Why [h] and aspirated consonants are different in Korean

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This paper examines the phonological processes affecting [h] and aspirated consonants in Korean and provides a comprehensive analysis in Optimality Theory. Following standard assumptions, [h] and aspirated consonants are treated as a class of aspirates and specified for the same laryngeal feature, e.g., [spread glottis]. Despite this formal similarity, they undergo different processes in the same syllabic positions, e.g., coda position and post-obstruent onset position. We argue that these facts require an analysis in which all coda aspirates violate a positional markedness constraint, but that [h] differs from aspirated consonants in lacking a surface place specification. In particular, placeless [h] is treated differently by faithfulness constraints, which makes it possible to account for the different processes it undergoes. Plausible alternations are also considered that employ various combinations of these assumptions with positional faithfulness constraints. This discussion shows the necessity of both positional markedness and the assumed placeless [h], because none of the alternatives can account for the full pattern in Korean.

1.   Introduction

This paper is about the phonological behavior of aspirated consonants and [h] in Korean. In particular, it focuses on the phonological processes affecting these segment classes shown below and asks how to motivate the distinct repairs for them in Korean. This question is of some interest, because a common strategy for motivating phonological repairs to laryngeal consonants, and marked codas generally, is to link the phonological repair to the occurrence of marked laryngeal features somehow. Aspirated consonants and [h], under standard assumptions, bear the same laryngeal feature, e.g., [spread glottis], and yet they differ as to whether a repair is required (1b) and the specific changes required by the repair (1c-d).

(1) Different Repairs for Aspirated Consonants and [h] in Korean

	C^h	h
a. Same: $_\sigma[$___	*No repair*	*No repair*
b. Different: $C_{Obstruent}\ _\sigma[$___	*No repair*	Repair: Coalescence
c. Different: ___$]_\sigma\ C_{Obstruent}$	Repair: Neutralization to C	Repair: Coalescence
d. Different: ___$]_\sigma$ #	Repair: Neutralization to C	Repair: Deletion

In Optimality Theory (Prince and Smolensky 1993, 2004), the problem of motivating different phonological repairs has been analyzed as a consequence of certain refinements of markedness and faithfulness constraints. In a very influential work, (Lombardi 2001) also found different repairs for voiced obstruents and independent place specifications in coda position, as charted below. Lombardi proposes that the reason [voice] has a proper subset of the repairs found for resolving coda Place features follows from a positional markedness constraint for coda Place, and the lack of a corresponding restriction for coda [voice]. Languages that only have a voicing contrast in onsets rank a positional faithfulness constraint high, and neutralize [voice] in codas via context-free markedness.

(2) Different Repairs for Coda [voice] and Place (Lombardi, 2001)

	[voice]	Place
Repairs	*Few* (proper subset) Devoicing	*Many* (superset) Devoicing Epenthesis Deletion
Implication	Positional Faithfulness	Positional Markedness

Will the Lombardian approach work for Korean? The Korean evidence alone is not enough to motivate this approach, since neutralization of aspirated consonants is not found for [h] in standard Korean. However, neutralization of [h] to a corresponding glottal stop or a coronal fricative is indeed attested cross-linguistically. It seems therefore that a viable null hypothesis for Korean is that the plethora of repairs observed for coda [h] is due to a context-sensitive markedness constraint, *h]$_\sigma$, and that aspirated consonants are treated just like voiced obstruents in Lombardi's model. In other words, neutralization of [spread glottis] in codas could be simply the result of context-free markedness, with positional faithfulness protecting aspirated consonants in onset position.

This paper tests the Lombardian approach and concludes that it is insufficient to account for all of the facts in Korean. In particular, while the Lombardian approach is successful in accounting for differences in codas, there are also differences in onset position that it cannot account for. The coalescence of [h] with an adjacent consonant, in both coda and onset position, we argue requires the assumption that [h] is placeless in surface representations. We show that this assumption, which is motivated by

independent facts of laryngeal transparency in Korean, can account for all of the data if it is coupled with a general positional markedness constraint against [spread glottis] in codas. Finally, we consider all possible combinations of these assumptions: positional markedness, positional faithfulness, and placeless [h], and conclude that only this particular combination of assumptions is necessary and sufficient for the facts of Korean.

The remainder of this paper is organized as follows. Section 2 lays out some important background assumptions about the Korean syllable and four key phonological processes in Korean, setting the stage for a presentation of the full distribution of aspirated consonants and [h] in section 3. The Lombardian approach (Hypothesis A) is fleshed out in section 4, and the problem with this analysis is clarified. Section 5 proposes a new analysis (Hypothesis B) that makes use of a general positional markedness constraint plus the assumption that [h] is placeless in surface representations. Section 6 discusses two alternative approaches, one with positional faithfulness for all aspirated consonants and surface placeless [h] (Hypothesis C), and another that just assumes surface placeless [h] (Hypothesis D). It concludes that both alternatives are insufficient and therefore support the core assumptions of Hypothesis B, namely general positional markedness for aspirates and surface placeless [h] in Korean. The last section sketches some predictions of this approach for future research.

2. Linguistic background

The consonant system of Korean, shown below, has three stop series distinguished by laryngeal setting. These are the plain stops, tense (or stiff voice) stops, and aspirated stops. The fricatives /s, s'/ only contrast for tenseness, and /h/ is assumed here to be a glottal fricative with the same laryngeal setting as aspirated stops (see below).

(3) Korean consonant phonemes

p	t	c	k	
p'	t'	c'	k'	
p^h	t^h	c^h	k^h	
	s			h
	s'			
m	n		ŋ	
	l			

Korean syllables consist of an obligatory vowel, which can be preceded by an optional onset consonant and/or glide and followed by an optional coda consonant: (C)(G)V(C). The occurrence of medial clusters and word-final consonants triggers a number of phonological processes, summarized below, that interact with the distribution of [h] and aspirated consonants discussed in the next section.

(4) Key phonological processes affecting medial clusters and final codas

a. <u>Coda Neutralization</u>: coda obstruents become corresponding plain stops; coronal distinctions neutralized to [+ant]; [h] deleted

$C_{obstruent}$#   → C_{plain} /ap^h/ → [ap] 'front'

$C_{cor.obstruent}\# \rightarrow C_{cor.dental.obstruent}$ /nac/ → [nat] 'daytime'
h#   → Ø   /anh / → [an] 'in'

b. <u>Post-obstruent tensing</u>: post-obstruent plain stops become corresponding tense stop
$C_{obstruent}C_{plain.stop} \rightarrow C_{obstruent.} C_{tense.stop}$ /hak-kjo/ [hak.k'jo] 'school'

c. <u>Coalescence</u>: [h] merges with a following or preceding plain stop
$C_{plain.stop}$ h   → C^h /pɛk-ho/ → [pɛ.kʰo] 'white tiger'
h $C_{plain.stop}$ → C^h /suh-talk/ → [su.tʰak] 'rooster'

d. <u>Obstruent-nasal assimilation</u>: obstruents become nasal stops before nasal stops, retaining their original place specifications
$C_{obstruent} C_{nasal}$ → $C_{nasal} C_{nasal}$ /hot-nun/ → [hon.nun] 'ocellus'

Stops in codas neutralized by (4a) are in fact unreleased. We assume, following standard assumptions, that this is a phonetic process and that it is beyond the scope of this paper. Also, intervocalic stops are typically voiced by a separate allophonic process. There is another phonological process (4b), subject to morphological restrictions, causing plain obstruents to be tensed after another obstruent. We assume that this process of post-obstruent tensing is also outside the scope of this paper because it does not directly interact with the constraints on [spread glottis].

    For concreteness we assume, following Ahn (1998), that [h] is an obstruent (cf., Kim-Renaud 1974). Though our analysis does not hinge on this assumption, [h] patterns with obstruents in many phonological patterns. A number of processes seem to be caused by a restriction on coda obstruents, including coda nasalization and neutralization. If [h] is an obstruent, the processes affecting coda [h] and other obstruents can be unified. [h] is also like other obstruents in that it can precede a glide + vowel sequence: [hwa] 'anger'.

3.   The distribution of [h] and aspirated consonants

    In simple onset positions, the behavior of [h] and aspirated consonants is the same. Both [h] and aspirated consonants are possible word-initially and word-internally after a vowel as shown below.

(5) <u>Onset Positions: Same Behavior</u>
a. *C^h: no change*   b. *[h] : no change*
/tʰal/   → [tʰal] 'mask   /hɛ/   → [hɛ] 'sun'
/cʰac-ki/ → [cʰat.k'i] 'searching'   /ha-ta/   → [ha.ta] 'to do (declarative)'
/ki-cʰa/ → [ki.cʰa] 'train'   /hjaŋki/ → [hjaŋki] 'smell'
/i- tʰal/   → [i.tʰal] 'escape'   /i-hɛ/   → [i.hɛ] 'understanding'

The data above show [h] can occur in V__V, but two additional rules may delete [h] under special conditions. The data in (6a) illustrate a casual speech phenomenon that deletes [h] between a vowel and a vocoid. There is also a lexically idiosyncratic rule of [h] deletion targeting stem final [h], as illustrated in (6b). Our analysis below focuses on the distribution of [h], as defined by regular Korean phonology, which excludes these

special rules. However, we believe our analysis can be extended to account for this data as well.

(6) Two Rules of Intervocalic [h] Deletion

a. *Casual speech [h] deletion*

/a-hop/ → [a.(h)op] 'nine'√
/kjo-hwan/ → [kjo.(h)wan] 'exchange'
/si-hɛŋ/ → [si.(h)ɛŋ] 'operation'
/sa-ha-la/ → [sa.(h)a.la] 'Sahara (desert)'

b. *Lexical [h] deletion verb stem finally*

/coh.a.to/ → [co.a.do] 'though it is good'
/manh.a.to/→ [man.a.do] 'though there is much'
/nah.a.to/ → [na.a.do] 'though one bears'
/nəh.ə.to/ → [nə.ə.do] 'though one inserts'

[h] and aspirated consonants behave differently when they follow another obstruent (except [h]) in a cluster. Aspirated consonants are not affected (7a), but [h] coalesces with the preceding obstruent (7b).

(7) Medial Onsets (post-obstruent): Different Behavior

a. *C^h: no change*

/pak-c^{h}a/ → [pak.c^{h}a] 'spur'
/nok-c^{h}a/ → [nok.c^{h}a] 'green tea'
/mok-t^{h}ak/ → [mok.t^{h}ak] 'wooden clacker'
/pok-t^{h}an/ → [pok.t^{h}an] 'bomb'

b. *[h] : coalescence*

/pap-ha-ko/ → [pa.p^{h}a.go] 'with rice'
/sip-ho/ → [si.p^{h}o] 'ten'
/kuk-hi-ta/ → [ku.c^{h}i.da] 'hardens'
/mək-hi-ta/ → [mə.k^{h}i.da] 'is eaten'

We see divergent behavior in coda position as well. When aspirated consonants appear in coda position before another obstruent, they are neutralized by losing their [spread glottis] specification (8a). [h], on the other hand, does not neutralize and instead coalesces with the following consonant.

(8) Codas (pre-obstruent): Different Behavior

a. *C^h: neutralization*

/ap^h-to/ → [ap.t'o] 'front also
/nat^h-kɛ/ → [nat.k'ɛ] 'piece
/kip^h-ta/ → [kip.t'a] 'it is deep.'
/mit^h-pa-tak/ → [mit.p'a.dak] 'bottom'

b. *[h] : coalescence*

/ilh-ta/ → [il.t^{h}a] 'loses'
/nah.ta/ → [na.t^{h}a] 'bear'
/suh-pəm/ → [su.p^{h}əm] 'male tiger'
/coh-ke/ → [co.k^{h}e] 'well'

Word-final codas also show divergent behavior but in a different way. Aspirated consonants word finally neutralize, whereas word-final [h] deletes.

(9) Coda (word final): Different Behavior

a. *C^h: neutralization*

/ap^h/ → [ap] 'front'
/pat^h/ →[pat] 'field'
/pu-ək^h/ → [pu.ək] 'kitchen'
/sot^h/ → [sot] 'kettle'

b. *[h] : deletion*

/anh/ → [an] 'inside'
/suh/ → [su] 'male'
/manh.a.to/→ [man.a.do] 'though there is much'
/hal-mə-ni/→ [hal.mə.ni] 'grandmother'

The table below summarizes the distributions of [h] and aspirated consonants and highlights the different phonological processes affecting them in parallel environments.

(10) <u>Summary table</u>

		C^h	[h]
a. Onset	Simple	Possible—no repair /pʰa/ → [pʰa] 'green onion'	Possible—no repair /i-hɛ/ → [i.hɛ] 'understanding'
	Post-obstruent	Possible—no repair /nok-cʰa/ → [nok.cʰa] 'green tea'	Coalescence /pak-hak/ → [pa.kʰak] 'knowledgeable'
b. Coda	Pre-obstruent	Neutralization /apʰ-to/ → [ap.t'o] 'front also'	Coalescence /suh-pəm/ → [su.pʰəm] 'male tiger'
	Word-final	Neutralization (=deaspiration) /pʰatʰ/ → [pʰat] 'red bean'	Deletion /anh/ → [an] 'inside'

4. Onset Faithfulness and [h]-specific Markedness

The different processes affecting aspirated consonants and [h] summarized above support the following analysis of phonological repairs.

(11) Different treatment of C^h and [h] in Korean

	C^h	[h]
Same: σ[___	*No repair*	*No repair*
Different: C$_{Obstruent}$ σ[___	*No repair*	Repair: Coalescence
Different: ___]σ C$_{Obstruent}$	Repair: Neutralization	Repair: Coalescence
Different: ___]σ #	Repair: Neutralization	Repair: Deletion

These facts suggest an interpretation based on the Lombardian analysis of coda [voice] sketched in the introduction. In particular, many repairs for [h] indicate a positional markedness constraint for [h], while the apparent paucity of repairs for aspirated consonants suggests the lack of a parallel markedness constraint and the addition of a positional faithfulness constraint for aspirated consonants. The absence of repairs to aspirated consonants in onset position suggests that this constraint is faithfulness to [spread glottis] in onset position. It is important to note, however, that other patterns of neutralization of coda [h] are necessary for this approach to work. Standard Korean does not repair [h] in a fashion parallel to neutralization of aspirated consonants, i.e., /Cʰ/→[C]. /h/ either deletes or coalesces in CC clusters. It is clear, however, why Korean does not simply neutralize /h/ to a glottal stop. Korean does not have a glottal stop, so overarching constraints on the segment inventory prevent this repair. It is conceivable that /h/ in clusters could be subject to a neutralization parallel to aspirated consonants, however, because languages do appear to neutralize /h/ to more central consonants. For example, coda /h/ is neutralized to a non-glottal plain stop in Thai phonotactics (Clements 1985; Lombardi 1991), and Korean dialects exhibit /h/→[s] → [t] in different positions, including coda position (Iverson 1989). This centralization is not a direct parallel, since it involves changing place of articulation, but neutralization to a glottal stop is not fully parallel either. Such a repair would involve trading one marked

laryngeal feature, [spread glottis], for another, namely [constricted glottis]. As we shall see below, the analysis of place in [h] and neighboring consonants will be crucial to understanding the problem with the Lombardian approach to Korean.

Given this characterization of [h] neutralization, the Lombardian approach can be implemented in Korean by combining the context-sensitive and context-free constraints given below.

(12) Context-sensitive Constraints
    a. Positional Faithfulness (IdentOnset(sg) = IdOns(sg))
        For corresponding segments x, x', if x' is in a onset, x' must be identical to x in [sg].
    b. Positional Markedness (PM): *h]$_\sigma$: No syllable-final [h].

(13) Context-free Constraints (same constraints used throughout)
    a. Markedness
        *sg: no [spread glottis] specification
        NoCoda: no coda consonants
        *ObstruentNasal: no obstruent-nasal sequences
        *n^h: No aspirated nasals
    b. Faithfulness (see Lombardi 2001 for extending Max/Dep to features)
        Dep: no insertion of segments
        Max: no deletion of segments
        Max(sg): no deletion of [spread glottis] specifications
        Max(place): no deletion of Place specifications
        Dep(place): no insertion of Place specifications
        Uniformity: no coalescence

The primary generalizations concerning different repairs in codas, and no repair in simple onsets, can be accounted for with the total ordering of constraints given below (some irrelevant constraints are left out). With PM (positional markedness) ranked high, coda [h] will be resolved, either by coalescence with a following obstruent or via deletion. Aspirated consonants in coda position have a different option, because they can both retain their place specification (required by Max(place)) and do better on *sg by simply shedding their [spread glottis] specification. Both aspirated consonants and [h] are preserved in onset position, however, because of IdentOnset(sg).

(14) Rankings for Lombardian Analysis
    *h]$_\sigma$ >> IdOns(sg) >> Max(pl) >> Max >> *sg >> Max(sg): >> Uniformity

A nontrivial problem arises, however, when one considers the ranking requirements of these segments in onset position following a coda consonant.

(15) Inconsistency of onset C^h and coalescence of /Ch/

Input	Winner ~ Loser	$*h]_\sigma$	IdOns(sg)	Dep(pl)	Dep	Max(pl)	Max	*sg	Max(sg)	Uniform	NoCoda
a. /Vk$_1$.t$^h_2$V/	Vk$_1$.t$^h_2$V ~ V.t$^h_{12}$V	e	e	e	e	W	e	e	e	W	L
b. /Vk$_1$. h$_2$V/	V.k$^h_{12}$V ~ Vk$_1$. h$_2$V	e	e	e	e	L	e	e	e	L	W

The assumed constraints, together with the assumption that [h] has a pharyngeal place specification, make it impossible to account for the difference between aspirated consonants and [h] in this environment. This is shown above with a comparative tableau (Prince 2003), which shows the violation profiles of winner-loser pairs and pin-points the constraints that either favor the winner (W), the loser (L), or are equal (e). The violation data above show that only three constraints (unshaded) can distinguish these outputs, Max(place), Uniformity, and NoCoda. No matter how these three constraints are ranked, however, at least one loser will be predicted, contrary to fact. For example, if Max(place) or Uniformity is ranked above NoCoda, to account for the lack of coalescence in (a), that will have the effect of precluding coalescence in (b). Furthermore, the constraint that is intended to distinguish [h] from aspirated consonants, $*h]_\sigma$, is totally irrelevant here. It is possible to account for this difference with an additional constraint, for example a positional markedness constraint banning obstruent + [h] sequences, but such an approach is only *ad hoc* and will not explain the repair to post-consonantal [h] in the context of a larger system.

We conjecture that the problem with this whole approach is not the broader typological effects of positional markedness and faithfulness, but the specific assumptions about the place of [h]. The reason why Max(place) favors the loser immediately above is because the primary [pharyngeal] specification is lost in coalescence. If [h] is in fact placeless, merging it with another consonant will not incur a Max(place) violation, which would allow for a consistent analysis of all of the data. The next section explores this basic idea and shows that when correctly implemented, this approach obviates the need for the two context-sensitive constraints proposed in this section.

5.   A role for surface underspecification of [h]

The idea that [h] is not specified at the surface for a primary place specification is not new. This assumption has been called upon in a variety of contexts to account for a general pattern of laryngeal transparency, i.e., contexts where the [h], or some subpart of [h], acts as if it is not present in phonological structure; see Steriade (1995) for general discussion and Myers (1998) and Causley (2000) for recent OT implementations. Indeed, the assumption that [h] is placeless has a precedent in Korean linguistic studies. Iverson (1989) assumes that [h] is placeless to motivate certain coda neutralization patterns (though his assumptions connecting [h] and underspecified coronals are inconsistent with our analysis, as well as our understanding of the data). Furthermore, the well-known process of palatalization in Korean provides further motivation for assuming that [h] is

placeless. In this process, coronal consonants become corresponding palatals when appearing before /i, j/ (16a). An intervening [h], however, does not block this pattern of otherwise local assimilation (16b).

(16) Evidence for transparency of [h] (Kim-Renaud 1974: 196)
    a. <u>Korean palatalization</u>:
    /kut-i/ → [ku.ci] 'firmly, without fail'
    /mə:l-li/ → [mə:ʎ.ʎi] 'far away'
    b. <u>[h] is transparent in palatalization</u>:
    /in-hyəŋ/ → [iɲ.hjəŋ] 'doll'
    /kaman-hi/ →[kamaɲ.hi] 'quietly'

If we assume that palatalization is local, i.e., it applies to two adjacent coronal nodes, the absence of a [phar] specification for [h] enables the target and trigger of palatalization to be adjacent in (16b) above.

To implement this theory of transparency, we assume that [h] is not specified for [phar] in surface forms, following the leading ideas of Myers (1998) for surface underspecification of low tone. In particular, we assume that there is a constraint, *Phar/SG, that explicitly bans the cooccurrence of [phar] and [spread glottis]. If the featural faithfulness constraints (see section 4) outrank *Phar/SG, then [h] may be specified at the surface and be active in other phonological patterns. If, on the other hand, *Phar/SG dominates faithfulness, as in Korean, [h] will be placeless and act as if it does not have a [phar] specification. This hypothesis goes hand in hand with the assumption that a placeless fricative will be interpreted in the post-phonology phonetics as a glottal fricative via a phonetic implementation rule, but we do not define this rule here.

This approach to surface underspecification is consistent with the Richness of the Base and the assumption that [h] can be underspecified in inputs as well. If input /h/ is specified for [phar] and [sg], *Phar/SG can prevent these features from cooccurring on the same segment in the output. Furthermore, if input /h/ is placeless, both faithfulness and *Phar/SG will ensure a lack of [phar] specification at the surface. This proposal does allow for the possibility that languages can have two phonologically distinct [h]'s, one with a [phar] specification and one without. We conjecture that this type of distinction is in fact attested, but cannot explore it in any detail in this paper.

The assumption that [h] is placeless makes it possible to distinguish [h] from aspirated consonants, as the analysis below illustrates. However, the fact that both these classes of aspirates are banned in coda position requires an additional constraint. We assume that this shared restriction follows from a positional markedness constraint, *sg]$_σ$, which simply bans any coda with a [spread glottis] specification.

(17) Hypothesis B: Placeless [h] and positional markedness
        a. <u>Placeless [h]:</u> *Phar/SG >> Max(place), (and also anti-migration faithfulness)
        b. <u>Positional markedness for all [spread glottis] consonants</u>: *sg]$_σ$ >> faithfulness

The specific rankings required for Korean by Hypothesis B are given below.

(18) Korean [h] and aspirated consonants under Hypothesis B

*Phar/SG, *sg]ₒ>>Dep, Dep(pl)>>Max, Max(pl)>>Max(sg), NoCoda>>*sg, Uniformity

We consider the effects of these constraints in a series of OT tableaux that highlight the similarities and differences between aspirated consonants and [h] in different syllabic contexts. First, in word-initial onset position and V__V contexts, both [h] and aspirated consonants preserve [spread glottis]. This is due to the role of context-free faithfulness and the lack of any constraints that specifically target onsets.

(19) Initial onset position: same

Inputs	Outputs	*sg]ₒ	Dep	Dep(pl)	Max	Max(pl)	NoCoda	Max(sg)	*sg	Uniform
a. /CʰV/	→ CʰV								*	
	*CV							*!		
	*_V				*!	*		*		
b. /hV/	→ hV								*	
	*sV			*!				*		
	*_V				*!			*		

The fully faithful candidate wins out over neutralization (second candidate) or simple deletion (third candidate) because Max, Max(place), Max(sg), and Dep(place) outrank *sg. In this comparison, it is important to note that neutralization of /CʰV/ to CV is different than /hV/ → [su] neutralization. Both involve a violation of Max(sg), but only the latter mapping inserts a new [coronal] specification, which results in a Dep(place) violation. Note that another plausible neutralization, i.e., changing /h/ to a glottal stop, is not possible because Korean does not have a glottal stop, so language particular rankings prevent this mapping.

Word-initial onsets that are preceded by an obstruent are treated differently than simple onsets. As shown in the tableau below, aspirated consonants are unaffected (20a), but [h] coalesces with the preceding obstruent to form an aspirated consonant (20b).

(20) Post-obstruent onset: different

Inputs	Outputs	*sg]σ	Dep	Dep(pl)	Max	Max(pl)	NoCoda	Max(sg)	*sg	Uniform
a. /CVC.tʰV/	→CVC.tʰV						*		*	
	*CVC.tV						*	*!		
	*CV.CʰV					*!			*	*
	*CV.C_V				*!	*		*		
b. /CVt.hu/	→ CV.tʰV								*	*
	*CVt.hu						*!		*	
	*CV.t_V				*!			*		
	*CVt.su			*!			*	*		

Following standard assumptions, coalescence is the merging of two segments, resulting in a violation of Uniformity. Coalescence, however, satisfies both Max(sg) (since the [spread glottis] is retained) and NoCoda. The ranking of NoCoda above Uniformity therefore makes coalescence more harmonic than doing nothing (second candidate in (20b)). Aspirated consonants do not have the coalescence option, however, because such a merging invariably results in a loss of the primary place specification of either the coda or onset consonant, which is prohibited by Max(place).

Aspirated consonants and [h] in coda position are similar in that they lose their [spread glottis], but different in the way they achieve this loss, as shown below. The similarity is due to a general ban on [spread glottis] in coda position, which is top-ranked in the tableau below. The difference between the two segment types stems again from the availability of neutralization for aspirated consonants only.

(21) Word-final codas: different

Inputs	Outputs	*sg]σ	Dep	Dep(pl)	Max	Max(pl)	NoCoda	Max(sg)	*sg	Uniformity
a. /CVCʰ/	→ CVC						*	*		
	*CVCʰ	*!					*		*	
	*CV_				*!	*		*		
	*CV.CʰV		*!						*	
b. /CVh/	→ *CV_				*			*		
	*CVh	*!					*		*	
	*CVs			*!			*	*		
	*CV.hV		*!						*	

'Neutralization' of /h/ to [s] is not possible because that incurs a fatal violation of Dep(place), and, as explained above, there is no natural laryngeal neutralization of input

/h/ that is consistent with the Korean segment inventory. Aspirated consonants, on the other hand, can shed their [spread glottis] to satisfy the positional markedness constraint *sg]$_\sigma$, as shown in (21a). This option is preferred because segment deletion (third candidate) violates Max and Max dominates NoCoda, and neutralization is also preferred to epenthesis because of high-ranked Dep.

Medial codas further support the general ban on coda aspirates and the different mechanisms available for the two segment classes. As with final codas, the constraint hierarchy prefers neutralization of aspirated consonants to wholesale deletion or epenthesis (22a). The same hierarchy actually prefers coalescence of coda [h] with a following obstruent (22b), because the absence of a place specification in the coda allows coalescence to satisfy *sg]$_\sigma$ and NoCoda without violating Max(place), just as it does when [h] is in onset position.

(22) Medial codas: different

Inputs	Outputs	*sg]$_\sigma$	Dep	Dep(pl)	Max	Max(pl)	NoCoda	Max(sg)	*sg	Uniformity
a. /CVCʰ.tV	→CVC.tV						*	*		
	CV.tʰV					*!			*	*
	CV_.tV				*!	*		*		
	CVCʰtV	*!					*		*	
	CV.CʰV.tV		*!						*	
b. /CVh.tV/	→ CV.tʰV								*	*
	CV_.tV				*!			*		
	CVh.tV	*!					*		*	
	CVs.tV			*!			*	*		
	CV.hV.tV		*!						*	

In summary, the full system can be modeled as the result of two relatively standard assumptions, namely the general ban on coda aspirates and the assumption that, in Korean, [h] is placeless. We argue that this analysis is therefore superior to Hypothesis A (from section 4) because A does not account for the full distribution, nor does it connect with the facts supporting the transparency of [h] in palatalization. There are other important differences between A and B that cannot be evaluated on the basis of data from Korean alone, so they are summarized in the last section.

6.   Discussion of Alternatives

The next question we ask is whether both of our assumptions are truly necessary. We address this question below by considering two additional hypotheses that involve straightforward modifications of our core assumptions. For comparison, these two new hypotheses are shown below, together with Hypothesis A and B, in a chart that indicates which constraints are assumed by each hypothesis. A new hypothesis, Hypothesis C,

retains the placeless [h] assumption, but employs positional faithfulness for onsets as an alternative to positional markedness. Hypothesis D attempts to account for all of the data with just the assumption that [h] is placeless. The insufficiency of all but Hypothesis B supports the argument that the core constraints of B are both sufficient and necessary for the analysis of Korean.

(23) Four Hypotheses with Possible Constraints

	PF: IdOns(sg)	PM: *sg]$_\sigma$	PM: *h]$_\sigma$	Placeless [h]
Hypothesis A. *Insufficient*	√		√	
Hypothesis B. *Sufficient*		√		√
Hypothesis C. *Insufficient*	√			√
Hypothesis D. *Insufficient*				√

Hypotheses A, C, and D are unable to account for all of the data in Korean. As shown in section 4, Hypothesis A accounts for the many repairs of [h] with positional markedness for coda [h]. This is charted below in (24) ('√' indicates a successful analysis). This hypothesis, however, is not sufficient because it does not provide a natural way to motivate coalescence in /CVC.hV/ contexts (onset medial /h/) as well as in /(C)Vh-CV(C)/ (coda medial /h/). Hypothesis C assumes placeless [h] and positional faithfulness for onsets. This hypothesis has limited success in distinguishing onsets from codas like Hypothesis A, but the absence of positional markedness leads to an irresolvable inconsistency between the medial and final codas. In a nutshell, it is impossible to rank Max relative to context-free *sg in a way that accounts for the different repairs in these positions. Hypothesis D, on the other hand, is equipped with constraints that can distinguish [h] and aspirated consonants but no constraints to distinguish onsets from codas. Approximately, context-free *sg can motivate processes across the board, predicting that Korean has no [spread glottis] at the surface. Or, a context-free faithfulness constraint can outrank *sg, and allow [spread glottis] in some codas, contrary to fact.

(24) Summary of results

	Onset				Coda			
	simple		**medial**		**Word final**		**medial**	
	C^h	h	C^h	h	C^h	h	C^h	h
Hypothesis A	√	√	X		√	√	√	√
Hypothesis B	√	√	√	√	√	√	√	√
Hypothesis C	√	√	√	√	X			
Hypothesis D	X							

In sum, Hypothesis A cannot account for the different phonological behavior of aspirated consonants and [h] due to the absence of an important assumption: placeless [h]. Further, Hypothesis C and D demonstrate that positional markedness is essential to motivate many repairs in coda position. In summary, both assumptions of Hypothesis B, positional markedness and surface underspecification of [h], are necessary.

7.   Predictions for Further Research

The assumptions of our analysis of Korean make some predictions for other languages. First, consistent with the Lombardian line of reasoning for coda place, our positional markedness constraint *sg]$_\sigma$ predicts the existence of many repairs for coda aspirates. We have found evidence for deletion, neutralization, and coalescence in Korean, but other repairs are also possible. These include epenthesis, as found for coda place in Ponapean (Itô 1989), and also special patterns of 'neutralization' where [h] is centralized. We note that Iverson (1989) proposed the latter type of neutralization for nonstandard Korean dialects. In sum, we conjecture that coda aspirates pattern like coda place in admitting a wider range of repairs, as has been found for coda ejectives in Fallon (2001).

In addition, the analysis predicts a typology of place specification of [h]: placeless [h], as in Korean, and [h] specified for place at the surface. Since the specification of [h] is determined through ranking, some languages will have surface [h] with a [pharyngeal] specification, thus they should pattern together with other consonants specified place. Also, as mentioned in section 5, a language particular ranking can predict languages with both placeless [h] and [h] specified for place, predicting the existence of two phonologically different [h]'s.

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