (8Bb☞)					*	*
☞ b pal.dal (8Bd➢)					*	

The lax stop /t/ is voiced after the lateral /l/, satisfying Mini Eff=0 in (9b), which is the most optimal candidate according (6). However, /t. s, c/ after the lateral /l/ as in (5a) are tensed in Sino-Korean nouns, as shown in candidate (9a). In addition, lax stops except /t/ as in (5b), are voiced after the lateral /l/, as shown in (9b).

Therefore, constraints and their rankings responsible for ObsT should be sensitive to morphological information. I suggest (10a) and (10b), which prevent voicing of lax-

O2 stops after verb-stem-ending nasals or after the lateral /l/ when O2 is /t, s, c/ in Sino-Korean nouns respectively.

(10) a. *[critical]$_{GLO}$/ V1N]$_{VS}$ __V2: (VS: verb stem)
GLO [critical], namely voicing, is not allowed after nasals that end verb stems.

b. *[critical]$_{GLO}$/ V1L__V2 when O2 is /t, s, c/: (Sino-Korean nouns)
GLO [critical], namely voicing, is not allowed after the lateral /l/ when O2 is /t, s, c/ in Sino-Korean nouns. (hereafter *[d, z, dʒ]$_{SinoK}$/ V1L__V2)

Before evaluating candidates against (10), because in OT constraints are supposed to be universal, I will provide phonetic motivation for the morphological or additional phonological conditions for PNT and PLT. Note that in Korean, lax obstruents are never voiced after unreleased stops, as shown in (3), due to the abundant tense gestures between the two vowels in $V_1O_1O_2V_2$.

In addition, Ohala (1983: 199) suggests that 'a voiceless one (stop) becoming voiced depends in a major way on the duration of the stop closure, a shorter duration allowing voicing to be maintained for all of, or a majority of, the stop duration'. Based on (3) and Ohala's suggestion, I propose the following harmonic scales for voicing of lax stops in $V_1C_1O_2V_2$.

(11) Favorable conditions for voicing of lax-O2 stops

	a. Lateral	O2		b. Nasals	O2		c. O1	O2
SL	**open**	closed	⊃	**open**	closed	⊃	**closed**	closed
Oral	**open**	closed		**closed**	closed		**closed**	closed

A ⊃ B: A is more favorable than B for voicing of lax-O2 stops.

(11) illustrates that the more C1 has [open] CDs in the vocal tract, the more lax-O2 is likely to be voiced in $V_1C_1O_2V_2$. Interestingly, the harmonic scales for voicing of lax-O2 stops in (10) are the reversed harmonic scales for tensification of lax-O2s in $V_1C_1O_2V_2$ (see chapter 3 (31)). Ohala (1983: 295) suggests that 'the longer the stop closure is, the greater is the likelihood that voicing will be extinguished.'

S. A. Jun (1995:250) shows that because of the overlapping of consonant and vowel gestures, word-medial lax voiceless stops in (3a) have the smallest and shortest glottal opening that facilitates voicing of lax stops. In addition, Browman and Goldstein (1990a: 370) describe voicing assimilation as 'a reduction in the magnitude of the glottal opening-and-closing gestures responsible for the voicelessness'.

Based on Ohala (1983), S. A. Jun (1995), and Browman and Goldstein (1990a), I assume that due to [open] CDs at the SL and Oral levels of the lateral /l/, gestures related to voicing, such as the [critical] glottal opening and sufficient airflow through the [critical] CD of the glottis, are distributed more in $V_1LO_2V_2$ (11a) than in $V_1O_1O_2V_2$ (11c). Therefore, voicing of lax-O2 stops after the lateral /l/ is more phonetically natural than voicing of lax-O2 stops after nasals or unreleased stops. In addition, due to the [open] CD at the SL level and the [closed] CD at the Oral level for nasals, voicing of lax-O2 stops after nasals is less phonetically natural than voicing of lax-O2 stops after the lateral /l/. However, voicing of lax-O2 stops after nasals is more phonetically natural than for voicing of lax-O2 stops after unreleased stops.

However, the phonetically grounded tendency of voicing can be interrupted in languages because of two reasons: a faithfulness constraint and/or morphology-sensitive constraints. If an input-output faithfulness constraint such as IDENT-IO[G] is ranked relatively high in a language, the input glottal gestures are maintained in the output. However, as seen in chapters 2 and 3, in Korean IDENT-IO[G] is ranked relatively low in the constraint hierarchy. Therefore, I assume that in Korean, morphological conditions, such as verb-stem-ending or Sino-Korean nouns, play a role in interrupting the voicing tendencies of lax voiceless stops in a given context.

In addition, I suggest that the stronger phonetic conditions for a phonological process are, the more conditions may be attached to interrupt the process. Therefore, because the L-lax O2 sequence has the strongest phonetic conditions for voicing of lax O2s, disallowing voicing of lax-O2 stops after the lateral /l/ requires both morphological and additional phonological conditions, as shown in (10b). Because the N-lax O2 sequence has weaker phonetic conditions for voicing of lax O2s than that of the L-lax O2 sequence, disallowing voicing of lax-O2 stops after nasals only requires the morphological condition, as shown in (10a). Therefore, there is a close relationship between distribution of voicing gestures and morphological conditions.

(10a) and (10b) are ranked higher than IDENT-IO[G] because the output forms in (4) and (5) do not preserved the input gestures. Violation of IDENT-IO[G] is taken for granted in the output froms of (4) and (5). As there is no conclusive evidence that (10a) and (10b) are ranked higher than *CCD/_{#, C} or Max-IO$_{seg}$, constraints (10a) and (10b) are unranked with respect to *CCD/_{#, C} as in (12) until proven otherwise.

(12) *COMPLEX, *[mid]$_{GLO}$/ V1N__V2 >> Max-IO$_{seg}$ >> *CCD/_{#, C}, *[critical]$_{GLO}$/ V1N]$_{VS}$ __V2, *[d, z, dʒ]$_{SinoK}$/V1L__V2>> IDENT-IO[G] >> Mini Eff=0

A. /o/$_{VS}$ + /nta/$_{IFS}$ 'come'

/n/: GLO [critical], SL [open], Oral [closed], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

o$_{VS}$ + nta $_{IFS}$	*COMP	*[mid]$_{GLO}$/ V1N__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	*[critical]$_{GLO}$/ V1N]$_{VS}$ __V2	IDENT -IO[G]	Mini Eff=0
a. on.ta		*!					*
b. on.t'a						*[GLO]	*!
c. on.tʰa						*[GLO]	**!
☞d. on.da						*[GLO]	

B. /an/$_{VS}$+/ta/ $_{IFS}$ 'hug'

/n/: GLO [critical], SL [open], Oral [closed], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

an$_{VS}$+ta $_{IFS}$	*COMP	*[mid]$_{GLO}$/ V1N__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	*[critical]$_{GLO}$/ V1N]$_{VS}$ __V2	IDENT -IO[G]	Mini Eff=0
a. an.ta		*!					*
☞ b. an.t'a						*	*
c. an.tʰa						*	**!
d. an.da					*!	*	

(12Aa) is eliminated by *[mid]$_{GLO}$/ V1N__V2, as GLO [mid] appears in the position where phonetic implementational conditions promote voicing rather than lax stops due to the [critical] CD of the glottis and the [open] CD at the SL Level for nasals. The constraint *[critical]$_{GLO}$/ V1N]$_{VS}$ __V2 is irrelevant to candidates in (12A) because the vowel /o/ ends the verb stem, instead of the nasal /n/, as in /o/$_{VS}$ + /nta/$_{IFS}$ 'come'. (12Ab), (12Ac), and (12Ad) violate IDENT-IO[G] once because the input [mid] glottal CD for /t/ is not preserved in each output candidate. Therefore, the next lower-ranked constraint Mini Eff=0 evaluates (12Ab), (12Ac), and (12Ad). Candidate (12Ad) satisfies Mini Eff=0 most optimally because both [n] and [d] have [critical] CDs at the glottis. Thus, there is no displacement of the glottis between [n] and [d]. Therefore, candidate (12Ad) is the most optimal candidate and the actual output form.

In the tableau (12B), the constraint *[critical]$_{GLO}$/ V1N]$_{VS}$ __V2 plays a role in candidate evaluation because the nasal /n/ ends the verb stem, as in /an/$_{VS}$+/ta/$_{IFS}$ 'hug'. Candidate (12Bd) is eliminated by *[critical]$_{GLO}$/ V1N]$_{VS}$ __V2. Candidates (12Bb) and (12Bc) are tied in violation of IDENT-IO[G]. Therefore, both candidates (12Bb) and (12Bc) are passed on to the next-lower ranked constraint Mini Eff=0. Although both candidates violate Mini Eff=0, (12Bb) is selected as the most optimal candidate because in (12Bb), the displacement of the glottis between two consonants is less than that of (12Bc).

Tableau (13) evaluates /paltal/$_{SinoK}$ 'development' and /pulpok/$_{SinoK}$ 'disobedience'. Note that /paltal/$_{SinoK}$ has /t/ after the lateral /l/ and /pulpok/$_{SinoK}$ has /p/ after the lateral /l/.

(13) *COMPLEX, *[mid]$_{GLO}$/ V1N__V2 >> Max-IO$_{seg}$ >> *CCD/_{#, C}, *[critical]$_{GLO}$/V1N]$_{VS}$ __V2, *[d, z, dʒ]$_{SinoK}$/V1L__V2>>
IDENT-IO[G] >> Mini Eff=0

A. /paltal/$_{SinoK}$ 'development' ($_{SinoK}$: Sino-Korean nouns)

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/t/: GLO [mid], SL [closed], Oral [closed], TT [closed]

/paltal/ $_{Sino-K}$	*COMP	*[mid]$_{GLO}$/ V1L__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	*[d, z, dʒ]$_{SinoK}$ /V1L__V2	IDENT -IO[G]	Mini Eff=0
a. pal.t̲al		*!					*
☞ b. pal.t̲'al						*	*
c. pal.t̲^{h}al						*	**!
d. pal.d̲al					*!	*	

B. /pulpok/$_{SinoK}$ 'disobedience' ($_{SinoK}$: Sino-Korean nouns)

/l/: GLO [critical], SL [open], Oral [open], TB [open], TT [closed]
/p/: GLO [mid], SL [closed], Oral [closed], Lips [closed]

/pulpok/$_{Sino-K}$	*COMP	*[mid]$_{GLO}$/ V1L__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	*[d, z, dʒ]$_{SinoK}$ /V1L__V2	IDENT -IO[G]	Mini Eff=0
a. pul.p̲ok		*!					*
b. pul.p̲'ok						*	*
c. pul.p̲^{h}ok						*	**!
☞ d. pul.b̲ok						*	

The constraint *[d, z, dʒ]$_{SinoK}$/ V1L__V2 is active in (13A) but inactive in (13B). Therefore, candidate (13Ab) is the most optimal candidate because it does not have the voiced [d] after the lateral [l] and articulatory effort is minimal. However output candidates in (13B) vacuously satisfy *[d, z, dʒ]$_{SinoK}$/ V1L__V2. Therefore, (13Bd) is selected as the most optimal candidate because there is no displacement of the glottis between [l] and [b]. Tableaux (12) and (13) show that constraints suggested in (10) and constraints suggested for POT in chapter 3 (33) correctly predict actual output forms in the verbal morphology and Sino-Korean nouns. Therefore, PNT in the verbal morphology and PLT in the Sino-Korean nouns result from interaction of the same output constraints suggested for POT. Thus, PNT, PLT, and POT are connected and related together to the extent that they share the same constraints.

Up to this point, I have suggested constraints responsible for PNT in the verbal morphology and PLT in Sino-Korean nouns in (10). In addition, I have also provided the phonetic motivation related to distribution of voicing gestures and morphological and additional phonological conditions in (10b).

Therefore, it is time to provide phonetic reasons why all lax O2s that follow nasals are tensed in verbal morphology while only /t, s, c/ that follow the lateral /l/ are tensed in Sino-Korean nouns. I suggest that lax O2s are tensed at the level where CDs of C1 and C2 form [closed][closed] or [closed][critical] CD sequences, as shown in (14) and (15).

(14)

		N	lax O2
	SL	[open]	[closed/critical]
	Oral	[closed]	[closed]
	TB	[closed]/ŋ/	[closed] /k/
	TT	[closed] /n/	[closed/critical] /t, c, s/
	Lips	[closed] /m/	[closed] /p/

In N-lax O2 sequences, [closed][closed] or [closed][critical] CD sequences are formed at the Oral level. Therefore, all lax O2s are tensed after nasals because lax O2s are specified with the [closed] CD at the Oral level for /p, t, k/, the [critical] CD at the Oral level for /s/, and the [closed/critical] CD at the Oral level for /c/. In N-lax O2 sequences, due to the overlapping of nasals and lax O2s, when the obstruents begin, there is still a bit of air flowing out of the nose (Kager 1999:61). Therefore N-lax O2 sequences do not have ideal conditions for ObsT. Thus, ObsT occurs when morphology-sensitive constraints such as (10a) are active, as shown in (12Bb).

In L-lax O2 sequences, [closed][closed] or [closed][critical] CD sequences are formed only at the TT level (shaded area), as shown in (15a).

(15) a	L	lax O2	b. L	lax O2
SL	[open]	[closed/critical]	[open]	[closed]
Oral	[open]	[closed]	[open]	[closed]
TB	[open]	[closed]	[open]	[closed] /p/
TT	[closed] /l/	[closed/critical] /t, c, s/	[closed] /l/	[open]
Lips	[open]	[open]	[open]	[closed] /k/

/t, s, c/ after the lateral /l/ form [closed][closed] or [closed][critical] CD sequences at the TT level because /l/ and /t, s, c/ share the TT, as shown in (15a). However, /p, k/ after the lateral /l/ never form [closed][closed] or [closed][critical] CD sequences, as shown in (15b). Therefore, /t, s, c/ after the lateral /l/ are tensed, resulting in [t', s', c'] respectively while /p, k/ after the lateral /l/ are voiced, resulting in [b] and [g], as shown in [mal.gi] from /malki/$_{\text{Sino-K}}$ 'finishing period' and [pul.bok]$_{\text{Sino-K}}$ from /pulpok/ 'disobedience'.

In the sequence of /l/-/t, s, c/, there is a prolonged [closed] CD of the tongue tip as shown in (15a). Distribution of tense gestures may be increased to a degree due to the long closure duration of the tongue tip. However, in /l/-/p, k/, there are no consecutive [closed] CDs of an oral articulator , as shown in (15b). When the oral articulator moves from the TT to the TB, a leakage of air occurs. Therefore, only ObsT of /t, s, c/ after the lateral /l/ is allowed in Sino-Korean nouns.

4. 2. 3 Summary

Tableaux (6), (12), and (13) reveal that phonetically motivated constraints and their hierarchies responsible for POT do not change according to lexical categories in Korean. Only morphology-sensitive constraints such as $*[\text{critical}]_{GLO}/V1N]_{VS}$ __V2 and $*[d, z, dʒ]_{SinoK}/V1L$__V2 are active or inactive according to lexical items evaluated as shown in (12) and (13). Therefore, I have shown that POT, PNT, PLT, and voicing of voiceless lax-O2 stops result from interaction of the same phonetically grounded constraints. Therefore, there is no need to suggest different phonological rules as has been the case in the Korean linguistic literature (Kim-Renaud 1974, Ahn 1985, Sohn 1987, and many others) (e.g. chapter 3 (48)).

In addition, I have suggested in the gesture-based account of PNT and PLT that morphological and/or additional phonological conditions emerge to interrupt strong phonological or phonetic conditions for voicing of lax-O2 stops. Therefore, there is a close relationship between morphological and/or additional phonological conditions and distribution of gestures relevant to voicing or tense in a given context.

In addition, the gesture-based account of PNT and PLT in this study provides phonetic reasons why all lax O2s are tensed after verb-stem-ending nasals in verbal morphology while only /t, s, c/ after the /l/ are tensed in Sino-Korean nouns, as shown in (14) and (15). Patterns of PNT and PLT are motivated by CDs in the vocal tract as is POT. Therefore, ObsT occurs at the levels where CDs of C1 and C2 form [closed][closed] or [closed][critical] CD sequences. This is because [closed][closed] or [closed][critical] CD sequences create favorable conditions for tensification of lax O2s rather than voicing of lax-O2 stops (Ohala 1983).

4.3 Patterns of /h/ and obstruent sequences

4.3.1 Introduction

No surface forms end with [h] in Korean. Therefore /h/ cannot be in syllable and word-final position. However, due to morphological concatenations such as addition of a prefix or suffix, there are cases where /h/ appears before lax-O2 stops, resulting in the sequence of $V_1hO_2V_2$, as shown in (16).

(16) a. Lax-O2 stop aspiration: fast or casual style of speech

Input	Output	
/su$\underline{h}$/$_{prefix}$ 'male' + /$\underline{k}$æ/ 'dog'	[su.$\underline{k}^h$æ]	'male dog'
/su$\underline{h}$/ $_{prefix}$ 'male' + /$\underline{p}$əm/ 'tiger'	[su.$\underline{p}^h$əm]	'male tiger'
/no$\underline{h}$/$_{VS}$ 'to place' +/ko/$_{IFM}$	[no.$\underline{k}^h$o]	'place and'
/no$\underline{h}$ /$_{VS}$ + /$\underline{c}$a/ $_{IFM}$	[no.$\underline{c}^h$a],	'let's place something'

b. Lax-O2 stop aspiration and CN of /h/:
slow or formal style of speech (Kim-Renaud 1974: 124)

Input	Output	
/su$\underline{h}$/$_{prefix}$ 'male' + /$\underline{k}$æ/ 'dog'	[su$\underline{t}$˺.$\underline{k}^h$æ]	'male dog'
/su$\underline{h}$/ $_{prefix}$ 'male' + /$\underline{p}$əm/ 'tiger'	[su$\underline{t}$˺.$\underline{p}^h$m]	'male tiger'
/no$\underline{h}$/$_{VS}$ 'to place' +/ko/$_{IFM}$	[no$\underline{t}$˺.$\underline{k}^h$o]	'place and'
/no$\underline{h}$ /$_{VS}$ + /$\underline{c}$a/ $_{IFM}$	[no$\underline{t}$˺.$\underline{c}^h$i]	'let's place something'

c. Lax-O2 stop aspiration and regressive place assimilation and CN:
slow but casual style of speech (Park 1990: 119)

Input	Output	
/su<u>h</u>/$_{prefix}$ 'male' + /<u>k</u>æ/ 'dog'	[su<u>k</u>˺.<u>k</u>ʰæ]	'male dog'
/su<u>h</u>/ $_{prefix}$ 'male' + /<u>p</u>əm/ 'tiger'	[su<u>p</u>˺.<u>p</u>ʰəm]	'male tiger'
/no<u>h</u>/$_{VS}$ 'to place' +/ko/$_{IFM}$	[no<u>k</u>˺.<u>k</u>ʰo]	'place and'
/no<u>h</u> /$_{VS}$ 'to place' + /<u>c</u>a/$_{IFM}$	[no<u>t</u>˺.<u>c</u>ʰa]	'let's place something'

If the underlying forms of the prefix 'male' and the verb 'to place' are /su/ and /no/ respectively, as in the output form (16a), /k/ in /kæ/ 'dog' and /k/ in /ko/$_{IFM}$ should be voiced between two vowels, rather than aspirated. Therefore, the underlying forms of the prefix 'male' and the verb 'to place' are /suh/ and /noh/ respectively, as shown in (16a).

Recall that in V1O1O2V2, O1 is neutralized as an unreleased stop in syllable-final position due to *CCD/_ {#, C} and lax O2 is tensed obligatorily in Korean. However, in the sequence of V1hO2V2, although /h/ is considered as an obstruent at the VT level, as shown in chapter 1 (27), a lax-O2 stop after /h/ is not tensed. Instead, /h/ and a lax-O2 stop are obligatorily coalesced into an aspirate stop, as shown in (16).

Although coalescence of /h/ and a lax-O2 stop in V1hO2V2 is obligatory, neutralization of /h/ in syllable-final position depends on the rate or style of speech as shown in (16b) and (16c). According to Park (1990) and Kim-Renaud (1974:124), output forms such as (16b) and (16c) appear 'in a slow, bookish, emphatic pronunciation'. I assume that output forms in (16c) result from regressive place assimilation, which is optional in the casual style of speech in Korean. Therefore, I analyze (16b) and (16c) together in this study. However, constraints related to place assimilation are not discussed here because this study mainly investigates manner of articulation (see J. Jun 1995 for place assimilation within OT)

In addition to (16), a lax-O1 stop and /h/ in V1O1hV2 are obligatorily coalesced into an aspirate stop, as shown in (17).

(17) a. Lax-O1 stop aspiration: fast or casual style of speech

Input	Output	
/nak$\underline{h}$a/	[na.$\underline{k}^{h}$a]	‘falling’
/kɨ$\underline{ph}$i/	[kɨ.$\underline{p}^{h}$i]	‘in a hurry’
/anc+hi +da/	[an.$\underline{c}^{h}$i.da]	‘be seated’
/mas/ ‘taste’ + /hako/ ‘and’	[ma.$\underline{t}^{h}$a.go]	‘and taste’

b. Lax-O1 stop aspiration and CN of O1: slow or formal style of speech

Input	Output	
/nak$\underline{h}$a/	[na$\underline{k}$˺.$\underline{k}^{h}$a]	'falling'
/kɨ$\underline{ph}$i/	[kɨ$\underline{p}$˺.$\underline{p}^{h}$i]	‘in a hurry’(adverb)
/mas/ ‘taste’ + /hako/ ‘and’	[ma$\underline{t}$.$\underline{t}^{h}$a.go]	‘and taste’

Although a lax-O1 stop and /h/ in V1O1hV2 are obstruents, neutralization of lax-O1 stops in syllable-final position depends on the rate or style of speech while aspiration of lax-O1 stops is obligatory in Korean. In summary, data in (16) and (17) shows that lax stops preceded or followed by /h/ are coalesced together obligatorily.

Up to this point, I have shown cases where lax O1 and O2 are stops in sequences of V1O1hV2 or V1hO2V2. When lax O1 and O2 are fricatives (F), phonetic realization of the fricatives depends on the location of the fricatives relative to /h/, as shown in (18).

(18) A. V1FhV2 (F: fricatives)

a. Aspiration: fast or casual style of speech

Input	Output	
/mas/ 'taste' + /hako/ 'and'	[ma.t^ha.go]	'and taste'
/su$\underline{h}$/$_{prefix}$ 'male' + /$\underline{h}$ama/	[su.$\underline{t}^h$a.ma]	'male hippo'

b. Aspiration and CN of O1: slow or formal style of speech

Input	Output	
/mas/ 'taste' + /hako/ 'and'	[mat˺.t^ha.go]	'and taste'
/su$\underline{h}$/$_{prefix}$ 'male' + /$\underline{h}$ama/	[sut˺.$\underline{t}^h$a.ma]	'male hippo'

B. V1hsV2

a. Tensification of /s/: fast or casual style of speech

Input	Output	
/su$\underline{h}$/$_{prefix}$ 'male' + /so/ 'cow'	[su.$\underline{s}$'o]	'ox'
/no$\underline{h}$/ 'to place' + /$\underline{s}$o/ $_{IFM}$	[no.$\underline{s}$'o]	'place (command)'

b. Tensification of /s/ and CN of /h/: slow or formal style of speech

Input	Output	
/su$\underline{h}$/$_{prefix}$ 'male' + /so/ 'cow'	[sut˺.$\underline{s}$'o]	'ox'
/no$\underline{h}$/ 'to place' + /$\underline{s}$o/$_{IFM}$	[not˺.$\underline{s}$'o]	'place (command)'

The Fh cluster in V1FhV2 (F: fricatives) (18A) patterns similar to (17). Therefore, output forms always have aspiration of lax stops. However, the oral fricative /s/ after /h/ is tensed as shown in (18B). In (18Ab) and (18Bb), neutralization of O1 depends on the rate or style of speech, as shown in (16b), (16c), and (17b). Hereafter, the term 'Aspiration' covers coalescence of /h/ and lax obstruents, as shown in (16), (17) and

(18A). Because tensification of /s/ in the /s/-/h/ sequence has been discussed in section 2.2.3 and chapter 3, (18B) will not be discussed in the following sections.

Patterns of /h/ in (16), (17) and (18) are treated with separate phonological rules in previous approaches (Kim-Renaud 1974, Park 1990 and others), as will be shown in the following section.

4.3.2 Previous studies

Though different in details, Aspiration in (16a) and (17a) is described in the Korean linguistic literature (Cho 1990, Park 1990, and Kim 1986) by using a mirror image rule such as (19).

(19) Mirror image rule (Park 1990: 113): Aspiration

$$\left\{\begin{array}{ll} \begin{bmatrix}-\text{tense}\\ -\text{continuant}\\ 1\end{bmatrix} & \begin{array}{c} h \\ 2 \end{array} \\ \begin{array}{c} h \\ 2 \end{array} & \begin{bmatrix}-\text{tense}\\ -\text{continuant}\\ 1\end{bmatrix} \end{array}\right\} \longrightarrow \begin{array}{cc} [+\text{asp}] & \varnothing \\ 1 & \end{array}$$

(19) states that a lax stop and /h/ are coalesced into aspirate stops, resulting in [su.$\underline{k}^h$æ] from /su$\underline{h}$/$_{prefix}$ 'male' + /$\underline{k}$æ/ 'dog' or [na.$\underline{k}^h$a] from /na$\underline{kh}$a/ 'falling', as in data (16a) and (17a).

According to Kim-Renaud (1974) and Park (1990), the rule order of CN-related rules (20a-c) after Aspiration (19) is responsible for output forms in (16b) and (17b), as shown in (20). The default rules (20b) and (20c) are suggested for /h/ → [t˺] in syllable-final position, as shown in (20d).

(20) a. h → [-release]/ ___$ ($: syllable boundary)
b. [h, -release] → [+coronal] } CN
c. [-release] → [-asp, -tense, -cont]

	Aspiration		CN
d. /su$\underline{h}$/$_{\text{prefix}}$ 'male' + /$\underline{k}$æ/ 'dog' →	[suh.$\underline{k}^{h}$æ]	→	[sut˺.$\underline{k}^{h}$æ]

In addition, Park (1990) proposes an optional rule which inserts a homorganic consonant between a vowel and a tense or aspirate consonant in order to explain data in (16c) and (17b). The insertion of a homorganic consonant is applied after aspiration as in (21).

(21) Input		Aspiration (18)		Insertion of a homorganic consonant
/kɨ$\underline{ph}$i/	→	[kɨ$\underline{p}^{h}$i]	→	[kɨp˺.$\underline{p}^{h}$i]

However, phonetic motivation for insertion of a homorganic consonant is not provided in Park (1990). Contrary to the rule order suggested in (20), output forms in (22) suggest CN before Aspiration, as shown in the comparison of (22b) and (22c). In (22b), when Aspiration is first applied, the structural description for Aspiration (19) is not met because there is no [-tense, -continuant] in /su$\underline{h}$/$_{\text{prefix}}$ 'male' +/$\underline{h}$ama/ 'hippo'. Therefore, only CN is applied in the input, resulting in *[sut˺.hama], as shown in (22b).

In (22c), CN is first applied to /suh+hama/ and the result of CN creates the environment for the application of Aspiration, as shown in (22c). Therefore, Aspiration is applied to 'suthama', resulting in [su.t^{h}a.ma]. However CN before Aspiration as in (22c) is the reverse of the rule order suggested in (20).

(22)

a.

Input	Output		
/su$\underline{h}$/$_{prefix}$ 'male' +/$\underline{h}$ama/ 'hippo'	[su.$\underline{t}^h$a.ma]	or [su$\underline{t}$˺.$\underline{t}^h$a.ma]	'male hippo'
/su$\underline{h}$/$_{prefix}$ 'male' +/holaŋi/ 'tiger'	[su$\underline{t}^h$o.raŋ.i]	or [su$\underline{t}$˺.$\underline{t}^h$o.raŋ.i]	'male tiger'

	Input	Aspiration	CN	Output
b.	/su$\underline{h}$/$_{prefix}$ 'male' /hama/→	Not Apply (NA)→	sut˺.hama	*[sut˺.hama]

	Input	CN		Aspiration	
c.	/su$\underline{h}$/$_{prefix}$ 'male' /hama/→	suthama	→	su.t^{h}ama	[su.t^{h}ama]

Park (1990) and Kim-Renaud (1974) describe the rule ordering paradox in (22) with the syllabification principle or the following module of rule application.

(23)	a.	b.
Input	/su$\underline{h}$/$_{prefix}$ 'male' +/$\underline{h}$ama/ 'hippo'	/no$\underline{h}$/$_{VS}$+ /ko/$_{IFM}$ 'and place'
syllabification	su$\underline{h}$.$\underline{h}$a.ma	NA
CN	sut.ha.ma	NA
Aspiration	su.t^{h}a.ma	no$\underline{k}^h$o
syllabification	NA	no.$\underline{k}^h$o
	[su.t^{h}a.ma] (18Aa)	[no$\underline{k}^h$o] (18a)
Insertion of	or	or
a homorganic consonant	[sut˺.t^{h}a.ma] (18Ab)	[nok˺.$\underline{k}^h$o] (18b)

For example, according to Park (1990), syllabification occurs at the end of each word cycle. In addition, in the presence of a syllable structure, syllable sensitive rules such as CN are applied before syllable non-sensitive rules such as Aspiration.

CN is applied before aspiration in data (23a) because the syllabification has occurred after prefixation. However, syllabification does not occur until the end of derivation for data like (23b). Thus, Aspiration is applied before CN in (23b), resulting in [no.k^{h}o] from /no$\underline{h}$/$_{VS}$+ /ko/$_{IFM}$ 'and place'.

However, Park (1990) predicts incorrect output forms for data such as /su$\underline{h}$/$_{prefix}$ 'male' +/kæ/ and /su$\underline{h}$/ $_{prefix}$ 'male' + /$\underline{p}$əm/ 'tiger', as shown in (24).

(24)	a.	/su$\underline{h}$/$_{prefix}$ 'male' +/kæ/
	Syllabification	suh . kæ
	CN	sut˺ . kæ
	Aspiration	NA
	Syllabification	NA
		*[sut˺.kæ]
		*[sut˺.k'æ]
	insertion of a homorganic consonant	or *[suk˺. k'æ]

b . Park (1990 :117)

'...the opposite order ASP before SFN... this is due to tighter cohesion between compounding elements in frequently used terms...'

Although the input in (24a) has the same prefix /suh/, meaning 'male' as in (23a), output forms of /suh+kæ/ are *[sut˺kæ], *[sut˺k'æ] or *[suk˺. k'æ], which are not correct.

Output forms of /suh+kæ/ should be [sukʰæ], [sut˺.kʰæ], or [suk˺.kʰæ], as shown in (18a), (18b), and (18c). Park (1990) claims that the rule ordering paradox in (24) is due to word frequency as shown in (24b). However, in the following section, I will show that Park's explanation based on word frequency fails to recognize generalizations in data (22).

In fact, the rule ordering paradox, namely CN before Aspiration, is also found in the sequence of V_1FhV_2, as shown in (22c) and (25a). In addition, the fricative /s/ in V_1hsV_2 is tensed, as shown in (25b).

(25)

	Input	Output		
a.	/pʰus+hopak/	[pʰut̲ʰobak]	or [pʰut̲˺.t̲ʰobak]	'unripe pumpkin' (compound noun)
b.	/suh + so/	[su.s̲'o]	or [sut˺.s'o]	'ox'
	/noh̲ +s̲o/	[no.s̲'o]	or [not˺.s̲'o]	'place (command)'

In the following section I will argue that phonetic realizations of /h/ + obstruent sequences in (16), (17), and (18) are consistent and predictable when phasing principles of gestures in a given context and characteristics of individual gestures are considered (Byrd 1996, Browman and Goldstein 1990a, Cho 1998a and 1998b). Therefore, output forms in (16), (17), and (18) result from interaction of phonetically-grounded constraints and faithfulness constraints, as do POT, PNT, and PLT.

4.3.3 The gesture-based account of /h/ and obstruent sequences

As a start, (26A) and (26B) evaluate candidates from /h/-/k/ and /k/-/h/ sequences against constraints suggested for POT (26), because both /h/ and /k/ are obstruents. Output constraints suggested for POT (26) correctly select output forms of (16a) and (17a) as the most optimal candidates, as shown in (26). (26A) and (26B) evaluate candidates from /noh/$_{VS}$ 'to place' + /ko/$_{IFM}$ 'place and' and /nokha/ 'falling' respectively. In 4.3.3, the sequence of two consonants is marked with numbers as in /no$\underline{h}_1$ + k_2o/ in order to relate input and output segments.

(26) *COMPLEX, *[mid]$_{GLO}$/ V1O1__V2 >> Max-IO$_{seg}$ >> *CCD/_{#, C},>> IDENT-IO[G] >> Mini Eff=0

A. /noh/+/ko/ 'and place (verb)'

/h/: GLO [open], SL [open], Oral [open]
/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/no$\underline{h}_1$+ k_2o/	*COMP	*[mid]$_{GLO}$/ V1O1__V2	Max-IO$_{seg}$	*CCD/ _{#, C}	IDENT-IO[G]	Mini Eff=0
a. no$\underline{h}_1$.k_2o		*!		*(GLO)		
b. no.k_2o			*!			
c. no$\underline{t}_1$. k_2^{hl}o				*!(GLO) *(SL)	*(TT)	*
d. no$\underline{t}'_1$. k_2^{hl}o				*!(GLO) *(SL)	*(TT)	***
e. no$\underline{t}^{\urcorner}_1$. k'$_2$o				*!(GLO)	*(TT) *(GLO)	*
⇨ f. no$\underline{t}^{\urcorner}_1$. k_2^{hl}o				*!(GLO)	*(TT)	**
☞g. no. k_2^{hl}o						

⇨ indicates free variation with the output depending on the style of speech.

B. /nakha/ 'falling'

/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]
/h/: GLO [open], SL [open], Oral [open]

/na$\underline{k}_1$+ h_2a/	*COMP	*[mid]$_{GLO}$/ V1O1__V2	Max-IO$_{seg}$	*CCD/_{#, C}	IDENT-IO[G]	Mini Eff=0
a. nak$_1$a			*!			
b. nak$_1$˺h$_2$a				*!(SL)	*(GLO)	**
⇨ c. nak$_1$˺k$_1$^{h2}a				*!(SL)	* (GLO)	**
☞d. na k$_1$^{h2}a						

Tableaux (26A) and (26B) illustrate that coalescence of a lax stop and /h/ results from most optimal satisfaction of output constraints in (26). Therefore it is unnecessary to suggest extra rules or constraints only for Aspiration, as have previous analyses (Cho 1990, Park 1990, and Kim 1986) does.

In addition, (26) illustrates how directions of Aspiration in data (16) and (17) are produced in the course of satisfying output constraints, as opposed to directions that are given or stipulated. Therefore Padgett's (1996:20) claim that the direction of assimilation is determined by output constraints is supported here. Therefore, the mirror image rule in (19) is not necessary to understand direction of Aspiration. As has been seen in this study thus far, constraints responsible for POT, PNT, PLT, and Voicing of lax stops after sonorants are also responsible for Aspiration, as illustrated in (26).

As output forms in (16a) and (17a) have been explained, it is now necessary to investigate data (16b), (16c), and (17b). In (16b), (16c), and (17b), there is Aspiration of lax stops and CN, as shown in candidates (26Af) and (26Bc). Note that candidates (26Af⇨) and (26Bc⇨) are used freely with (26Ag☞) and (26Bd☞) respectively in the slow or formal style of speech.

In (26), there are two main points to be explored. First, why is (26Bc⇨) preferred over candidate (26Bb) even though (26Bb) and (26Bc⇨) are tied in constraint violations? Second, why do (26Af⇨) and (26Bc⇨), which are free variants of (26Ag☞) and (26Bd☞) respectively, have unreleased stops in syllable-final position?

In order to explain the preference of (26Bc⇨) over candidate (26Bb), it is necessary to introduce the phasing principles suggested by Browman and Goldstein (1990a and 1992), Byrd (1996), and Cho (1998a and 1998b). The phasing principles deal with how gestures are organized when they are overlapped in time in a given context.

The phasing principles are based on the idea that gestures have their own intrinsic time and space. In addition, gestures do not move one after another but are phased with respect to other gestures. The overlapping of gestures is sensitive to locations where gestures appear in a syllable structure, the articulator involved, the location of a gesture, prosody, and grammatical categories such as morphemes (Browman and Goldstein 1990, Byrd 1996, Cho 1998b).

For example, Browman and Goldstein (1990a) suggest that gestures are likely to be overlapping each other within a syllable structure. In addition, according to Byrd (1996) and Cho (1998b), there are less overlap pings and less timing variables in an onset consonant cluster (#CC) than in a hetero-syllabic consonant cluster (C#C) or a coda cluster (CC#), as shown in (27a).

(27) a. #CC << C#C, CC# ,
(A<< B: A is less overlapped and less variable in its timing than B)
b. [s] . [g] << [d] . [g]
c. [g] + [s] << [g]+ [d]

In addition, Byrd (1996) states that phasing principles should also reflect place, manner, and sequence effects. For example, the alveolar fricative /s/ is less overlapped by the following velar stop /g/ (27c) than is an alveolar stop in coda position. Byrd also found that the fricative [s] is less overlapped than [d] regardless of the syllable position (27b and c).

Browman and Goldstein (1990a and 1992) propose how input gestures are organized in the output when two gestures overlap in time. When two input gestures are on different tiers, gestures are overlapped in time without disturbing each other's tract. When two input gestures are on the same tier, the two gestures disturb each other because the same articulator moves toward different targets. Thus, gestures are likely to be altered.

For example, according to Browman and Goldstein (1992), in /ada/ the consonant and vowel gestures achieve their target invariably regardless of the overlapping of vowel gestures. This is because input gestures for /d/ and /a/ are on different tiers, namely the TB for /a/ and the TT for /d/. However, in /idi/, /d/ and /i/ are on the same tier (TB), thus the consonant and vowel gestures cannot achieve their targets simultaneously because the TB moves toward different positions, resulting in palatalization of /d/.

All gestures are overlapped in time to a certain degree. However, languages differ in the length of overlapping between segments. Experimental studies have shown that Korean has longer overlapping time between onset and coda consonants than English does (J. Jun 1995, Cho 1998a and 1998b, Keating 1990, and Silverman and Jun 1994). As Korean allows relatively longer overlapping time between segments, there are cases when the phasing principles discussed so far play a crucial role in Korean grammar.

Based on the fact that Korean has longer overlapping time between onset and coda consonants than English does, I adopt the constraint Overlap suggested by Cho (1998b) as shown in (28).

(28) Overlap: Two adjacent gestures must be overlapped.

The constraint Overlap favors the overlapping of gestures in time. Therefore, gestures do not move one after another. In other words, gestures are likely to be phased with respect to other gestures. In the case of gestural overlapping, the phasing principles introduced in this section play a role in shaping the phonetic realization of segments involved.

According to Browman and Goldstein (1992), there are three distinct types of temporal overlap: minimal overlap, partial overlap, and complete overlap. Based on these three types of temporal overlap, Cho (1998a and 1998b) evaluates the constraint Overlap in a gradient fashion. However, in this study, I will consider the constraint Overlap in terms of the presence or absence of the overlapping of gestures, as will be shown in (29).

The output forms in (16a) and (17a) and their free variants (16b), (16c), and (17b) satisfy Overlap always, resulting in Aspiration. However, free variants of (16a) and (17a) violate *CCD/_{#, C} due to unreleased stops in syllable-final position, as shown in data (16b), (16c), and (17b). Therefore, satisfaction of Overlap takes precedence over satisfaction of *CCD/_{#, C} in actual output forms. Therefore, Overlap is ranked higher than *CCD/_{#, C}, as shown in (29).

(29) *COMPLEX, *[mid]$_{GLO}$/ V1O1__V2 >> Max-IO$_{seg}$, Overlap >> *CCD/_{#, C}>> IDENT-IO[G] >> Mini Eff=0

/nakha/ 'falling'

/k/: GLO [mid], SL [closed], Oral [closed], TB [closed]

/h/: GLO [open], SL [open], Oral [open]

/na<u>k</u>$_1$+ h$_2$a/	*COMP	*[mid]$_{GLO}$/ V1O1 V2	Max-IO$_{seg}$	Overlap	*CCD/ _{#, C}	IDENT -IO[G]	Mini Eff=0
a. nak$_1$a			*!				
b.nak$_1$˺h$_2$a				*!	*(SL)	*(GLO)	**
⇨ c. nak$_1$˺k$_1$^{h2}a					*!(SL)	* (GLO)	**
☞d. na k$_1$^{h2}a							

The ranking between Overlap and Max-IO$_{seg}$ is not known at this time as available data was unable to determine the ranking between Overlap and Max-IO$_{seg}$.

Up to this point, I have provided a reason why [nak˺.k^{h}a] (26Bc⇨ or 29c) is preferred over [nak˺.ha] (26Bb or 29b) even though they are tied in other constraint violations. [nak˺. k^{h}a] (26Bc⇨) is preferred over [nak˺.ha] (26Bb) because Overlap (28) plays a crucial role in selecting output forms, as shown in (29).

Note that free variants of (16a) and (17a) in the slow or formal style of speech always have unreleased stops in syllable-final position, as shown in (30).

(30) a. slow/formal style of speech — b. fast/casual style of speech

	a. slow/formal	b. fast/casual
/nohko/	[not˺.k^{h}o] (18f)	[no.k^{h}o] (18g)
/nakha/	[nak˺.k^{h}a] (18c)	[na.k^{h}a] (18d)

I suggest that syllable-final unreleased stops in the slow or formal style of speech are due to the decreased gestural overlap. The increase or decrease of the gestural overlap is also viewed as a function of speech rate in Browman and Goldstein (1990a and 1990b), Byrd and Tan (1996), J. Jun (1995), and Cho (1998a and 1998b). Especially Byrd and Tan's experimental study shows that decreasing articulatory duration and increasing co-production between successive articulations are the characteristics of fast speech.

In order to investigate the phasing relationship between two adjacent gestures, Cho (1998b) conducted an interesting experimental study using Korean. Cho observed the consonant sequences in (31), using an Electro-magnetic midsagital articulometer (EMA) for the approximation of the temporal movements of articulators and an Electropalatography (EPG) for the temporal relationship between gestures.

Cho (1998b: 31) found that there is less variability in gestural timing and intergestural overlap in the tauto-morphemic-C1C2 sequences than in the hetero-morphemic-C1C2 sequences, as shown in (31a) and (31b).

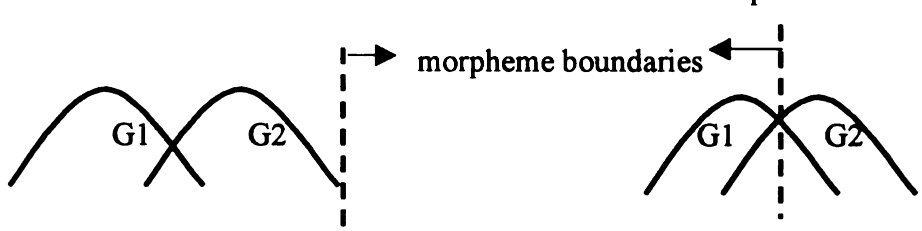
(31) a. Tauto-morphemic sequence

k p
c^h c
p i

b. Hetero-morphemic sequence

k # p
c^h # c
c^h # c

# indicates a morpheme boundary.



less variability in gestural timing;
less overlap

more variability in gestural timing;
more overlap

Based on the above observation, Cho (1998b) concluded that the intergestural timing is lexically specified. In addition, Cho suggested a constraint IDENT (Timing) (32) that demands maintaining of intergestural timing belonging to the same lexical entry in order to explain plaltalization in the sequence of 'ti' and 'ni'.

(32) IDENT (timing): (Cho 1998b)
Intergestural timing belonging to the same lexical entry must be preserved

I suggest that in the slow or formal style of speech such as (16b), (16c), and (17b), speakers make effort to maintain the lexically specified timing. Therefore, IDENT (timing) plays an active role in the slow or formal style of speech.

Output forms in (30) are in the free-variation relationship because they can be used freely without changing meaning. Note that output forms in (16b), (16c), and (17b) violate *CCD/_ {#, C} and maintain the input timing due to unreleased stops in syllable-final position. Therefore, IDENT (timing) is ranked higher than *CCD/_ {#, C} in the slow or formal style of speech, as shown in (33a).

(33) a. *CCD/_ {#, C} >>IDENT (timing) (in the fast or casual style of speech)
b. IDENT (timing) >>*CCD/_ {#, C} (in the slow or formal style of speech)

However, in (16a) and (17a), *CCD/_ {#, C} is satisfied because there are no syllable-final unreleased stops but IDENT(timing) is violated because the input timing slot occupied by /h/ or lax stops is not maintained in the output. Therefore, *CCD/_ {#, C} is ranked higher than IDENT (timing) in the fast or casual style of speech, as shown in (33b). Note that (33) implies free ranking between *CCD/_ {#, C} and IDENT (timing) depending on the rate or style of speech. Main constraints and their rankings such as Max-IO_{seg} and Overlap are maintained while sub-parts of constraints are freely ranked.

(34) evaluates candidates from /suh + horaŋi/ 'male tiger' with the V_1FhV_2 sequence (data in (18A)), for the fast or casual style of speech.

(34) *COMPLEX, *$[mid]_{GLO}$/ V_1O_1__V_2 >> Max-IO_{seg}, Overlap >>
*CCD/_{#, C} >> IDENT(timing) >> IDENT-IO[G] >> Mini Eff=0

$/suh/_{prefix}$ 'male' + /horaŋi/ 'tiger' 'male tiger'

/h/: GLO [open], SL [open], Oral [open]
/h/: GLO [open], SL [open], Oral [open]

/ suh_1+$h_2$oraŋi /	*$[mid]_{GLO}$/ V_1O_1 V_2	Max-IO_{seg}	Overlap	*CCD/ _{#, C}	IDENT (Timing)	IDENT -IO[G]	Mini Eff=0
a. suh_1.h_2o.raŋ.i			*!	*(GLO)			
b. sut_1.h_2o.raŋ.i			*!	*(GLO) *(SL)		*TTCD	*
c. su.h_2o.raŋ.i		*!	*		*		
d.sut_1˺.h_2o.raŋ.i			*!	*(SL)		*TTCD	**
e.sut˺$_1$.$t_1{}^{h2}$o.raŋ.i				*!(SL)		*TTCD	**
☞f su.$t_1{}^{h2}$o.raŋ.i					*	*TTCD	

Note that in the fast or casual style of speech, *CCD/_{#, C} is ranked higher than IDENT(timing), as shown in (34). (34c) is eliminated by Max-IO_{seg}. In fact, it is hard to determine if [h] in (34c) is from the first or second /h/. Candidates (34a), (34b), (34d) are eliminated by Overlap because there is no overlap between the first /h/ and the second /h/. (34e) satisfied IDENT(timing) due to maintaining of the input timing slot for the first /h/, resulting in CN. However satisfaction of *CCD/_{#, C} takes precedence

over satisfaction of IDENT(timing) in fast or casual speech. Therefore, (34f☞) is the most optimal candidate because it satisfies *CCD/_{#, C}, which is ranked higher than IDENT(timing).

(35) evaluates candidates from /suh + horaŋi/ 'male tiger' in the slow or formal style of speech. In the slow or formal style of speech, IDENT(timing) is ranked higher than *CCD/_{#, C}, as shown in (35), because, speakers put forth effort to maintain lexically specified timing.

(35) *COMPLEX, *[mid]$_{GLO}$/ V1O1__V2 >> Max-IO$_{seg}$ >> Overlap >> IDENT(timing) >> *CCD/_{#, C} >> IDENT-IO[G] >> Mini Eff=0

/suh+horaŋi/ 'male tiger'

/h/: GLO [open], SL [open], Oral [open]
/h/: GLO [open], SL [open], Oral [open]

/ suh$_1$+h$_2$oraŋi /	*[mid]$_{GLO}$/ V1O1__V2	Max-IO$_{seg}$	Overlap	IDENT (Timing)	*CCD/ _{#, C}	IDENT -IO[G]	Mini Eff=0
a. suh$_1$.h$_2$o.raŋ.i			*!		*(GLO)		
b. sut$_1$.h$_2$o.raŋ.i			*!		*(GLO) *(SL)	*TTCD	*
c. su.h$_2$o.raŋ.i		*!	*	*			
d. sut$_1$˺.h$_2$o.raŋ.i			*!		*(SL)	*TTCD	**
☞e. sut˺$_1$.t$_1$^{h2}o.raŋ.i					*(SL)	*TTCD	**
f su.t$_1$^{h2}o.raŋ.i				*!		*TTCD	

A comparison of (35e) and (35f) clearly shows that in slow or formal speech, IDENT(timing), which requires maintaining of the lexically specified timing, is active in selecting the most optimal candidate. (35e) satisfies *CCD/_{#, C} but satisfaction of IDENT(timing) takes precedence over satisfaction of IDENT(timing). Therefore, free variants of (16a), (17a), and (18Aa) have unreleased stops in syllable-final position because IDENT(timing) is ranked higher than *CCD/_{#, C} in the slow or formal style of speech.

According to Kager (1999: 404-07), a free ranking approach is appropriate in explaining free variation because explanations for degrees of dissimilarity between output forms derive from maintaining most constraint hierarchies, while free ranking only a portion of constraints, as shown in (34) and (35).

The gesture-based account of Aspiration in this study provides simplicity and generalizations in explaining data (16), (17), and (18A), as shown in (26), (29), (34), and (35). Previous studies of Aspiration (Cho 1990, Park 1990, and Kim 1986) could not offer such explanations.

In the gesture-based account of Aspiration, output forms in (16), (17), and (18) are the most optimal candidates that are selected in the course of satisfying output constraints. Thus, there is no need of a mirror image rule for Aspiration, different kinds of syllabification modules, or a rule ordering paradox for data in (22) as shown in section 4.3.2.

Chapter 5 Conclusion

The analyses in this study have been based on two main theoretical assumptions: Articulatory Phonology, which integrates phonetics and phonology (Browman and Goldstein 1986, 1989, 1990a, 1990b, 1990c, 1991, 1992 and Browman 1994) and Optimality Theory (Prince and Smolensky 1993 and McCarthy and Prince 1993a, 1994 and 1995). Articulatory Phonology is adopted for the units of representation and Optimality Theory for relating an input to an output.

I adopted the articulatory gesture as the basic unit of phonetic and phonological representation. In Articulatory Phonology, the presence or absence of a gesture, different constriction degrees (CDs), and the timing or organization of gestures (Browman and Goldstein 1986 and 1991) are contrastive. Therefore, any changes in gestures or organization of gestures, in turn, are reflected in phonology. Especially CDs in articulators and constriction degree hierarchies (CDHs) predicted from the CD of an individual articulator were found to be useful in this study. This is because manner of articulation is closely related to CDs of the vocal tract. Therefore, the gesture-based accounts of consonant patterns in Korean have provided insight into understanding various phonological phenomena in Korean.

In chapter 2 of this study, Coda Neutralization (CN) is considered as a by-product of phonetic implementational conditions in a given context. The absence of active glottal gestures and lack of air escaping through the oral cavity for obstruents in syllable-final position create articulatorily and acoustically unfavorable conditions to maintain contrastive CDs in the vocal tract. Thus CN was analyzed systematically in terms of

CDs, which are closely related to manner of articulation. I have shown in section 2.1 that interaction of *Contrastive Construction Degree (CCD) /_{#, C} and IDENT-IO[Gesture] is responsible for CN. Therefore, I conclude that CN is a neutralization in manner of articulation that occurs systematically in syllable-final position in Korean. Previous studies of CN fail to treat CN as a neutralization in manner of articulation because they treat CN as delinking of laryngeal features, [+continuant] and/or [-anterior], as shown in section 2.1.2 (3). Note that delinking of [-anterior] indicates neutralization in place of articulation.

In addition, I have shown that constraints responsible for CN also play a crucial role in Coda Consonant Cluster Simplification (CCCS) of Seoul Korean (SK) and Kyung-Sang Korean (KSK), especially when two obstruents compete for the coda position. In a fricative + stop cluster, the fricatives never appear in the output because *CCD/_{#, C} is relatively ranked higher than IDENT-IO[G]. In addition, in KSK, when competition for the coda position occurs in a sonorant-obstruent cluster, a candidate ending with a sonorant is selected as the most optimal candidate regardless of articulators of obstruents because *CCD/_{#, C} is ranked relatively higher than constraints that require the Tongue Body, Lips, and Tongue Tip articulators (TB_{Art}, $Lips_{Art}$ and TT_{Art} respectively) to be maintained, as shown in section 2.2.2.2 (53). Furthermore, in CCCS, phonetic realizations of syllable-initial consonants are predicted based on gestural characteristics of non-surfaced consonants, as shown in section 2.2.3 (58).

In chapter 3, I have argued that Post-Obstruent Tensification (POT) results from enriched tense gestures at the oral-closure release of O2 in the sequence of $V_1O_1O_2V_2$, where O2 is a lax obstruent. In V1O1O2V2, phonetic implementational conditions promote tensification of lax O2s because of long closure duration between two vowels and the minimal glottal opening at oral-closure release for O2, which are coupled with heightened oral pressure and tension in the vocal tract. Therefore, the phonetically grounded constraint *$[\text{mid}]_{GLO}$/ V1O1__V2, which prevents lax O2s in V1O1O2V2 due to distribution of tense gestures, plays an active role.

The gesture-based account of POT in this study offers several advantages that previous studies on POT (Han 1992 and 1997, Lee 1994, Kim-Renaud1974, and Rhee 1997) do not offer. The following generalizations and predictions are made through the gesture-based account of POT: First, when C2s do not have the [open] CD at the Supralaryngeal (SL) level, C2s participate in Obstruent Tensification (ObsT) obligatorily. When C2s have the [open] CD at the SL level, C2s do not participate in ObsT except for certain cases in the verbal morphology and Sino-Korean nouns. Therefore ObsT is sensitive to CDs at the SL level. Second, the more [open] the CD in C1, the more conditions are attached to ObsT because the [open] CD at the oral level is more likely to create favorable phonetic implementational conditions for voicing, rather than tensification (Ohala 1983).

Chapter 4 dealt with Post-Nasal Tensificatin (PNT) and Post-Lateral Tensification (PLT). In previous studies, PNT and PLT were described with morphological conditions and additional phonological rules, without providing any phonetic and phonological motivations, as shown in section 3.3 (48). In addition, POT, PNT, and PLT were unconnected and unrelated. I have shown that phonetically motivated constraints and their hierarchies responsible for POT are also responsible for PNT and PLT to a degree. Therefore, POT, PNT, PLT, and Voicing of lax-O2 stops result from interaction of the same phonetically grounded constraints and morphology-sensitive constraints such as *[critical]$_{GLO}$/V1N]$_{VS}$ __V2 and *[d, z, dʒ]$_{SinoKorean}$/V1L__V2, as shown in section 4.2.2 (12) and (13).

In addition, this study provided phonetic reasons why all lax O2s are tensed after verb-stem-ending nasals in verbal morphology while only /t, s, c/ after the lateral /l/ are tensed in Sino-Korean nouns, as shown in section 4.2.2 (14) and (15). I suggested that lax O2s are tensed at the level where CDs of C1 and C2 form [closed][closed] or [closed][critical] CD sequences. In N-lax O2 sequences, [closed][closed] or [closed][critical] CD sequences are formed at the Oral level. Therefore, all lax O2s are tensed after nasals. In L-lax O2 sequences, [closed][closed] or [closed][critical] CD sequences are formed only at the TT level, and only when lax O2s are /t, s, c/ because /l/ and /t, s, c/ share the TT, as shown in section 4.2.2 (15a).

In addition, I have argued that Aspiration in /h/ + obstruent sequences as in (16), (17), and (18) are consistent and predictable when phasing principles of gestures in a given context and characteristics of individual gestures are considered (Byrd 1996, Browman and Goldstein 1990a, and Cho 1998a and 1998b).

The tableaux in section 4.3.3 (26A), (26B), (29), (34) and (35) illustrate that Aspiration results from most optimal satisfaction of output constraints suggested for ObsT. Therefore it was unnecessary to suggest extra rules or constraints only for Aspiration, as previous Korean linguistic literature (Cho 1990, Park 1990, and Kim 1986) does. Especially, section 4.3.3 (29) illustrates that the constraint Overlap is active and ranked relatively high, resulting in Aspiration. I have also shown that directions of Aspirations are determined in the course of satisfying output constraint hierarchies most optimally, rather than by different rules or stipulations such as the mirror image rule in section 4.3.2 (19) and (20). In addition, [sut˺.kʰæ], [nak˺.kʰa], and [mat˺.tʰa.go], which are free variants of [na.kʰa], [su.kʰæ], and [ma.tʰa.go], are explained based on the close relationship between the rate of speech and intergestural timing of gestures. Output forms with unreleased stops in syllable-final position result from the constraint ranking order of IDENT(timing) over *CCD/_{#, C} in the slow or formal style of speech. However, output forms without unreleased stops in syllable-final position result from the constraint ranking order of *CCD/_{#, C} over IDENT(timing) in the fast or casual style of speech. The explanation for free variants of [na.kʰa], [su.kʰæ], and [ma.tʰa.go] was possible by adopting the basic concept of Articulatory Phonology that gestures have their own time and space specified in the lexical entry. Therefore, the rule-ordering paradox between (20) and (22) in section 4.3.2 is resolved by free ranking between *CCD/_ {#, C} and IDENT (timing) according to the rate or style of speech while other constraints and their rankings are maintained.

In conclusion, Korean consonant patterns (CN, POT, PNT, PLT, Voicing of lax stops, and Aspiration), which are closely related to manner of articulation, have been explained in terms of CD in the vocal tract in this study. Therefore, this study presented a unified analysis of Korean consonant patterns within Articulatory Phonology (Browman and Goldstein 1986 and 1990a) and Optimality Theory (Prince and Smolensky 1993 and McCarthy and Prince 1993a, 1994 and 1995)

By adopting basic tenets of Articulatory Phonology and Optimality Theory, I have shown that phonological phenomena treated as separate, as exceptions, or as unrelated

phenomena can be combined and treated as regular and related phenomena within a gestural approach.

Korean linguistic studies (Cho 1990, Kim-Renaud 1974, S.A. Jun 1993 and 1995, Rhee 1997, and Silva 1993) have suggested implicitly and explicitly that various aspects of Korean consonant patterns investigated in this study would benefit greatly from an approach that takes into account the interplay between phonetics and phonology.

However, few studies have been attempted that connect phonetic characteristics to phonological explanations by using the same representational units (gestures in this study) for both phonetics and phonology. Most studies based on Articulatory Phonology deal with only one phonological phenomenon in Korean phonology such as place assimilation or palatalization (J. Jun 1995 and Cho 1998a and 1998b), so they could not identify generalizations that lie behind different phonological phenomena such as CN, CCCS, PNT, POT, Aspiration, and others.

In addition, previous Korean studies based on Articulatory Phonology focus only on explaining gestural movements in a certain context (S. A Jun 1995). None of the previous studies of which I am aware investigate various aspects of Korean consonantal behaviors in terms of CDs, which are closely related to manner of articulation.

This study makes several contributions to promoting a better understanding of Korean Phonology and Phonology in general. First, efforts made in this study to explain Korean consonant patterns in terms of gestures provide a systematic and unified analysis. Second, by integrating phonetics and phonology using phonetically grounded constraints, some idiosyncratic phonological phenomena are better able to be explained and understood.

I would like to propose a suggestion for future studies to enhance our understanding of the interplay between phonetics and phonology as well as Korean phonology. It would be helpful to know if phonological descriptions based on gestures, especially CDs, could be extended to other languages and provide similar benefits for the understanding of those languages.

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