The [voice] system of Korean stops revisited with special reference to the aspirated-lax merger*

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Mi-Ryoung Kim. 2012. The [voice] system of Korean stops revisited with special reference to the aspirated-lax merger. *Studies in Phonetics, Phonology and Morphology* 18.2. 211-243. Korean stops are considered unique because they have three voiceless stops. Arguing against the unique system, Kim and Duanmu (2004) propose the system of Korean stops that underlying "tense" stops are regular voiceless unaspirated stops, and "lax" stops are regular voiced stops. Their analysis has some shortcomings in that the current sound change in Korean, merging of aspirated and lax stops in initial position, was not taken into consideration. In the present study, their [voice] system is revisited by providing merging of aspirated and lax stops and phonetic implementations of tense stops. I suggest that the nature of the sound change can be better understood in the [voice] system than the [tense] system. Otherwise it remains a puzzle, in particular, why lax stops are correlated with low tones, and why they become heavily aspirated **(Korea Soongsil Cyber University).**

Keywords: Korean stops, sound change, voice onset time (VOT), fundamental frequency (f0), merger or neutralization, tonogenesis, tensification, lax aspiration, consonant-tone interaction

1. Introduction

Most languages except for few have a [voice] system in their underlying (or phonological) representation[1]. Although they all share the same phonological categories as either voiced or voiceless, their phonetic implementations are different across languages. For example, both English and French have a series of [-voice], which might be symbolized as /p,t,k/, and a series of [+voice], which might be represented as /b,d,g/. English and French are then said to differ as to their use(s) of phonetic voicing to implement these categories. Thus, French implements utterance-initial [-voice] stops as [p,t,k] (voiceless unaspirated) and their voiced counterparts as [b,d,g] (voiced), whereas English expresses the same categories as [p^h,t^h,k^h] (voiceless

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[1] In the whole paper the [voice] system (approach) refers to a system that contains a voiced and voiceless distinction underlyingly in a particular language. Different from the traditional approach of Korean stops, the system is proposed by M.-R. Kim (2000), Kim and Duanmu (2004), and among others. The [tense] system (approach) in the present study refers to a traditional approach where Korean has three voiceless stops or has special stops regardless of their different analyses in terms of hypotheses (geminate vs. singleton), terms, and laryngeal features. It also contains a Korean-specific lax and tense distinction that is different from that in other languages to which is ultimately related with a voiceless-voiced distinction.

aspirated) and [b̥, d̥, g̊] or [b, d, g] (voiceless or voiced) respectively (Jansen 2007: 271). Although there is a voiced-voiceless distinction in German, voiced stops are always voiceless; initially, finally, and even medially (Iverson and Salmons 1995). Taking cross-linguistic phonetic implementations of a phonological voicing across languages, Korean might be the similar case to which phonological voicing is rarely realized voiced as in German. The possibility of a phonological voicing for Korean lax stops has been speculated in M.-R. Kim (2000) and Kim and Duanmu (2004).

A language carries a voicing distinction in the underlying representation does not show a clear-cut distinction between voiced and voiceless consonants in their phonetic realization (Keating 1984, Kingston and Diehl 1994, Ladefoged and Maddieson 1996, Jansen 2007). In some languages, English being a familiar example, the vocal folds may not vibrate throughout the closure for a voiced stop. Most English speakers appear to leave the vocal folds in a constant position throughout such a sequence, but passive devoicing occurs as the supralaryngeal pressure builds up behind the oral closure. In contrast to English and several other Germanic languages, a considerable number of languages have voiced stops which require more energetic efforts to produce sustained vocal fold vibration. Such languages include well-known ones such as French and Thai.

Korean is known to be cross-linguistically atypical in that, instead of a voiced-voiceless distinction, there is a tense-lax (or fortis-lenis) distinction. While languages with two kinds of voiceless stops are common, such as Hindi, Thai, and Chinese, Korean is the only language that reportedly has three. Different from languages described in terms of voicing and aspiration, three Korean voiceless stops are described as "tense or fortis," "lax or lenis," and "aspirated." The traditional view is well expressed in the following words of Cho et al. (2002: 225):

> The Korean consonant system is unique among the world's languages... The complexity of the phonetic properties of the three-way contrastive Korean stops implies that speech production is far more complicated that we can predict from simplified phonological representations or even the more sophisticated general speech production model that are currently available.

Similar to Cho et al. (2002), researchers following the traditional system of Korean stops are to take the view that Korean has an unusual phonology, and so may other languages. In this approach, it is quite natural to propose or accept language-specific analysis for Korean, or for other languages. Although the lax stop in Korean is phonetically realized as two phonetic implementations, either voiced or voiceless, the voiceless stop has been

chosen as an underlying form in literature. Not much attention has been paid on the speculation that the voiced stop can be an underlying form.

Arguing against the traditional approach that Korean has an unusual phonology, Kim and Duanmu (2004) propose that underlying "tense" stops are regular voiceless unaspirated stops, and "lax" stops are regular voiced stops. Kim and Duanmu (2004: 97) states:

> We believe that all languages are governed by similar phonological principles. It is possible that there are new phonological properties not yet known (and hence phonological theory may need significant revisions), but in order to establish them, compelling evidence is needed. In our view, there is no compelling evidence that Korean has unusual phonological properties.

Under the [voice] system, they provide an analysis of consonant-tone interaction in terms of a theory of standard tonogenesis. However, their analysis has two shortcomings. First, the merging phenomena of aspirated and lax stops were not taken into consideration. As a result, the analysis for the important aspect of the sound change was not provided. Second, recent phonetic implementations of tense stops were not provided as potential evidence to support that tense stops can be regular voiceless unaspirated stops.

Adopting the basic idea of Kim and Duanmu (2004) that Korean has regular stops, we revisit their analysis and overcome their shortcomings. In the present paper, we present the current sound change (i.e. merging of aspirated and lax stops and consonant-tone interaction) as well as phonetic implementations of tense consonants as supporting evidence of the [voice] system. We propose that Korean has a phonological voicing and the current sound change (i.e. merging of aspirated and lax stops) is closely related with standard tonogenesis. We suggest that the nature of the ongoing sound change of Korean stops can be better understood in the [voice] system than in the [tense] system. As a reviewer points out, our proposal is quite a radical departure against long-standing beliefs that Korean has special stops and it is expected to receive numerous criticisms. However, it is worthwhile taking the [voice] system into consideration from a different perspective. Otherwise it remains a puzzle, in particular, why lax stops are correlated with low tone (or f0)[2], and why they become heavily aspirated.

In section 2 we review two approaches of the Korean stop system: the

[2] Following a common approach in generative phonology (Pierrehumbert 1980), we represent both tone and intonation with the same phonological features H (high) and L (low). In addition, we use the terms "tone" to refer to all pitch patterns whether they are used to distinguish word meaning (as in Chinese) or not (as in English) (Kim and Duanmu 2004: 61).

[tense] system for the traditional analysis vs. the [voice] system for the alternative analysis. The former approach is to take the view that three Korean stops are all voiceless whereas the latter is to take the view that they are underlyingly voiceless and voiced. In section 3 we review some recent phonetic implementations of Korean stops with regard to consonant-tone interaction, merging of aspirated and lax stops, and the phonetic behavior of tense stops. In section 4 we offer our analysis. In section 5 we offer conclusions.

2. The stop system of Korean

2.1 The [tense] system

The [tense] system (approach) in the present study refers to a traditional approach where Korean has three voiceless stops or has special stops. It also contains a Korean-specific lax and tense distinction that is different from that in other languages to which is ultimately related with a voiceless-voiced distinction. Owing to its unique status as described in Introduction, the terms to describe Korean stops have been diachronically changed in literature. The lax series is called 'lenis', 'weak', 'plain', 'slightly aspirated', and 'breathy'; the tense stop is called 'fortis', 'strong', 'glottalized', 'long', 'unaspirated', and 'forced'; the aspirated series is also called 'heavily aspirated', 'strongly aspirated', and 'super aspirated' (C.-W. Kim 1965, Han and Weitzman 1970, Kagaya 1974, Kim-Renaud 1974, K.-H. Kim 1987, Ahn 1985, Jun 1993, Silva 1992, M.-R. Cho Kim 1994, Han 1996, M.-R. Kim 2000, Cho et al. 2002, Kim et al. 2005, 2010).

Many recent studies use the term "fortis-lenis (or tense-lax)" distinction to describe Korean stops. However, the terms are idiosyncratically used. In most of languages, the fortis-lenis distinction is originally related to a voiceless-voiced distinction (Kohler 1979, Jessen 1998, Jansen 2007): the 'phonologically voiceless' obstruents in English and French are classified as tense or [+tense], while the 'phonologically voiced' obstruents are described as lax or [-tense]. Because of this, the fortis-lenis distinction cannot capture the uniqueness of Korean stops and it confuses the reader to mislead the terms. In addition to the terms there are no unique features as well as symbols to represent three voiceless stops different from other regular stops. For example, there are three different symbols of tense stops, /p'/, /p*/ and /p/. This inconsistency is due to the fact that there is no International Phonetic Association (IPA) to represent Korean tense stops in a proper way. In addition some researchers propose that tense consonants are underlyingly geminates /pp/ (Han 1996, Silva 1992, 2006 and among others).

To distinguish three voiceless stops, numerous laryngeal features have been newly introduced, adopted, disappeared, and alternated as discussed

below (see also Appendix A for the summary chart of laryngeal features). Besides [voice] and [aspirated], C.-W. Kim (1965) introduces a feature [tense] to describe the tense-lax distinction. Taking all features together, the aspirated stop is [+aspirated, +tense, -voice], the tense stop is [-aspirated, +tense, -voice], the voiceless lax stop is [-aspirated, -tense, -voice], and the voiced lax stop is [-aspirated, -tense, +voice]. His [tense] analysis was adopted by numerous researchers (Kim-Renaud 1974, Ahn 1985, Gim 1997, Kim et al. 2005, 2010). However, it has not been survived for a long time because it is replaced by either [fortis] or [stiff]. Recently, however, the feature [tense] is readopted by Kim et al. (2005, 2010). They propose that, based on the results of midsagital and coronal MRI data, the feature [tense] is considered as an invariant feature to distinguish tense and aspirated stops from lax stops. The [tense] analysis was criticized by Kim and Duanmu (2004: 80) in that with a new feature [tense], one can predict many potential stops that are not found in the world's languages. In addition, the [tense] analysis must assume that besides voiceless-H and voiced-L, there is Korean specific consonant-tone interaction: [+tense]-H and [-tense]-L. The [tense]-tone correlation is not found in any other languages, and Korean remains an exception.

Following C.-W. Kim (1965), Halle and Stevens (1971) propose two features for vocal cord tension: [stiff vocal cords] and [slack vocal cords]. Along with [spread glottis] and [constricted glottis], the aspirated stop is described as [+spread, +stiff], the tense stop is [+constricted, +stiff], the voiceless lax stop is [+spread, -slack, -stiff], and the voiced lax stop is [-spread, +slack]. Halle and Stevens' feature system has been adopted by numerous studies such as K.-H. Kim (1987), Silva (2006), and Jun (1993, 1996). However, their system has been criticized by many researchers for permitting impossible combination of features and for over-predicting (Duanmu 1996, Kim and Duanmu 2004 and among others). Because of the over-prediction problem, the simplified feature (e.g., just one [stiff] instead of two [stiff] and [slack] or [spread] instead of [spread] and [constricted]) was suggested by Kim and Duanmu (2004: 79).

Lombardi (1991) and others (K.-H Kim 1987, Jun 1993) propose that Korean has three degrees of aspiration (vocal cord constriction), whereby the aspirated stop is [+spread, -constricted], the tense stop is [-spread, +constricted], and the lax stop is [-spread, -constricted]. The feature [constricted] is problematic because it is a feature for the glottal stop [ʔ]. Lombardi (1991) says that her choice of [+constricted] was motivated by the fact that [tense] is a poorly defined feature, but it is unclear whether [+constricted] fits the Korean case. She also notes that Korean tense stops are not quite the same as glottalized stops in other languages (Lombardi 1991: 124-125).

In the traditional consonant system, there is no adequate analysis to

represent the unique status of Korean stops in a proper way. As already described, the tense-lax (fortis-lenis) distinction is originally related with a voiceless-voiced distinction in other languages. The feature [stiff] is adopted by Jun (1996) and Silva (2006) to account for the consonant-tone interaction in Korean. Owing to the atypical status of three Korean voiceless stops, their analyses propose that Korean is the only language that reports [-stiff]-L interaction where [-stiff] refers to a voiceless stop, instead of a voiced one. Likewise there exists a paradox between the unique hypothesis of Korean stops and their analysis commonly found in other languages. If the traditional system pursues the uniqueness of the Korean system, it needs to modify laryngeal features that are not shared to represent stops in the world's languages.

Despite many controversial issues about the analysis of Korean stops, there has been a large consensus in two aspects. First, three Korean stops all are phonologically voiceless, and hence they are special. Under the [tense] system, the three voiceless stops in Korean are represented in (1).

(1) Korean stops and affricates under the [tense] system

	Bilabial	Aveloar	Alveo-palatal	Velar
lax	p (ㅂ)	t (ㄷ)	ʧ (ㅈ)	k (ㄱ)
tense	p*(ㅃ)	t* (ㄸ)	ʧ* (ㅉ)	k*(ㄲ)
aspirated	p^h (ㅍ)	t^h (ㅌ)	$ʧ^h$ (ㅊ)	k^h (ㅋ)

(The Korean orthography is in parenthesis)

Aspirated and tense stops are voiceless both initially and medially. Lax stops are voiceless initially and voiced medially when they occur between two voiced sounds[3]. In final position there is only one series of stops (unreleased and completely neutralized, see Kim and Jongman 1996). In the paper we consider that lax stops have two phonetic forms: either voiced in medial position or voiceless in initial and final position. In (1), instead of a voicing distinction, there is a tense-lax distinction in the underlying representation. A second agreement is that three voiceless stops in (1) are considered as phonemes because of a minimal triplet in initial position. The classic examples of a minimal triplet are presented in (2), to which we refute

[3] Some researchers have considered the lax stop voicing a lexical rule that applies within a word (C.-W. Kim 1965, Han and Weitzman 1970, and among others). Others consider it a post-lexical rule which voices lax stops intervocalically within a phonological phrase (Ahn 1985, Cho 1996, Silva 1992, Jun 1994). Observing the gradient and quantitative characteristics of lax stop voicing that depend on speech rate and segmental contexts, Jun (1994) suggested that the rule in Korean is not a phonological rule but a phonetic rule. The issue of whether the medial voicing of lax consonants is a phonological rule or a phonetic rule is controversial (see Kim and Duanmu, 2004: 65 for more discussion).

later.

(2) Traditional minimal triplet

/t^{h}al/ 탈	'mask'	voiceless aspirated
/t*al/ 딸	'daughter'	voiceless tense
/tal/ 달	'moon'	voiceless lax

There has been little doubt that the examples in (2) are not a minimal triplet and hence, aspirated /t^{h}/, tense /t*/, and lax /t/ are separate phonemes, as seen in different Korean orthographies (ㄷ, ㅌ, ㄸ). Kim and Duanmu (2004) propose that the examples in (2) are not a genuine minimal triplet anymore because of consonant-tone interaction. For example, /t*al/ and /tal/ in (2) cannot be a minimal pair because of tonal differences. In addition to the pair /t*al/ and /tal/, the pair /t^{h}al/ and /tal/ is more problematic because of merging of aspirated and lax stops to which it becomes clear in section 3.2.

2.2 The [voice] system

The [voice] system (approach) refers to a system that has a voiced and voiceless distinction in a particular language. Since the [voice] system is quite new to the reader, in this paper, they will be referred to lax, tense, and aspirated, respectively. In the [tense] system, Korean stops are considered unique, as discussed in section 2.1. Arguing against the unique system, Kim and Duanmu (2004) propose the regular system of Korean stops: underlying "tense" stops are regular voiceless unaspirated stops (/ptk/), "lax" stops are regular voiced stops (/bdg/), and "aspirated" stops are regular voiceless aspirated stops (/p^{h}t^{h}k^{h}/) (see M.-R. Kim 2000). It underlies that, instead of a tense-lax (fortis-lenis) distinction, there is a voiced-voiceless distinction for Korean stops in the underlying representation, as commonly found in other languages.

Unlike voiceless aspirated and tense stops, lax stops have two phonetic implementations, either voiced in medial position or voiceless in initial and final position. Kim and Duanmu (2004: 65) describes, "Since the lax stop has two forms (voiceless and voiced), there are two possible analyses. One is to choose the voiceless form as underlying and propose a voicing rule for the medial environment. The other is to choose the voiced form as underlying and propose a devoicing rule for the initial environment." Many studies chose to represent lax stops as underlying voiceless, as reviewed in section 2.1. On the other hand, some studies chose to represent lax stops as underlying voiced, such as Jones (1956), Hashimoto and Yu (1972), B.-G. Lee (1985), Moon (1974), Oh (1981), Kingston and Diehl (1994), Choi (1995), M.-R. Kim (2000), Kim and Duanmu (2004), and Kenstowicz and

Park (2006).

Taken the [voice] system into consideration in the Korean consonant system, (2) can be replaced into (3) where three phonation types in Korean are described in terms of voicing and aspiration.

(3) Korean stops and affricates under the [voice] system

	Bilabial	Aveloar	Alveo-palatal	Velar
voiced	b (ㅂ)	d (ㄷ)	ʤ (ㅈ)	g (ㄱ)
voiceless aspirated	p^h (ㅍ)	t^h (ㅌ)	$ʧ^h$ (ㅊ)	g^h (ㅋ)
voiceless unaspirated	p (ㅃ)	t (ㄸ)	ʧ (ㅉ)	k (ㄲ)

(where voiced, voiceless unaspirated, and voiceless aspirated are lax, tense, and aspirated, respectively in the [tense] system)

To distinguish three stops, Kim and Duanmu (2004) propose the two features [stiff] (= [voice]) and [spread] (= [aspirated]) according to a modified version of Halle and Stevens' laryngeal features where there needs only one feature (i.e. [stiff] instead of [stiff] and [slack] and [spread] instead of [spread] and [constricted]). However, in the [tense] system, there must be another feature [slack] to describe a voiced stop because [-stiff] corresponds to a voiceless lax stop (Jun 1996, Silva 2006). The use of the two features instead of one has the over-prediction problem. According to Kingston and Diehl (1994), features that tend to co-occur usually enhance each other phonetically (see also Stevens and Keyser 1989). Under such considerations, the laryngeal features in the [voice] system for Korean stops are analyzed in (4).

(4) Laryngeal features in the underlying [voice] system

	voiced	vl unaspirated	vl aspirated
Stiff	-	+	+
Spread	-	-	+

In (4), the voiced stop ("lax") is specified with [-stiff, -spread], the voiceless unaspirated stop ("tense") is specified with [+stiff, -spread], and the voiceless aspirated stop ("aspirated") is specified with [+stiff, +spread]. In (4), underlyingly, both [stiff] and [spread] are specified. However, another analysis is possible if one assumes that only [-stiff] or [+spread] is specified.

In the present study, we adopt the basic analysis of Kim and Duanmu's system (2004). Despite this alternative system, we will continue to use the traditional terms, tense, lax, and aspirated when referring to the three types for readers' convenience. In next section we review some phenomena as supporting evidence for the [voice] system, consonant-tone interaction, merging of aspirated and lax stops, and phonetic implementations of tense consonants.

3. Phenomena

3.1 Consonant-tone interaction[4]

Consonant-tone interaction in Korean has been studied in a number of works (Gim 1969, 1997, Jun 1993, 1996, Kim and Duanmu 1998, 2004, M.-R. Kim 2000, 2005, 2008, 2011, under review). Since it is not new, we review it briefly below (M.-R. Kim 2000: 34-45, Kim and Duanmu 2004: 61-64 for more detailed discussion). Based on the largely quantitative acoustic analysis for segmental factors such as onset and coda consonants, vowel types, and vowel length, M.-R. Kim (2000) proposes that Korean has a strong correlation between onset types and f0, referred as "consonant-tone interaction": H tone was correlated with aspirated and tense consonants and L tone with lax and other voiced counterparts. The examples of consonant-tone interaction in Korean words are represented in (5) for monosyllables and (6) for disyllables where the data were from Jeonnam and Seoul speakers (Kim and Duanmu 2004: 62)[5].

(5)

Word	Gloss	Tonal pattern	Tones on syllables
[t^{h}al]	'mask'	H	H
[t*al]	'daughter'	H	H
[tal]	'moon'	L(H)	L(H)
[mal]	'horse'	L(H)	L(H)

(H is optional in the LH pattern depending on speaker variation)

(6)

Word	Gloss	Tonal pattern	Tones on syllables
[p^{h}araŋ]	'blue'	H	H-H
[p*algaŋ]	'red'	H	H-H
[param]	'wind'	LH	L-H
[mallaŋ]	'soft'	LH	L-H

[4] The term 'consonant-tone interaction' is still controversial on whether it is appropriate to refer to the effect of onset consonants on f0 contour for the Korean data. For example, Jun (1996) refers to 'intonational' instead of 'tonal.' Although tones should not be represented in the lexicon, we adopt the term 'interaction' here in the paper. The reviewer comments consonant-tone interaction in Korean might correspond to those of depressor consonants in Africa Bantu languages. There is a depressor consonant that depresses (lowers) the tone of a neighboring syllable. Thus, lax consonants can be depressor consonants. However, the effect is ultimately a consequence of the phonation (type of voicing) of the consonants. According to the reviewer's comments, if we just describe that lax consonants lowers pitch whereas aspirated and tense consonants raise it, the issue of where tones in Korean comes from remain unsolved.

[5] Longer words also show the same two tonal patterns, H and LH, although the tone may vary from the third syllable on (e.g., [horuragi] 'whistle' H (H-H-H-H or H-H-L-L) and [turumagi] 'traditional topcoat' LH (L-H-H-H or L-H-L-L). The variation suggests an optional rightward spreading of the H tone. Jun (1996: 97) suggests that in long words the H pattern is HHL in Jeonnam Koran but HHLH in Seoul Korean, and the LH pattern is LHL in Jeonnman Korean but LHLH in Seoul Koran.

M.-R. Kim (2000) proposes that the effect in Korean must be considered as tonal, in the sense that it should be represented phonologically with tonal features because of the following reasons. First, the effect on f0 in Korean differs sharply from that in English or French (Jun 1993, 1996, M.-R. Kim 2000). In English or French, there is an intrinsic effect of onset consonants on f0: voiceless consonants raise f0 whereas voiced consonant lowers f0. The effect only appears at the beginning of a given syllable (Hombert et al. 1979). Thus, the effect in English and French is purely phonetic, in the sense that it is local and need not be represented with tonal features. In contrast, the magnitude of the effect of the initial consonant on f0 in Korean is twice that found for English. The effect can persist through several syllables.

Second, the effect in Korean is similar to that in languages which underwent tonogenesis. In the standard model of consonant-tone interaction (i.e., the tonogenesis model), voiceless consonants correlate with H, and voiced consonants correlate with L (voiceless-H and voiced-L). The most familiar type of tonogenesis is the development of tones due to the loss of a voicing distinction on consonants in prevocalic position. Two examples are shown in (7), where (7a) underwent tonogenesis whereas (7b) did not. For example, in Vietnamese, a low tone develops on vowels due to a previously voiced obstruent series, and a relatively high tone develops on vowels due to a previously voiceless series. As exemplified in (7b), Shanghai Chinese still retains onset voicing in addition to tonal differences where the high rise occurs with a voiceless onset and the low rise occurs with a voiced onset (Matisoff 1973, Hu 1980, Duanmu 1996).

(7) a. Historical Vietnamese Vietnamese

pa	—>	pa	high
ba	—>	pa	low

b. Shanghai Chinese

[se]	high rise	‘umbrella’
[ze]	low rise	‘wealth’

As shown in (7), the effect of prevocalic voicing on tone can be generalized as “voiceless-high” and “voiced-low;” that is, a voiceless onset consonant triggers a high tone, and a voiced onset consonant triggers a low tone. Note that a number of characteristics such the influences of prevocalic voicing on f0 contour, the loss of voicing, and the loss of a consonantal opposition have sequentially occurred throughout the history. Cases similar to (7) have been reported in many other languages, including Siamese (Gandour 1974), Burmese (Maddieson 1984), (Baxter 1992), Kammu (Svantesson and House 2006), Tibetan (Duanmu 1992), SiSwati (Wright and Shylock 1993), Kipsikiis (Heida 1982), and Kurtop (Hyslop 2009). Kim and

Duanmu (2004) propose that consonant-tone interaction in Korean can be viewed as standard tonogenesis.

Third, the effect in Korean is consistently found in other dialects. In addition to Jeonnam and Seoul Korean, the effect of onset consonants on tone has also been reported in Kyungsang Korean known as accentual dialects. M.-R. Cho Kim (1994) showed that the consonant-tone interaction is present in Pusan, part of the South Kyungsang dialects. Kenstowicz and Park (2006) showed the effect for both North and South Kyungsang Korean. The results are important, because they demonstrate that, at least in the Kyungsang dialects, there are two fundamentally different tonal phenomena: pitch accents as well as consonant-tone interaction. The results of accentual dialects imply that the consonant-tone interaction can be expected to occur across dialects in Korean because all have three-way phonation differences. However, further quantitative research is necessary to confirm that the effect holds across all dialects in Korean.

The consonant-tone interaction in Korean can be also found in L2 speech production (Kim and Park 2001, M.-R. Kim 2005, under review). In L2 English production, Korean English speakers show a voice-tone interaction corresponding to consonant-tone interaction in L1 Korean: L tones are correlated with L2 voiced stops and H tone with L2 voiceless stops. The results suggest that consonant-tone interaction in L1 speech is transferred to the voice-tone interaction in L2 speech. M.-R. Kim (under review) reports that L2 voiced stops are produced in dual characteristics in terms of VOT and f0: on the one hand, they are produced with a short voicing lag similar to tense stops, and on the other hand, they are produced with a low tone similar to lax stops.

Fourth, in addition to the speech production data described above, perceptual studies provide additional evidence about the consonant-tone correlation in that Korean listeners rely on the tonal differences in contrasting Korean stops. Kim et al. (2002) show that, in Korean word pairs like [tal] 'moon' and [t^hal] 'mask' or [t*al] 'daughter', the vocalic portion carries more contrast than the consonantal portion. The results suggest that tone (or f0) plays an important role in contrasting the words. In word pairs like [tal] and [t^hal] in Korean, if the contrast mainly lies in the initial stops, as traditional analyses assume, we expect the stop portion to carry more perceptual information. On the other hand, if the contrast also occurs in tone (e.g., [tal] with low tone and [t^hal] with high tone) or perhaps mainly in tone, as the present analysis assumes, we expect the vowel or vocalic portion to carry just as much perceptual information or perhaps more information. The relative importance of tone will become much clearer in section 3.2.

A reviewer points out, "In tone languages, tone is phonemic. But in Korean, tone alone is not phonemic. As argued by the authors, tense and lax series are still distinguished by [voice] feature—a segmental feature. Usually

in tone languages, different tones can be associated on to the same segmental materials to be contrastive. But this is not what is happening in Korean. Given the tone-consonant combination is fully predictable, it is hard to agree that tones should be represented in the lexicon." As discussed in the whole paper, we totally agree with the reviewer that tones are neither lexical (phonological) nor phonemic. Thus, they must not be in the lexicon at present. Instead of arguing the lexical tone, we argue in the present paper that the importance of tonal implementations in speech production as well as perception must be discussed to understand sound change in progress. The important fact lies in that Korean stops are undergoing sound change. For example, the role of VOT is getting weaker whereas its f0 is getting bigger, as discussed in production and perception studies. One question arises, "if the effect in Korean is neither purely phonetic nor phonological, how can we capture the importance of tone and the current sound change in progress?" It must be somehow discussed at a certain level of representation. Since there is no appropriate level of representation to refer to sound change in progress, we believe that it must be discussed at the phonological level of representation instead of purely phonetic level of representation. Further research is necessary about how we represent sound change in progress when the effect is not purely phonetic.

As already discussed in Kim and Duanmu (2004: 78-86) in detail, under the [tense] system, the consonant-tone interaction phenomena must be analyzed in terms of language-special mechanisms such as "tense-H and lax-L," "[stiff]-H and default-L," or "[stiff]-H and [-stiff]-L," Analyses under the [tense] system introduce a Korean-specific analysis of consonant-tone interaction. Under The [voice] system, however, the consonant-tone correlation is a similar case of the familiar voiceless-high and voiced-low in the standard tonogenesis theory, and there is no need to assume idiosyncratic consonant-tone interaction. In addition, the issue of why, unlike other voiceless consonants, voiceless lax consonants trigger low tones instead of high tones can be understood.

3.2 Merging of aspirated and lax stops

Voice onset time (VOT) has been used as a primary cue to contrast voiced and voiceless contrasts across worlds' languages (Lisker and Abramson 1964 and among others). For example, in English, VOT is a primary cue and f0 is a secondary cue to contrast voiced and voiceless stop in both production as well as perception (Keating 1984, Kingston and Diehl 1994, Jansen 2007). In contrast, in Korean, VOT becomes a secondary cue whereas f0 (or tone) is a primary cue in contrasting aspirated and lax stops (Kim et al. 2002, Kim under review) because of their VOT merger in the consonantal portion but sub-phonemic tonal differences in the vocalic portion. In section 3.1 we

discuss that there is consonant-tone interaction in Korean and tonal differences play an important role in distinguishing /tal/ 'moon' from /t*al/ 'daughter'. In this section we focus the word pair between /tal/ 'moon' from /t^hal/ 'mask' in that tonal differences are crucial to distinguish /tal/ 'moon' from /t^hal/ 'mask' because of the merger between aspirated and lax stops.

In this paper the merger refers that onset types between lax and aspirated consonants in initial position are being overlapped or neutralized in terms of VOT. The phenomena are quite new, and have been recently reported in a growing number of experimental studies such as Choi (2002), M. Kim (2004), Silva et al. (2004), Silva (2006), Wright (2007), Park (2008), M.-R. Kim (2008, 2011, under review), Kang and Guion (2008), and Oh (2011). It can be described as sound change in progress in Korean.

Evidence of diachronic VOT shift was collected by Silva et al. (2004). In support of the sound change of lax and aspirated stops in terms of VOT, previous VOT results from 60's to present were summarized in Table 1 where mean VOTs and their ranges are roughly "aggregated mean" calculate by simply averaging mean VOT values reported in each study. Earlier studies in 1960's~70's reported that on average, VOTs are shortest for Korean tense stops (i.e. unaspirated), longer for lax (i.e. lightly aspirated), and longest for aspirated (i.e. heavily aspirated) (C.-W. Kim 1965, Lisker and Abramson 1964, Han and Weitzman 1970, Halle and Stevens 1971, Kagaya 1974). Despite systematic mean differences, in the sixties, the VOT overlap between tense and lax stops is more frequent than that between aspirated and lax ones.

In the nineties, compared with in the results of the sixties, mean VOT values of lax stops are slightly longer whereas those aspirated ones are slightly shorter (Shimizu 1991, M.-R. Cho Kim 1994, Y. Kim 1995, Cho 1996). The VOT lengthening phenomena for lax stops but its shortening phenomena for aspirated stops seems to be robust in the results of recent studies after 2004.

Table 1. Mean VOTs (ms) and ranges from 1960's to present. Their aggregated ranges are given in parentheses

	Tense	Lax	Aspirated	Asp-lax
1960's~1970's	11ms (0~52ms)	32ms (15~100ms)	104ms (30~210ms)	**68ms**
1990's~2002's	14ms (9~50ms)	49ms (15~89ms)	91ms (75~121ms)	**42ms**
2004's~present	15ms (2~26ms)	63ms (17~171ms)	77ms (22~196ms)	**14ms**

The comparative data in Table 1 indicate that the VOT differences between aspirated and lax stop have gradually decreased from 68 ms in

1960's, 42 ms in 1990's~2002's to 14 ms after 2004's. The results of recent studies after 2004 show that there is a partial or complete or VOT overlap between aspirated and lax consonants (M. Kim 2004, Silva 2006, Wright 2007, Park 2008, M.-R. Kim 2008, 2011, under review, Kang and Guion 2008, Oh 2011, Kong et al. 2011). To help visualize the VOT merger between aspirated and lax consonants, Figure 1 was plotted by M.-.R Kim (2008: 8).

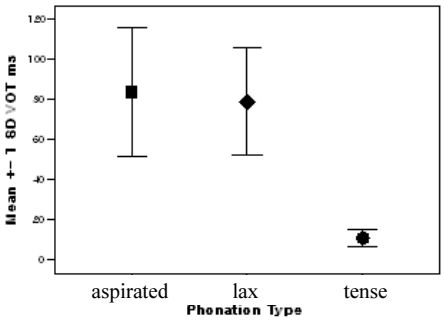

Figure 1. Overall mean VOT mean values (ms) and range (within 1 standard deviation) aggregated from nine female speakers according to aspirated, lax, and tense stop

With regard to the merger phenomenon, various factors such as age, gender, dialect, and L2 fluency have been reported. Silva (2006: 292) reported that speakers who were born after 1965 show a partial or complete overlap while speakers who were born before 1965 show no or little overlap. However, his data showed some individual variation even with the same generation. Similarly, the effect of age on VOT overlap was found in recent studies such as Wright (2007: 74), Park (2008), and Kang and Guion (2008). However, there is speaker variation on the effect of age on VOT. Choi (2002) reports that there is a substantial VOT overlap between lax and aspirated stops for just one of two Seoul male speakers (2002: 7) under the same generation. M.-R. Kim's (2008) reports that two out of six older speakers who were born even before 1960 show the partial or complete VOT merger between the stops. Her data did not correspond to the Silva's data on the effect of age on VOT. Although there is a tendency in that the merger is more frequent among younger speakers than old speakers, there seems speaker variations even in the same generation. According to M.-R. Kim's (2008: 12) data, younger speakers overall produce shorter VOTs for both aspirated and lax stops than older speakers. However, they produce lax stops with longer VOTs, compared with the previous results. Because of speaker variations even within the same age group, it is questionable that there is a clear-cut to define the merger from generation to generation as reported in Silva (2006).

With respect to the effect of dialect on VOT and f0, Choi (2002) reported that Seoul Korean shows relatively more overlapping distribution in VOT and more three-way separation in f0 distribution. Jeonnam Korean, on the other hand, shows the opposite pattern. She also reported that female speakers show more overlap in both VOT and f0 than male speakers. Similarly, the effect of gender on VOT was reported in Oh (2011). She found that the overlaps between lax and aspirated stops were larger for females than males. Overall means of percent overlap between the two stop types were approximately 35.1% for males and 70.6% for females in isolation, and 45% for males and 70.6% for females in the sentence.

Recently, the effect of L2 proficiency on VOT was reported in M.-R. Kim (2011). She found that more proficient speakers produce shorter VOTs for both aspirated and lax stops and show a stronger merger than less proficient ones. However, the effect of L2 proficiency on VOT also shows speaker variations in M.-R. Kim (under review). Even under the similar L2 proficiency, some speakers show a merger while some speakers do not. However, she found that, different from VOT variations among speakers, the effect of onset consonants on f0 contour was consistent for both L1 and L2 stops.

Overall, recent VOT results suggest two: First, there is a partial or complete overlap between aspirated and lax consonant types in contemporary Korean. Second, there are some speaker variations in terms of age, gender, dialect, and L2 English proficiency (Silva 2006, M.-R. Kim 2008, 2011, under review). Speaker variations suggest that the merging phenomena between these two stops are still in the process of ongoing and the sound change in Korean is in progress (see also Appendix B for VOT variations from researcher to researcher). Further study is necessary to confirm which factor mainly triggers sound change in contemporary Korean.

3.3 The phonetic implementations of tense consonants

In this section we review three phonetic implementations of tense consonants: lax-to-tense alternation (tensification), early acquisition of tense consonants, and perceptual similarity between tense and voiceless unaspirated consonants.

Since C.-W. Kim (1965), the tense-lax distinction has been introduced into a Korean consonant system and its distinction has been adopted in a number of studies (Kim-Renaud 1974, Ahn 1985, K.-H. Kim 1987, Kim et al. 2010). He proposed a phonetically-based phonological feature “tensity”, which is characterized by tension of articulation, and argued that this feature is primary in differentiating the three Korean stops. Tension, as in Jakobson et al. (1952), is defined in terms of a number of acoustic/articulary properties, as compared to [-tense] segments. A [+tense] segment is characterized by a stronger burst, longer period of increased pressure or higher amplitude of

pressure during closure, a greater amount of airflow during release, and greater lip muscle activity. Under the traditional system, tense consonants are laryngeally marked whereas lax ones are not. Considering the complicated articulatory and acoustic features of tense consonants in production, it is natural to expect that laryngeally marked [+tense] consonants are harder to produce or acquire than laryngeally unmarked [-tense] ones.

Following the same idea of tensity in C.-W Kim (1965), Kim et al. (2005, 2010) claim that the feature [tense] is an invariant feature to distinguish tense stops from lax stops in Korean. Investigating midsagittal and coronal MRI data, they found that the tense and aspirated stops of Korean have more concomitant tongue larynx raising than the lax stops and that the aspirated consonants have greater glottal opening than the other series. The concomitant tongue and larynx raising and the glottal opening were proposed to be invariant articulatory correlates of the features [+tense] and [+spread glottis], respectively: fortis and aspirated consonants are specified as [+tense] and aspirated as [+spread glottis]; otherwise consonants are [-tense] and [-spread glottis]. They conclude that the feature [tense] is defined in terms of the tensing of both the primary articulator (lips, tongue blade or dorsum) and the vocal folds and that the feature [spread glottis] is defined in terms of glottal opening, as in Halle and Stevens (1971). According to the description of the feature [tense] above, it is expected that tense consonants must need more articulartory efforts than lax counterparts. It is also expected that it is harder to acquire and it is perceived different from regular voiceless unaspirated stops in other languages. However, the unexpected patterns were obtained from production and perception studies of tense consonants below.

In speech production, lax consonants are often alternated with or pronounced as tense consonants without changing the meaning of the words whereas the opposite pattern from tense to lax counterparts has rarely occurred. The phenomenon is traditionally called "tensification" to which underlyingly lax consonants /p, t, c, k/ become tense consonants [p*, t* c*. k*] (where c=tʃ). Some examples of tensification are given in (8).

(8) Tensification
a. Post obstruent tensing
   /kakto/ → [kakt*o] 'angle'
   /makte/ → [makt*e] 'stick'
b. Post sonorant tensing
   /paltal/ → [palt*al] 'development'
   /panpok/ → *[panp*ok] but [panbok] 'repetition'
   /paŋto/ → *[paŋt*o] but [paŋdo] 'method'
c. Initial and medial tensing
   /cacaŋmyun/ → [cacaŋmyun] or [c*acaŋmyun] or 'black noodle'
   /hyogwa/ → [hyogwa] or [hyok*wa] or 'effect'

The process of tensification has long been controversial because it is not always predictable. For example, tensification always occurs after a post-obstruent as in (8a). In contrast, in (8b) it is sometimes occurs but not always. In (8c), both forms are acceptable. Although the second forms with tense consonants are preferred to pronounce among people, the first forms without tensification is forced to pronounce by the Principles of Standard Korean Language Dictionary. According to Lee's survey (2009), despite the Principles, tensification (i.e. lax to tense alternation) has gradually increased from the older to the younger generation in Seoul Korean. Under the [tense] system, since tensity is related to multiple articulatory and acoustic properties, tensification is cross-linguistically not a natural process in speech production. It is hard to understand why tense consonants are preferred to lax ones for pronunciation. A reviewer points out that lax consonants are still more frequent than tense ones. We totally agree with the reviewer because tense consonants are rarely found in written texts. The question is that why the opposite pattern from tense to lax stop never occurs and why people change their pronunciation of tense ones from lax words in orthography. The results suggest that tense consonants are pronounced as default or unmarked stops. Under the [tense] system, it is hard to understand the phenomena. Under the [voice] system, the phenomenon is well understood because tense consonants are laryngeally the most unmarked one, voiceless unaspirated stops as commonly found in other languages.

Move on to another phenomenon on the early acquisition of tense consonants. Jakobson et al.'s (1952) phonological universal says, "voiceless and unaspirated consonants can be acquired earlier than either voiced or aspirated consonants". Beckman et al. (2003) discussed that the order of acquisitions is closely related with the state of glottis. In acquisition across languages, it is easier to acquire phonemes without laryngeal features than the counterparts. If C.-W. Kim's tensity is correct, tense consonants must be more difficult to acquire, compared to lax consonants. Surprisingly, numerous phonetic studies have shown that, among the three phonation contrasts, tense consonants are acquired earlier than lax and aspirated ones (Jun 2007, M.-R. Kim 2007, Kim and Stole-Gammon 2009, 2011, Kong et al. 2011). Because of the same reasons of articulatory complexity, it is hard to understand why children can easily acquire tense consonants rather than the other two. Kim and Stole-Gammon (2011) proposed that the early acquisition of tense consonants may be explained by articulatory complexity with Korean-specific phonetic properties. In order to account for the early acquisition of tense consonants, the traditional system again requires a language-special mechanism for Korean only.

In addition to speech production, the perceptual behavior of tense consonants is not easy to understand under the [tense] system in speech perception. It is a mystery why tense consonants in Korean and voiceless

unaspirated consonants in other languages are perceptually similar. Chang (2006) examined the perception of tense consonants in Korean and voiceless unaspirated in Chinese, Spanish, and English. The results of a perceptional experiment with native Korean speakers showed that, in the initial position, tense consonants are not perceptibly different from the voiceless unaspirated consonants of the other languages.

To sum up, we review three phonetic implementations of tense consonants. First, there is a lax-to-tense alternation (tensification) but not the opposite pattern. Second, tense consonants are acquired earlier than lax counterparts. Third, tense consonants are perceived as voiceless unaspirated ones in other languages. Under the [voice] system, the aforementioned phonetic implementations are a natural phonological process because tense consonants correspond to voiceless unaspirated ones as the most unmarked stops. In contrast, under the [tense] system, it is hard to understand the phenomena. The Korean-specific mechanisms are required to account for the idiosyncratic behaviors of tense consonants. As described in introduction, it is worth noting that the phonetic implementations of the same phonologically voiced and voiceless contrasts are not phonetically same but different across languages and even with a particular language.

4. The analysis

For our analysis, we briefly review problems of the [tense] system in section 4.1. And we discuss how lax aspiration and consonant-tone interaction can be accounted for under the [voice] system in section 4.2 and 4.3.

4.1 Problems

The [tense] approach has a number of problems in accounting for the phenomena in section 3. First, both lax-L tone and lax aspiration are hard to explain. As discussed in Jun (1996), Silva (2006), the approach can adopt a Korean-specific account: [-stiff]-L (or [-tense]-L]) tone where [-stiff] refers to a voiceless consonant, instead of a voiced one. Second, the sound change of lax stops is hard to understand. For example, lax stops have the dual characteristics in terms of VOT and f0: they are correlated with L tone but are heavily aspirated. Again it requires a Korean-specific or idiosyncratic account for the phenomena. Silva (2006: 303) shortly describe that lax consonants become aspirated in initial position from the feature [spread] via redundancy rule. It is hard to understand why voiceless lax consonants, which are underlyingly unmarked with laryngeal features, obtain aspiration in the phonetic representation. In order to obtain a default L tone, a lax consonant must be unspecified with [stiff]. However, in order to obtain aspiration, it must have [spread] in the underlying representation. Under

Silva's analysis, there is no relationship between L tone and aspiration for lax consonants. Third, the phonetic implementations of tense consonants are hard to be accounted for. As already discussed in section 3.3, the [tense] approach requires a Korean-specific mechanism to account for the idiosyncratic behavior of tense consonants. The [tense] approach needs to be reconsidered because it cannot capture the phenomena.

4.2 Genuine minimal triplet in medial position

Taking consonant-tone interaction and merging of aspirated and lax consonants into consideration, one question arises: how do Korean speakers distinguish 탈 'mask' from 달 'moon'? A reviewer states,

> "Although the f0 cue becomes more reliable than the VOT cue, Korean speakers are still aware of consonantal contrasts probably more than f0 contrasts. So f0 cue is more like allophonic property than phonemic property – no need to represent in the lexicon. Pitch alone is not contrastive in modern Korean, so the authors should be careful not to give an impression of arguing that Korean is now a 'tonal' language, which is counter-intuitive to many native speakers."

As a reviewer argues, we totally agree that Korean is not a tonal language and tones in Korean are not lexical. However, we do not agree that f0 differences as well as lax aspiration should be treated as allophonic properties. What we argue is that Korean is undergoing sound change in progress. Neither phonological nor phonetic representation can capture the phonetic implementations of three stops well. Although f0 cue is not contrastive, its important role in speech production as well as perception must be somehow represented. If we should choose one of presentations, it must be a phonological presentation rather than phonetic presentation because of the reasons provided in earlier sections. In phonology, we can discuss cross-linguistic phonetic differences, the sound change in progress, a new approach toward the stop system related with phonetic implementations. According to the reviewer's comments, it is not clear where we discuss the sound change in progress.

Because of the VOT merger and tonal differences between 탈 'mask' vs. 달 'moon' in (2), we can say that they are not a genuine minimal pair anymore in initial position if we follow a strict definition of a minimal pair. A minimal pair is defined as a pair of words whose pronunciations differ by exactly one sound and that have different meanings (Crystal 2003, Ladefoged 2006). For example, the words *pie* and *buy* can be a minimal pair where the sounds [p] and [b] are distinctive or contrastive to distinguish the

meaning of the two words. When two sounds can be used to differentiate words they are said to belong to different phonemes. In other words, the sounds [p] and [b] in the words *pie* and *buy* are phonemes /p/ and /b/ respectively, since the vocalic portions following /p/ and /b/ are phonetically same. To become a minimal pair, the phonetic environment except for /p/ and /b/ must be exactly the same in the words. As a reviewer point out, the vowels are slightly different in terms of f0 as well as the closure duration. However, their f0 perturbation as well as duration is intrinsically motivated and purely phonetic, different from the sub-phonemic status of tone in Korean. The allophonic differences are cross-linguistically attested as well. Hence, there is no doubt for the words *pie* and *buy* to be a minimal pair.

Following a strict definition of a minimal pair, three examples in (2) is not a genuine triplet. Under the [voice] system, the examples of (9) are represented with voicing, aspiration, and tone in the phonemic and phonetic representation.

(9) Two-way contrasts in initial position

Phonemic	Phonetic	Gloss
/t^{h}al/ 탈	[t^{h}al] voiceless, aspirated, H tone	'mask'
/dal/ 달	[t^{h}al] voiceless, aspirated, LH tone	'moon'
/tal/ 딸	[tal] voiceless, unaspirated, H tone	'daughter'

Kim and Duanmu (2004: 90-91) state, "Given the fact that initial tense and lax stops trigger a tonal difference, there is no genuine minimal pair for voiceless tense and voiceless lax stops." Since their analysis cannot capture the merger between aspirated and lax stops, we overcome their shortenings by providing (9). In (9), neither the pair 탈-달 nor the pair 딸-달 can be a minimal pair because of the tonal differences and the VOT (aspiration) merger. Taking (9) into consideration in a Korean consonantal phonology, the genuine minimal triplet can be found when it occurs only in medial position, as given in (10).

(10) Genuine minimal triplet in medial position

Underlying/Orthography		Surface	Tone	Gloss
/a.ba/	아바	[a.ba]	L-H	'God'
/a.pa/	아빠	[a.pa]	L-H	'father'
/a.p^{h}a/	아파	[a.p^{h}a]	L-H	'be sick'
/goŋ.ʤa/	공자	[koŋ.ʤa]	L-H	'Confucius'
/goŋ.ʧa/	공짜	[koŋ.ʧa]	L-H	'gratis'
/goŋ.ʧ^{h}a/	공차	[koŋ.ʧ^{h}a]	L-H	'allowance'

The examples in (10) are a genuine minimal triplet where there are no tonal differences and the VOT merger. Note that M.-R. Kim (2000: 153) reports that there is little effect of non-initial consonants on f0 contour. It establishes genuine contrasts among voiced, voiceless unaspirated, and voiceless aspirated consonants in the medial position.

4.3 Analysis of lax aspiration

M.-R. Kim (2008, 2011, under review) shows that the VOT duration for lax consonants is increased. As a result, they are heavily aspirated toward the merger with aspirated stops. How can we account for this fact?

Concerning lax aspiration and consonant-tone interaction, Silva (2006) provides a prosodic analysis rather than a phonological analysis, as his suggestions are as follows (Silva 2006: 304);

> Aspirated stops, by virtue of their underlying marking for [spread glottis], acquire a tonal value of H; similarly, tense stops, with their surface-level marking for [constricted glottis], likewise acquire an H tone. In contrast, lax stops do not receive any tonal marking, leaving them to be realized by a default-L tone. .....The aspiration feature [spread] in Korean no longer functions phonemically; rather it is now a prosodically conditioned redundant property. More specifically, the insertion of [spread] occurs only in phrase-the initial position, an example of a prosodically driven strengthening process.

Silva's analysis has three problems. First, the relationship between lax consonants and default L tone has not been well attested in other languages. There needs a language-special mechanism: laryngeally unmarked (voiceless)-L vs. laryngeally marked-H. Second, since tense consonants are geminates of lax consonants in his analysis, it is not clear how tense consonants obtain [stiff] and how they introduce H. Third, under the strengthening process, it is not obvious why voiceless lax consonants have characteristics in terms of VOT and f0. It seems to be contradictory to say that laryngeally unmarked lax stops obtain L tone while they have a prosodically driven strengthening process. On the one hand, obtaining L tone is a weakening process. On the other hand, obtaining aspiration is a strengthening process. This paradox needs to be solved in his analysis.

In our analysis under the [voice] approach, lax consonants are plain voiced stops underlyingly. Empirical data (see Table 1 and Appendix B) show that the VOT duration of lax consonants are diachronically shifted from lightly aspirated (i.e., lax devoicing) to heavily aspirated (i.e., lax aspiration). The diachronic VOT shift for lax consonants is represented well in (11).

(11) Diachronic VOT (or aspiration) shift from lightly aspirated to heavily aspirated for lax consonants

UR	Devoicing/tone	SR with aspiration and tone
/dal/ 달	-------> [d̥al] / LH ------->	[t^hal] LH

The process of voicing to aspiration in (11) is not new. It is very common to obtain aspiration and tone from underlyingly voiced consonants as commonly found in standard tonogenesis. Two examples of the effect of prevocalic voice on tone and aspiration can be found in Lhasa Tibetan and Kammu where both aspiration and tone are originated from voicing. Lhasa Tibetan is another well-known case of tonogenesis. An example from Lhasa Tibetan is shown in (12a), where H is a high tone and LH is a rising tone on a monosyllable (Hu 1980, Duanmu 1992, 1996). Note that originally voiced stops become heavily aspirated in Lhasa Tibetan. Lhasa Tibetan acquired tone relatively recently. A similar case can be found in Kammu (Laos). Svantesson and House (2006) reported that Kammu is a language in which the process of acquiring tones is still ongoing. As exemplified in (12b), Eastern Kammu is non-tonal, and retains the original contrasts between voiceless and voiced stops. In Northern and Western Kammu, syllables with originally voiceless and voiced initials have developed high and low tones respectively. Originally voiced initials become voiceless in Northern Kammu but heavily aspirated in Western Kammu.

(12) Tonogenesis in Tibetan

a. Historical Tibetan — Lhasa Tibetan

k^ho	-->	[k^ho]	H 'he'
go	-->	[k^ho]	LH 'hear'

b.

Eastern	Northern	Western	
taaŋ	taaŋ H	taaŋ H	'pack'
daaŋ	taaŋ L	t^haaŋ L	'lizard'
t^haaŋ	t^haaŋ H	t^haaŋ H	'to clear'

Looking at the data in (12), one is to take the view that the diachronic VOT (aspiration) change of lax consonants corresponds to the Kammu data. Base on the Korean data, there are speaker variations on VOT in terms of dialect (Choi 2002). It is possible that tone and aspiration in Korean dialects may correspond to those in Kammu. To confirm the effect of dialect on VOT and f0, further study is necessary. With this view, one can say that the current sound change is closely related with tonogenesis. Without tonogenesis, the sound change in Korean is totally language-specific or idiosyncratic. The other possibility is to take the view that sound change in

Korean is in progress. We cannot say that Korean will become a tone language unless there is a complete merger of a consonantal opposition. Since tone is not lexically contrastive, we cannot say that it is not phonemic. As a reviewer points out, in order to support the ongoing merger, other acoustic cues such as intensity and f0 must be examined. The fact that sound change in Korean is still in progress can be supported by results of speaker variations as discussed earlier.

4.4 Analysis of tense consonants

According to the [tense] approach, Korean is the only language that distinguishes [p] vs. [p*] (i.e., lax vs. tense). With respect to tensity, tense consonants are laryngeally specified whereas lax ones are unmarked (C-W. Kim 1965, Kim 1987). Tension, as in Jakobson et al. (1952), is defined in terms of a number of acoustic/articulatory properties, as compared to [-tense] segments. A [+tense] (or similar features such as [+constricted glottis] and [+fortis]) segment) is characterized by a stronger burst, a greater amount of airflow during release, and greater lip muscle activity. This characterization led us to expect that we may need an extra articulatory and perceptual effort in order to produce and perceive tense consonants. However, the phonetic implementations do not correspond to the complicated characteristics of tense consonants.

In order to describe tense consonants different from the two other voiceless consonants, numerous features such as [tense], [fortis], [constricted glottis] have been proposed (C.-W. Kim 1965, Halle and Stevens 1971, Gim 1997). The use of features for tense consonants has long been controversial. Halle and Stevens (1971) replace the feature [tense] with the feature [constricted glottis]. However, using [constricted glottis] is also problematic because it is originally a feature for the glottal stop [ʔ]. In order to claim that the tense stop is a glottalized [ʔ], one must show that the tense stop has the same glottal closure as [ʔ]. Kim and Duanmu (2004) discuss that there is an over-prediction problem. The traditional features [voice] and [aspirated] give four stops: [p^h p $b^ɦ$ b] (ignoring implosives and clicks), all of which have been found. With a new feature [tense], the number is doubled (see Kim and Duanmu 2004: 60). They argue that there is no language that makes use of all the stops, or anywhere close.

Under the [tense] analysis, a number of questions arise. First, why is there frequent tensification or lax to tense alternation in Korean? Why not the opposite pattern? It is quite unnatural to explain that laryngeally unmarked lax consonants become laryngeally marked tense consonants which need extra articulatory efforts in production. Second, why do children acquire articulartorily complicated tense consonants first instead of simple and

unmarked lax ones? Kong et al. (2011) explains that they can acquire tense consonants earlier than others because of a short VOT. There still needs a language-specific explanation on more complicated consonants to be acquired earlier than less complicated ones. Third, why are tense consonants similarly perceived as voiceless unaspirated ones in other languages? In Chang's (2006) perceptional study, in word initial position, tense consonants are not perceptibly different from the regular voiceless unaspirated consonants of the other languages such as Chinese, Spanish, and English. These questions remain unanswered in the traditional [tense] analysis. Under the [tense] system, phenomena such as tensification (i.e. tense-lax alternation), the early acquisition of tense consonants, and perceptual similarity between tense and voiceless unaspirated stops are very unnatural. All facts require a Korean-specific account because Korean is the only language that reports those phenomena.

In our analysis, however, tense consonants are at least marked in the sense that the tense series are regular voiceless unaspirated as found in other languages. We claim that there are no more tense consonants in Korean phonology. With this assumption, the phonetic implementations of tense consonants in section 3.3 are easily understood. If tense consonants are unmarked ones in Korean consonantal phonology, it is quite natural to explain why marked lax consonants become unmarked voiceless unaspirated (i.e. tense) ones, why children acquire tense (i.e. voiceless unaspirated) consonants easier than other consonants, and why tense consonants are perceptibly similar to the regular voiceless unaspirated consonants of the other languages such as Chinese and English.

Assuming that tense consonants are regular voiceless unaspirated consonants, they are laryngeally unmarked or unspecified in terms of voicing and aspiration (i.e. [-voice] and [-aspirated] or [-stiff] and [-spread]). There will be no tensification in Korean as one of the strengthening phenomena in speech production. In the present study, so-called "tensification" will be one of the weakening processes, by losing a [voice] quality. Similar cases can be found in English. In English, the voiced sound in /b/ in the word 'buy' becomes devoiced as [b̥ai]) by delinking of the [voice] feature in initial position and /p/ in the word 'spy' become unaspirated. In production, it is not surprising to see that Korean speakers produce both /b/ and /p/ similar to tense consonants. If then, the tensification process in (8) can be revisited in (13), as simply a process from voiced to voiceless unaspirated stops.

(13) Voiced to voiceless unaspirated (lax to tense) alternation
a. Post obstruent tensing
/gagdo/ → [k^{h}akto] 'angle'
/magde/ → [makte] 'stick'

b. Post sonorant tensing
/bal͟dal/ → [p^{h}al͟tal] 'development'
/ban͟bok/ → [p^{h}an͟bok] 'repetition'
/baŋ͟do/ → [p^{h}aŋ͟do] 'method'
c. Initial and medial tensing
/j͟ajaŋmyun/ → [j͟ajaŋmyun] or [c͟^{h}ajaŋmyun] or 'black noodle'
/hyog͟wa/ → [hyog͟wa] or [hyok͟wa] or 'effect'

In (13), there is a voiced-to-voiceless unaspirated alternation after post obstruents in (13a), after /l/ in (13b), and initially in (13c). Voiced lax consonants are phonetically realized as either voiceless aspirated or unaspirated in initial position, voiced or devoiced in medial position, voiceless unreleased in final position. In Korean, lax aspiration (voiced to aspirated) and lax tensification (voiced to unaspirated) belong two separate processes: one is ongoing tonogenesis as in Kammu (b→p^{h}) while the other is just phonetic devoicing process as in English (b→b̥).

5. Conclusion

Unlike most languages in the world, Korean consonants are traditionally characterized by a three-way voiceless contrast in the initial position. They are called, "aspirated", "tense or fortis", and "lax or lenis" (e.g. /t^{h}al/ 탈 'mask', /t*al/ 딸 'daughter', and /tal/ 달 'moon'). The system basically assumes that Korean has an unusual consonantal phonology and it needs a language-specific mechanism to account for phonetic facts such as consonant-tone interaction, merging of aspirated and lax consonants, and the phonetic implementations of tense consonants in production and perception.

In contrast, under the [voice] system, Korean is not unusual. Similar to other languages, Korean has regular stops which can be simply defined in terms of voicing and aspiration: a regular voiceless unaspirated stop for the "tense" stop, a regular voiced stop for the "lax" stop, and a regular voiceless aspirated stop for the aspirated stop. In the current analysis, the consonant-tone interactions as well as merging phenomena together are analyzed under a standard tonogenesis theory. The early acquisition of tense consonants, tense preference (i.e., lax to tense alternation), and perceptual similarity between tense and voiceless unaspirated consonants can be better understood under the [voice] system than the traditional system without introducing Korean-specific explanations. Concerning the phonetic and phonological properties, the analyses of the two systems are compared in Table 2.

As seen in Table 2, the traditional [tense] system requires a language-special mechanism to explain Korean phonetic and phonological properties whereas the [voice] system does not. Compared with the [tense] system, the [voice] system offers a better analysis of Korean properties and a simpler

theory of distinctive features in that we assume no special features or special kinds of consonants, or special consonant-tone correlation as well as lax aspiration.

Both approaches can possibly account for Korean phonetics and phonology. The main difference between the two systems lies in whether Korean is the special case or not. As pointed out by Kim and Duanmu (2004), we believe that there is no compelling evidence to consider Korean unique. Even without a special mechanism it might be possible that Korean phonetics and phonology can be better explained.

Table 2. Summary chart between the [tense] vs. [voice] system

	[tense] system	[voice] system
Voicing Contrast	all voiceless	voiced vs. voiceless
Three-way contrast	initially	medially
Feature [tense]	Yes	No
Terms	idiosyncratic	"aspirated", "voiceless unaspirated", "voiced"
laryngeal features	see appendix A	[+spread, +stiff] for aspirated, [-spread, +stiff] for unaspirated, and [-spread, -stiff] for voiced
consonant-tone interaction	idiosyncratic	voiced-low vs. voiceless-high
lax aspiration or merging of two stops	idiosyncratic	cross-linguistic (tonogenesis)
early acquisition of tense Cs	idiosyncratic	cross-linguistic (Jakobson's universal principle)
Tense production and perception	idiosyncratic	cross-linguistic (unmarkedness)
Definition of a minimal pair	loose	strict
Perceptual similarity between tense and voiceless unaspirated	Idiosyncratic (hard to explain why)	cross-linguistic (tense = voiceless unaspirated

REFERENCES

AHN, SANG-CHEOL. 1985. *The Interplay of Phonology and Morphology in Korean.* PhD Dissertation. University of Illinois, Urbana-Champaign.

AHN, SANG-CHEOL and GREGORY K. IVERSON. 2004. Dimensions in Korean laryngeal phonology. *Journal of East Asian Linguistics* 13.4, 345-379.

BAXTER, WILLIAM. 1992. *A Handbook of Old Chinese Phonology*. Berlin: Mouton de Gruyter.

BECKMAN, E. MARY, KIYOKO YONEYAMA, and JAN EDWARDS. 2003. Language-specific and language universal aspects of lingual obstruent productions in Japanese-acquiring Children. *Journal of the Phonetic Society of Japan* 7, 18-28.

CHANG, CHARLES B. 2006. Tense consonants in Korean revisited: A cross linguistic perceptual study. *Proceedings of the Fourth University of Cambridge Postgraduate Conference in Language Research*, 35-42.

CHO, TAEHONG. 1996. *Vowel Correlates to Consonant Phonation: An Acoustic-perceptual Study of Korean Obstruents*. MA thesis. University of Texas at Arlington.

CHO, TAEHONG, SUN-AH JUN, and PETER LADEFOGED. 2002. Acoustic and aerodynamic correlates of Korean stops and fricatives. *Journal of Phonetics* 30.2, 193-228.

CHOI, HANSOOK. 2002. Acoustic cues for the Korean stop contrast: dialectal variation. *ZAS papers in Linguistics* 28, 1-12.

CHOI, CHUN-TAE. 1995. *Godae gugeo umjeolgujowa yuseong jeohaeumedehan yeongu* [A Study of Syllable Structure and Voiced Obstruents in Old Korean]. PhD Dissertation. Kyemyeong University.

CRYSTAL, DAVID. 2003. *A Dictionary of Linguistics and Phonetics* (5th ed.). Oxford, UK: Blackwell Publishers Ltd.

DUANMU, SAN. 1992. An autosegmental analysis of tone in four Tibetan languages. *Linguistics of the Tibeto-Burman Area* 15, 65-91.

DUANMU, SAN. 1996. Tone: An overview. In L. L.-S. Cheng and R. Sybesma (eds.) *The First Glot International State-of-the-Article Book: The Latest in Linguistics*. Mouton de Gruyter, Berlin, 251-286.

GANDOUR, JACKSON. 1974. Consonant types and tone in Siamese. *Journal of Phonetics* 2, 337-350.

GIM, CHA-GYUN. 1969. Jeonnam bangeone seongjo [Tone in Jeonnam Korean]. *Hangul* 144, 142-171.

GIM, CHA-GYUN. 1997. Jeonnam bangeone seongjo Jeongdojajilgwa urimalui ummunhyeonsang [Gradient features and phonological phenomena in Korean]. *Chungnam Nonmunjip* 24, 161-253.

HALLE, MORRIS, and KENNETH STEVENS. 1971. A note on laryngeal features. *Quarterly Progress Report* 101, 198-213.

HAN, JEONG-IM. 1996. *The Phonetics and Phonology of "Tense" and "plain" consonants in Korean*. PhD Dissertation. Cornell University.

HAN, S. MIEKO and REYMOND S. WEITZMAN. 1970. Acoustic features of

Korean/P,T,K/, /p,t,k/, and /p^h,t^h,k^h/. *Phonetica* 22, 112-128.
HASHIMOTO, MANTARO J. and CHANG-KYUN YU. 1972. Phonological distinctions of Korean consonants. *Eomunhak* 26, 49-61.
HEIDA, OSAMU. *1982.* Consonant types and tone in Kipsikiis*. Studia Phonologica* XVI, 12-25.
HOMBERT, JEAN-MARIE, JOHN J. OHALA, and WILLIAM G. EWAN. 1979. Phonetic explanation for the development of tones. *Language* 55, 37-58.
HU, TAN. 1980. Zangyu (Lhasa Hua) shengdiao yanju [A study of Tone in Lhsa Tietan]. *Minzu Yuwen* 1, 22-36.
HYSLOP, GWENDOLYN. 2009. Kurtop tone: a tonogenetic case study. *Lingua* 119, 827-845.
IVERSON, GREGORY K. and Joseph C. SALMONS. 1995. Aspiration and laryngeal representation in Germanic. *Phonology* 12, 369-396.
JAKOBSON, ROMAN, FANT G., and MORRIS HALLE. 1952. *Preliminaries to Speech Analysis*. Cambridge, MA: MIT Press.
JANSEN, WOUTER. 2007. Phonological 'voicing', phonetic voicing, and assimilation in English. *Language Sciences* 29, 270-293.
JESSEN, MICHAEL. 1998. *Phonetics and Phonology of tense and lax obstruents in German.* Amsterdam: Benjamin.
JONES, DANIEL. 1956. *An Outline of English Phonetics*, eight ed. Heffner, Cambridge.
JUN, SUN-AH. 1993. *The Phonetics and Phonology of Korean Prosody*. PhD Dissertation. The Ohio State University.
JUN, SUN-AH. 1994. The status of the lenis stop voicing rule in Korean. In Kim-Renaud (eds.). *Theoretical Issues in Korean Linguistics*, Center for the Study of Language and Information, Standford University, 101-114.
JUN, SUN-AH. 1996. Influence of microprosody on macroprosody: a case of phrase initial strengthening. *UCLA Working Papers* 92, 97-116.
JUN, SUN-AH. 2007. Phonological development of Korean: A case study. *UCLA Working Papers in Phonetics* 105, 51-65.
KAGAYA, RYOHEI. 1974. A fiberscopic and acoustic study of Korean stops, affricates, and fricatives. *Journal of Phonetics* 96, 43-68.
KANG, KYUNGHO and SUSAN GUION. 2008. Clear speech production of Korean stop: changing phonetic targets and enhancement strategies. *Journal of Acoustical Society of America* 124, 3909-3917.
KEATING, PATRICIA. 1984. Phonetic and phonological representation of stop consonant voicing. *Language* 60.2, 286-319.
KENSTOWICZ, MICHAEL and PARK, CHIYOUN. 2006. Laryngeal features and tone in Kyungsang Korean: a phonetic study. *Studies in phonetics, phonology, and morphology* 12.2, 247-264.
KIM, CHIN-WOO. 1965. On the autonomy of the tensity feature in stop classification (with special reference to Korean stops). *Word* 21, 339-359.
KIM, KEE-HO. 1987. *The Phonological Representation of Distinctive Features: Korean Consonantal Phonology*. PhD Dissertation.

University of Iowa.

KIM, HYUNSOON and ALLARD JONGMAN. 1996. On acoustic and perceptual evidence for complete neutralization of manner of articulation in Korean. *Journal of Phonetics* 24, 295-312.

KIM, HYUNSOON, SHINJI MAEDA and KIYOSI HONDA. 2005. Stroboscopic cine-MRI study on the phasing between the tongue and the larynx in Korean three-way phonation contrast. *Journal of Phonetics* 33, 1-26.

_____. 2010. Invariant articulatory bases of the features [tense] and [spread glottis] in Korean plosives: New stroboscopic cine-MRI. *Journal of Phonetics* 38, 90-108.

KIM, MIDAM. 2004. Correlation between VOT and f0 in the perception of Korean stops and affricates. *Proceedings of the 8th International Conference on Spoken Language,* 49-52.

KIM, MINJUNG and CAROL STOEL-GAMMON. 2009. The acquisition of Korean word-initial stops. *Journal of Acoustical Society of America* 125, 3950-3961.

_____. 2011. Phonological development of word-initial Korean obstruents in young Korean children. *Journal of Child Language* 38, 316-340.

KIM, MI-RAN CHO. 1994. *Acoustic Characteristics of Korean Stops and Perception of English Stop Consonants.* PhD Dissertation. University of Wisconsin, Madison.

KIM, MI-RYOUNG. 2000. *Segmental and Tonal Interactions in English and Korean: A Phonetic and Phonological study*. PhD Dissertation. The University of Michigan.

_____. 2005. Voicing and tone correlation in L2 English. *Speech Sciences* 12.4, 1-16.

_____. 2007. The acquisition of Korean stops: a longitudinal case study of an infant (written in Korean). *Korean Journal of Linguistics* 32.3, 385-410.

_____. 2008. "Lax" stops in Korean revisited: VOT neutralization. *Studies in Phonetics, Phonology and Morphology* 14.2, 185-203.

_____. 2011. The relationship between cross-language phonetic influences and L2 proficiency in terms of VOT. *Speech Sciences* 3.3, 3-11.

_____. under review. L1-L2 transfer in VOT and f0 by Korean English learners: L1 sound change and L2 speech production.

KIM, MI-RYOUNG, PATRICE BEDDOR and JULIE HORROCKS. 2002. The contribution of consonantal and vocalic information to the perception of Korean initial stops. *Journal of Phonetics* 30.1, 77-100.

KIM, MI-RYOUNG and SAN DUANMU. 1998. The correlation between onset voicing and tone: a tonogenesis effect in Chonnam Korean. P*roceedings of the 11th ICKL* (11th international Conference on Korean Linguistics), ed. B.-S. Park and H.-S. James Yoon. University of Hawai'i at Manoa.

429-438.

_____. 2004. "Tense" and "lax" stops in Korean. *Journal of East Asian Linguistics* 13, 59-104.

KIM, MI-RYOUNG and KYUNG-JA PARK. 2001. A Korean consonant-tone transfer in L2 (English) acquisition. "Tense" and "lax" stops in Korean. *Journal of the Pan-Pacific Association of Applied Linguistics* 5, 279-295.

KIM, YOUNGHO. 1995. *Acoustic characteristics of Korean coronal stops, affricates, and fricatives.* M.A. Thesis. The University of Texas at Arlington.

KIM-RENAUD, YOUNG-KEY. 1974. *Korean Consonantal Phonology*. PhD Dissertation, University of Hawaii.

KINGSTON, JOHN, and RANDY L. DIEHL. 1994. Phonetic knowledge. *Language* 70.3, 419-453.

KOHLER, KLAUS J. 1979. Dimensions in the perception of fortis and lenis plosives. *Phonetica* 36, 332-343.

KONG, EUN JONG, MARY E. BECKMAN, and RANDY JAN EDWARDS. 2011. Why are Korean tense stops acquired so early?: The role of acoustic properties. *Journal of Phonetics* 39, 196-211.

LADEFOGED, PETER and IAN MADDIESON. 1996. *The Sounds of the World's Languages*. Oxford, UK: Blackwell Publishers Ltd.

LADEFOGED, PETER. 2006. *A Course in Phonetics* (5th ed). Boston, MA: Thomson Higher Education Press.

LEE, BEONG-GEON. 1985. *Hyundai hangugeoui saengseong eumunron* [The Generative Phonology of Modern Korean] Ilji Co., Seoul, Korea.

LEE, HO-YOUNG. 2009. Tensification preference of native Seoul speakers of Korean (written in Korean). *Journal of the Korean Society of Speech Sciences* 1.2, 151-162.

LISKER, LEIGH and ARTHUR S. ABRAMSON. 1964. A cross-language study of voicing initial stops: Acoustical measurements. *Word* 21, 384-422.

LOMBARDI, LINDA. 1991. *Laryngeal features and laryngeal neutralization*. PhD Dissertation. University of Massachusetts Amherst.

MADDIESON, IAN. 1984. The effect on f0 of a voicing distinction in sonorants and their implications for a theory of tonogenesis. *Journal of Phonetics* 12, 9-15.

MATISOFF, JAMES A. 1973. Tonogenesis in Southeast Asia. In Consonant types and tone. L. Hyman (ed.). *Southern California Papers in Linguistics* 1, 72-95.

MOON, YANG-SOO. 1974. Yeoksa eoneohak [Historical Linguistics]. *Eoneoyeongu* 10.2, 1-7.

OH, EUNJIN. 2011. Effects of speaker gender on voice onset time in Korean stops. *Journal of Phonetics* 39, 59-67.

OH, JONG-GAP. 1981. *Gugeo yuseong jeohaeeumui byeoncheone wanhan yeongu* [A Study of Korean Voiced Obstruents with special Reference to /b, d, z, g/]. PhD Dissertation. Yeongnam University.

PARK, HAEIL. 2008. *Brain Activation Patterns in Perception of Korean*

Laryngeal Contrasts. PhD Dissertation. The University of Wisconsin-Milwaukee.

PIERREHUMBERT, JANET B. 1980. Phonological and phonetic representation. *Journal of Phonetics* 18, 375-394.

SILVA, DAVID. 1992. *The Phonetics and Phonology of Stop Lenition in Korean*. PhD Dissertation. Cornell University.

_____. 2006. Acoustic evidence for the emergence of tonal contrast in contemporary Korean. *Phonology* 23.2, 287-308.

SILVA, DAVID, YOUNGJEOUNG CHOI, and JI EUN KIM. 2004. Evidence of a diachronic shift in the VOT values of Korean stop consonants. *Harvard Studies in Korean Linguistics* 10, 173-185.

SHIMIZU, KATSUMASA. 1991. *A cross-language study of voicing contrasts of stop consonants in Asian languages*. PhD Dissertation. University of Edinburgh.

STEVENS, KENNETH N. and SAMUEL JAY KEYSER. 1989. Primary features and their enhancement in consonants. *Language* 65.1, 81-106.

SVANTESSON, JAN-OLOF and DAVID HOUSE. 2006. Tone production, tone perception and Kammu tonogenesis. *Phonology* 23, 309-333.

WRIGHT, JULIO. 2007. *Laryngeal Contrast in Seoul Korean.* PhD Dissertation. The University of Pennsylvania.

WRIGHT, RICHARD and AARON, SHRYOCK. 1993. The effects of implosives on pitch in SiSwati. *Journal of the International Phonetic Association* 23.1, 16-23.

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APPENDIX A
The summary chart of laryngeal features in the [tense] system

	Tense	Lax Initial	Aspirated	Lax Medial	Laryngeal features
C.-W. Kim (1965) Kim-Renaud (1974) Ahn (1985)	[+aspirated, +tense, -voice]	[-aspirated, -tense, -voice]	[+aspirated, +tense, -voice]	[-aspirated, -tense, +voice]	[aspirated], [tense], [voice]
Halle and Stevens (1971)	[+constricted, -spread, +stiff, -slack]	[+spread, -constricted, -stiff, -slack]	[+spread, -constricted, +stiff, -slack]	[-spread, -constricted, -stiff, +slack]	[spread], [constricted], [stiff], [slack]
K.-H. Kim (1987) Lombardi (1991) Jun (1993)	[-spread, +constricted]	[-spread, -constricted]	[+spread, -constricted]		[spread] and [constricted]
Silva (1992)	Geminate: [-spread, +constricted]	[-spread, -constricted]	[+spread, -constricted]		[spread], [constricted]
Jun (1996)	[-spread, +constricted, +stiff]	[-spread, -constricted, -stiff]	[+spread, -constricted, +stiff]		[spread], [constricted], [stiff]
Gim (1997)	[+fortis, -aspirated]	[-fortis, -aspirated]	[+fortis, +aspirated]		[fortis], [aspiration]
Ahn and Iverson (2004)	Geminate: [+constricted, +stiff]	unmarked	[+spread, +stiff]		[spread], [constricted], [stiff]
Silva (2006)	Geminate; [stiff] at the surface	Unmarked; [spread] at the surface	[stiff]; [spread] at the surface		[spread], [stiff]
Kim et al. (2010)	[+tense]	[-tense, -spread]	[+tense, +spread]		[spread], [tense]

APPENDIX B

Approximate "aggregated" mean VOT values of tense, lax, and aspirated consonants from 1960 to 2011. Their ranges are given in parentheses

	Tense	Lax	Aspirated	Asp-lax
Lisker and Abramson (1964)	12 (0-35)	30 (10-65)	103 (65-200)	73
C.-W. Kim (1965)	15	38	92	54
Han and Weitzman (1970)	7 (0-53)	30 (10-100)	107 (66-148)	77
Shimizu (1991)	15 (0-40)	33 (15-70)	91 (75-110)	58
Silva (1992)	9	62 (56-70)	78	16
Kim, Cho M.-R. (1994)	9 (9~11)	51 (15~78)	78 (75~87)	27
Y. Kim (1995)	11 (7-14)	64 (31-108)	115 (88-158)	51
Cho (1996)	25 (10-50)	59 (36-89)	100 (79-121)	41
M.-R. Kim (2000)	11 (4-19)	39 (19-80)	76 (62-94)	37
Cho et al (2002)	21	58	113	55
Silva et al (2004)	14 (8~21)	72 (42~91)	92 (67~127)	20
Kenstowicz and Park (2006)	22	50	81	31
Wright (2007)	NA	48 (19~80)	57 (28~87)	9
Park (2008)	NA	75 (58~87)	75 (60~93)	0
M.-R. Kim (2008)	11 (2-26)	79 (17-171)	84 (22-196)	5
Oh (2011)	15 (9~24)	52 (32~75)	70 (39~97)	18

(VOT values were not available but the overlapping phenomena were reported in Choi (2002), M. Kim (2004), Silva (2006), and Kang and Guion (2008))