Aspects of phonetics and phonology of Icelandic preaspiration*

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Suh, Chang-Kook. 2001. Aspects of phonetics and phonology of Icelandic preaspiration. *Studies in Phonetics, Phonology and Morphology* 7.1. 63-83. In this paper, I defend the claim that preaspirated consonants in Icelandic (i.e. Icelandic preaspiration) are the phonetic realization of an aspirated geminate. This implies that preaspiration is contingent on the length of consonants in stressed syllables. The phonology creates an aspirated geminate, and the phonetic component then interprets that aspirated geminate as something that sounds like preaspiration followed by a singleton consonant. For those purposes, we first look at phonetic aspects of preaspiration, and then show how we get aspirated geminates, phonologically. Accordingly, we need to show where the aspirated geminates come from (i.e. underlying and derived). These are accounted for through the interaction of the constraints in a predicted way**. (Chonan University)**

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1. Introduction

Icelandic preaspiration has posed problems to researchers by its idiosyncratic and complex pattern of laryngeal feature distribution (Thráinsson 1978, Clements 1985, Hermans 1985, Sagey 1986, Anderson and Ewen 1987, Hayes 1990, Suh 1997, Keer 1999).

In this paper, I defend the claim that preaspirated consonants in Icelandic (i.e. Icelandic preaspiration) are the phonetic realization of an aspirated geminate following Thráinsson 1978, Hermans 1985, and Suh 1997.

(1) Preaspiration Hypothesis:

Preaspiration is the phonetic realization of aspirated stop geminates

This assumption implies that preaspiration is contingent on the length of consonants in stressed syllables. The phonology creates an aspirated geminate, and the phonetic component then interprets that aspirated geminate as something that sounds like preaspiration followed by a

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singleton consonant.[1] Under this assumption, then, we need to show how we get aspirated geminates, phonologically. That is, we need to show where the aspirated geminates come from (i.e. underlying and derived). Accordingly, our discussion focuses on geminates. However, for the fuller understanding of geminate behavior with respect to preaspiration, it is imperative that we should examine the overall pattern of closely related data.

2. Distribution of Post and Pre Aspirates

Icelandic has three surface stops, postaspirated, preaspirated and unaspirated. According to Hermans (1985: 260), preaspirated and postaspirated stops are in complementary distribution on the surface. Preaspirated stops cannot occur initially, after long vowels, or after consonants. This implies that preaspirated stops can occur after short vowels. Given the phonotactics of Icelandic, this means that preaspirated stops are not possible onsets. On the other hand, post aspirated stops cannot appear after short vowels. That is they are barred from codas. Neither pre nor post aspirated stops cannot appear after *s* (Keer 1999: 2).

At the phonetic level, Icelandic has only short postaspirated stops and short preaspirated ones. It doesn't have any long aspirated stops. On the other hand, Icelandic has both short unaspirated stops and long ones. The following figure (2) summarizes the distribution of Icelandic surface stops.

(2) Distribution of Icelandic Surface Stops

Unaspirated		Postaspirated		Preaspirated	
Short	Long	Short	Long	Short	Long
[p]	[pp]	[p^h]	*[p^hp^h]	[hp]	*[hphp]
[t]	[tt]	[t^h]	*[t^ht^h]	[ht]	*[htht]
[k]	[kk]	[k^h]	*[k^hk^h]	[hk]	*[hkhk]

These phonetic gaps support our assumption that preaspirated stops are derived from geminate post aspirated stops. Though postaspirated geminates exist in the phonology of Icelandic, they can never show up in the physical world of the phonetic component as expressed by our Preaspiration Hypothesis. Thus, postaspirated geminates will never be attested at the phonetic level. Instead, preaspirated stops will be realized on the surface.

3. Phonetics and Phonology of Icelandic Preaspiration

[1] Keer (1999) makes a similar claim on Icelandic preaspiration. He claims that Icelandic preaspiration is a type of metathesis between the stop and the aspiration.

3.1 Phonetic Aspects of Preaspiration

Aspiration is typically a property of obstruent stops. The term *aspiration* usually refers to postaspiration in which the aspiration is realized after the stop. The term *preaspiration*, on the other hand, implies that the aspiration is realized before the stop. Thus, we can say that stops can be preaspirated as well as (post)aspirated. With respect to preaspiration, the following descriptions are quite characteristic:[2]

> "Some languages have aspiration, or a short [h] which comes before stops rather than after." (Smalley 1973: 397)

> "We must also note that in some languages (e.g. Gaelic and Icelandic) consonants may be pre-aspirated; there may be a period of voicelessness at the end of a vowel before the articulatory stricture is made." (Ladefoged 1973: 77)

In addition to this, Stevens (1975: 19) views preaspiration as timing the laryngeal movements in advance of the supralaryngeal closure. Similarly, Catford (1968: 332) views preaspiration in terms of the offset or cessation of the voicing of the preceding vowel.

Summarizing all these descriptions, preaspiration seems to be characteristically voiceless and close to [h], and it seems that preaspiration and (post)aspiration are simply differences in the relative timing of laryngeal and supralaryngeal articulatory gestures.

Now the following phonological representations can provide the source for preaspiration.

(3) Phonological Representations of Aspirated Geminates

$/p^hp^h/$	$/t^ht^h/$	$/k^hk^h/$
μ	μ	μ
|	|	|
C	C	C
|	|	|
p	t	k
+SG	+SG	+SG

There is general agreement among Icelandic phoneticians that preaspiration in Icelandic normally has the phonetic quality of [h], i.e.

2 See Thráinsson (1978) for an elaborate discussion of phonetic description of preaspiration.

a spreading of the glottis with no inherent supralaryngeal configuration.[3] Phonetically, preaspiration is a sequence of *h*, followed by a non-aspirated *p*, *t* or *k*. Preaspiration [h] typically has a normal segment length in Icelandic, whereas postaspiration is generally much shorter (Garnes 1974).[4] Then, the phonological representations in (3) can be changed into the phonetic ones shown in (4).

(4) Phonetic Representations of Preaspiration

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   [hp]          [ht]           [hk]
  C    C        C    C         C    C
  |    |        |    |         |    |
[+SG] p      [+SG] t        [+SG] k
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Now, let's see what happens if the structures in (3) are given a phonetic (articulatory) interpretation. Hermans (1985: 247-248) assumes that long stops are realized with a relatively long period of silence. If we follow this idea, this then means that the articulators are given two contradictory commands. First, they are instructed to realize a long period of silence, second they have to realize a 'puff of air' within this period. This seems to be articulatorily ill-formed. Thus, this apparent inpronounceable phonological structures are corrected in the articulatory component which fits into articulatory movements as shown in (4). Our Preaspiration Hypothesis captures well this mechanism. Hermans (1985: 259) further argues that for some reason fully aspirated geminates are highly marked, perhaps even impossible from phonetic point of view. Thus, this phonetic implementation may be universal process. Long aspirated stops (i.e. C^hC^h) can never show up in the 'physical world' because they are altered by the articulatoy mechanism.

Then, we have to ask why Icelandic has preaspiration as well as postaspiration in the same language, and why postaspiration is very common while preaspiration is very rare. Investigation of the phonological aspects of preaspiration in Icelandic will provide some insights into that problem. In the following section, we will undertake such a phonological investigation of Icelandic Preaspiration, in the hope that it will shed some light on the general nature of preaspiration in other languages.

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3 The phonetic quality of preaspiration varies somewhat, depending on the preceding vowel and the succeeding consonant, but that seems to follow from general principle of coarticulation (Thráinsson 1978: 5).

4 The results of objective measurements taken from Garnes (1974) clearly show that preaspiration takes a normal segment slot in Icelandic. See Thráinsson (1978: 30) for more discussion. This fact also confirms our assumption that preaspiration is derived by postaspirated stop geminates, underlying or derived.

3.2 Phonological Aspects of Preaspiration in Icelandic

Based on Thráinsson (1978) and Hermans (1985), we assume that modern Icelandic has two contrastive sets of stops: non-aspirated voiceless stops /p, t, k/ and aspirated voiceless stops /p^h, t^h, k^h/. As we have seen in the previous section, preaspiration (e.g. hp) and postaspiration (p^h) are quite different. Preaspiration has full segment length, while postaspiration is much shorter and thus does not take any segment length (cf. Anderson and Ewen 1987: 194).

Now, let us look at lengthening phenomena, which connects with preaspiration itself.

3.2.1 Lengthening and Preaspiration

Examples of the consonant lengthening (i.e. gemination) in Icelandic are shown in (5).[5]

(5)	rakna	[rakk.na]	'curse, swear'
	p^{h}arna	[p^{h}att.na]	'child (gen. plur)'

In a stressed VC-syllable, a word-internal non-aspirated voiceless consonant is lengthened (i.e., geminated). There is no preaspiration here.

On the other hand, in an open stressed syllable, a vowel is lengthened (6a), and also a vowel is lengthened even in a stressed closed syllable if the syllable is word-final (6b):

(6) a.	prúna	[pru:.na]	'brown'
	t^{h}ak^{h}a	[t^{h}a:.k^{h}a]	'take'
	vit^{h}ja	[vi:.t^{h}ja]	'to call on'
b.	mein	[mɛi:n]	'damage'
	sem	[sɛ:m]	'as, like'
	út^h	[ú:t^h]	'out'

The examples in (7) are also a case of lengthening.

(7)	vak^{h}na	[vahk.na]	'wake up'
	vit^{h}na	[viht.na]	'witness (subst.)'

[5] Following Hermans (1985), I assume that the sequence of stops or /s/ and /r,v,j/ forms a tautosyllabic structure. Else, the cluster is heterosyllabic (cf. Vennemann 1972). In Icelandic, primary stress falls on the initial syllable and secondary stresses fall on alternating syllables thereafter (Hayes 1995). Since stress is predictable, we will not provide stress marks in this paper.

Singleton aspirated stops are lengthened (geminated) and this, in turn, is realized as preaspiration (e.g. /va*k*ʰna/ → /va*k*ʰ*k*ʰna/ ⇒ [va*hk*na] 'wake up').[6]

However, there is no lengthening (nor preaspiration) in words with medial or word-final plain geminates.

(8) a.	flippi	[flippi]	'collar'
	kʰaffi	[kʰaffi]	'coffee'
	likkja	[likkja]	'to lie'
	sattur	[sattYr]	'full'
b.	flakk	[flakk]	'flag'
	kʰrytt	[kʰrItt]	'spices'

Finally, the following examples deserve mentioning.

(9)	eikn	[eik:n]	'property'
	fukl	[fIk:l]	'bird'
	kakn	[kak:n]	'advantage'

Unlike (6b), consonant lengthening occurs instead of vowel lengthening if an obstruent is followed by a sonorant word-finally.[7]

Capturing regularities based on the Icelandic data pattern given above, I hypothesize the following two things: (i) lengthening is motivated to satisfy a bi-moraic requirement on the stressed syllable (ii) only vowels and geminates are moraic.[8] For these purposes, two different strategies are employed in the phonology of Icelandic: (i) vowel lengthening (ii) consonant gemination. Later, according to our Preaspiration Hypothesis (1), preaspiration occurs as the phonetic realization of geminate aspirated stops.

Given those hypotheses, aspirated geminates and preaspiration cannot be separated in any way in Icelandic. As a result, consonant lengthening (i.e. gemination) as well as underlying geminates can cause preaspiration in Icelandic.

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[6] This is closely related with our Preaspiration Hypothesis given in (1). For detailed discussion of this issue, see section 3.2.3.2.

[7] The vowel remains short and the consonant is not lengthened if the morpheme [s] is added (e.g. /mein-s/ → [meins] 'gen. sg. of mein (damage)', /baθ-s/ → [baθs] 'gen. sg. of baθ (bath)'. This is not true if [s] is added to a single aspirated stop (e.g. /fatʰ-s/ → [fa:tʰs] 'gen. sg. of fatʰ (piece of clothing)). That is, this time vowel lengthening occurs in the same environment. These examples are out of consideration since they are unpredictable on phonological grounds, but morphologically related in each case.

[8] The moraic status of the geminate consonants has been fully discussed in moraic theory of phonology, and thus I do not mention it any more, here (see Hayes 1989).

3.2.2 The General Pattern of Lengthening

Having established that Icelandic Preaspiration is sounds like a sequence of [h] followed by a non-aspirated stop *on the phonetic level*, our next task is (i) to show where we get consonant geminates (underlying and derived), and (ii) to determine how we get consonant geminates (consonant lengthening vs. vowel lengthening) *in the phonology*. With respect to (i), we will show why consonants must be geminated, and with respect to (ii), we will show how we get consonant lengthening (i.e. derived geminates) and vowel lengthening in a different way.

The detailed discussion will follow later. However, before going on, it will be useful if we summarize the Icelandic examples which are relevant to the lengthening phenomena. Recall that lengthening results in bimoraic stressed syllables. According to our hypothesis, singleton coda consonants are not moraic, thus coda lengthening is required to make the coda moraic. Else, vowels will be lengthened. The following data are given as a summary of general patterns of Icelandic lengthening.

(10) Vowel Lengthening: /V.CV/ → [V:.CV] (cf. (6a,b))

a.	prúna	[pru:.na]	‘brown’
	t^{h}ak^{h}a	[t^{h}a:.k^{h}a]	‘take’
	vit^{h}ja	[vi:.t^{h}ja]	‘to call on’
b.	mein	[mei:n]	‘damage’
	sem	[se:m]	‘as, like’
	út^h	[ú:t^h]	‘out’

(11) Consonant Lengthening: /VC$_1$.C$_2$V/ → [VC$_1$C$_1$.C$_2$V] (cf. (5), (7), & (9))

a.	rakna	[rakk.na]	‘curse, swear’
	p^{h}arna	[p^{h}att.na]	‘child (gen. plur)’
b.	vak^{h}na	[vahk.na]	‘wake up’
	vit^{h}na	[viht.na]	‘witness (subst.)’
c.	eikn	[eik:n]	‘property’
	fukl	[fIk:l]	‘bird’
	kakn	[kak:n]	‘advantage’

(12) No Lengthening (cf. (8a,b))

a.	flippi	[flippi]	‘collar’
	likkja	[likkja]	‘to lie’
b.	flakk	[flakk]	‘flag’
	k^{h}rytt	[k^{h}rItt]	‘spices’

c. $t^hap^hp^hi$	[t^hah.pi]	'cork'
$t^hrap^hp^ha$	[t^hrah.pa]	'step'
d. up^hp^h	[Yhp]	'upstairs'
$t^hak^hk^h$	[t^hahk]	'thanks'
e. $feit^h$-t^h	[feiht]	'fat (neut. sg.)'
$ljót^h$-t^h	[ljouht]	'ugly (neut. sg.)'

Thus far, we have looked at the general patterns of lengthening phenomena in connection with Icelandic preaspiration. In previous rule-based approaches to Icelandic preaspiration phenomena, no clear suggestions have been made to explain the fundamental reason why consonants and vowels are lengthened mutually exclusively. In the present analysis, however, the same issue will be accounted for through the interaction of universal constraints which are independently motivated. For that purpose, in the following section, we consider the constraints and their interaction proposed for the OT analysis of Icelandic preaspiration.

3.2.3 Constraints and their Interactions in Icelandic Preaspiration

Now, let us turn to the OT analysis of Icelandic Preaspiration. A major claim of this section is that various types of the examples (consonant gemination, vowel lengthening and no lengthening) are accounted for through the interaction of the constraints in a predicted way.

3.2.3.1 Bimoraic Requirement for the Stressed Syllable in Icelandic

According to Hayes (1995), Icelandic is a *trochaic* language. Thus, primary stress falls on the initial syllable and secondary stresses fall on alternating syllables thereafter. In Icelandic, all vowels (and diphthongs) are short underlyingly, and as the lengthening data in (14) show, in Icelandic, non-geminate codas are not moraic. Thus, as Hayes (1995: 82-85) describes, to make the stressed syllable heavy, either lengthening of the stressed vowel or gemination of the consonant is required.[9] According to Hayes (1989: 257), geminates *almost always* bear a mora. This claim can be extended to the position that a geminate can bear a mora even in the cases where a short consonant is not moraic.[10] From the

[9] In Icelandic, trochaic lengthening is limited to the main-stressed syllable. Here, lengthening is simply a direct manifestation of stress and not an optimization of foot structure (Hayes 1995: 84).

[10] This claim, however, is against the Principle of Equal Weight for Codas (Tranel 1991) which says, *"Coda portions of geminate consonants behave in the same way as other coda consonants with respect to syllable weight"*. For more details, see section 2.3.2 Weight and Length in Moraic Theory.

fact that lengthening is necessary to make the initial stressed syllable bimoraic, I suggest the constraint [μμ]σ.

(13) [μμ]σ: Stressed syllables are bimoraic (cf. Hammond 1993)

The constraint [μμ]σ states that two morae are required for the stressed syllable. As we will see later, lengthening phenomena will be governed by the constraint [μμ]σ, and the ranking relation with other constraints will be clearly established once we present the constraints on lengthening.

3.2.3.2 Vowel Lengthening vs. Consonant Gemination

In Icelandic, insertion of a vocalic mora (i.e. vowel lengthening) and a consonantal mora (i.e. coda gemination) produce different results, so we need to distinguish them under the DEP-IO family. First, let us consider vowel lengthening cases. As shown in the examples in (10) (and (6)), vowels are lengthened in an open stressed syllable to satisfy the bimoraic requirement of the stressed syllable (e.g. /prúna/ → [pru:.na] 'brown', t^hak^ha → [t^ha:.k^ha] 'take'). The constraint DEP-IO($^{\mu}$V) is proposed to take care of these examples:

(14) DEP-IO($^{\mu}$V): Every vocalic mora of the output has a correspondent in the input (Prohibits vocalic mora epenthesis) (cf. McCarthy and Prince 1995, Prince and Smolensky 1993)

Now, let us look at the examples of derived geminates (cf. (5), (7), (9) and (11)). In a stressed closed syllable, coda consonants are geminated to satisfy the bimoraic requirement of the stressed syllable (e.g. /rakna/ → [rakk.na] 'curse, swear', /vak^{h}na/ → [vak^{h}k^{h}na] → [vahk.na] 'wake up').[11] According to the Preaspiration Hypothesis (1), it is claimed that preaspiration is the phonetic manifestation of derived or underlying aspirated geminates (cf. Thráinsson 1978, Hermans 1985). Underlying geminate aspirated stops provide the proper environments for the phonetic realization of preaspiration (i.e. /$^{\mu}$p^h/ → [$^{\mu}$hp]) without any operation in the phonology. However, derived geminates cause a violation of DEP-IO($^{\mu}$C) unlike underlying geminates, due to the gemination of the singleton consonants. In order to capture coda consonant gemination, DEP-IO($^{\mu}$C) is proposed as shown in (15).

[11] According to the syllabification process proposed by Hermans (1985: 238), geminate [kk] should belong to the same syllable. This says that [kn] cannot be tautosyllabic (cf. Vennemann 1972).

(15) DEP-IO($^{\mu}$C): Every mora of the consonant segment of the output has a correspondent in the input (Prohibits consonantal moraic epenthesis) (cf. McCarthy and Prince 1995, Prince and Smolensky 1993)

The motivation for consonant gemination and vowel lengthening is due to the bimoraic requirement of the stressed syllable in Icelandic. Derived geminates have DEP-IO($^{\mu}$C) violation, while lengthened vowels have DEP-IO($^{\mu}$V) violation to satisfy bimoraic requirement of the stressed syllable. Thus, it is evident that the constraint [μμ]σ must dominate both DEP-IO($^{\mu}$C) and DEP-IO($^{\mu}$V) in Icelandic. Also, we can see that DEP-IO($^{\mu}$V) must dominate DEP-IO($^{\mu}$C), when both vowels and consonants are possible candidates for lengthening. Thus we have the following ranking regarding the three constraints.

(16) [μμ]σ >> DEP-IO($^{\mu}$V) >> DEP-IO($^{\mu}$C)

This ranking explains coda gemination in a stressed closed syllable. For an illustration, we now turn to tableau analysis.

Consider the form /rakna/ 'curse, swear'. In a stressed VC-syllable the consonant is only lengthened (i.e. geminated) without preaspiration since the consonant is a non-aspirated stop. The following tableau shows that gemination is favored over vowel lengthening.

(17) /rakna/ → [ra<u>kk</u>.na] 'curse, swear'

/rakna/	[μμ]σ	DEP-IO($^{\mu}$V)	DEP-IO($^{\mu}$C)
a. ☞ μμ | | r a k.na			*
b. μ | r a k.na	*!		
c. μμ |/ r a k.na		*!	

Candidate (a) violates DEP-IO($^{\mu}$C) due to the gemination of coda consonant [k]. However, candidate (a) is chosen as the optimal output because DEP-IO($^{\mu}$C) is ranked bottommost among the three constraints. Candidates (b) and (c) are eliminated due to crucial violations of [μμ]σ and DEP-IO($^{\mu}$V), respectively. Thus, consonant gemination (without preaspiration) is produced if the syllable is closed by a non-aspirated stop consonant. By contrast, underlying non-aspirate geminate consonants do not undergo any operations since they are already long and satisfy bimoraic requirement of the stressed syllable (e.g. /flippi/ → [flippi] ‘collar’).

Now, let us turn to the derived geminates which show preaspiration as well as gemination (e.g. /p^h/ → [$^{\mu}p^h$] → [$^{\mu}$hp]). As the following tableau shows, a singleton aspirated consonant is geminated to meet the bimoraic requirement of the stressed syllable.

(18) /vak^hna/ → [vak^hk^hna] → [vahkna]

/vak^hna/	[μμ]σ	DEP-IO($^{\mu}$V)	DEP-IO($^{\mu}$C)
a. μ | v a k^h.na	*!		
b. μμ |/ va k^h.na		*!	
c. ☞ μμ | | vak^h.na [vahk.na]			*

Looking at the above tableau (18), candidates (a) and (b) are eliminated by the crucial violations of [μμ]σ and DEP-IO($^{\mu}$V), respectively. The form in (a) has only one mora, thus it violates [μμ]σ. In (b), DEP-IO($^{\mu}$V) is violated due to the lengthening of the vowel, but this form satisfies the higher ranked constraint [μμ]σ. On the other hand, candidate (c) violates DEP-IO($^{\mu}$C) due to the lengthening of the coda consonant. In spite of this constraint violation, candidate (c) is chosen as the actual output form because DEP-IO($^{\mu}$C) is lower ranked than [μμ]σ and DEP-IO($^{\mu}$V).

Now, let us look at the case in which a vowel is lengthened if it is placed in an open stressed syllable. With those constraints given in (16), we cannot produce correct actual output form. The reason is that we cannot rule out the form in which the onset of the second syllable is geminated, violating DEP-IO($^{\mu}$C) because the new moraic coda does not have a moraic coda correspondent in the input. This would incorrectly prefer [t^hahka] to [t^ha:.k^ha]. Somehow, we need to prevent a *pure* onset from also becoming a coda.

In order to account for this pattern, we turn to the constraints NOCODA and MAX-IO.

(19) a. NOCODA: Coda consonants are not allowed (Prince and Smolensky 1993)
b. MAX-IO: Every segment of the input has a correspondent in the output (No phonological deletion) (McCarthy and Prince 1995, Prince and Smolensky 1993)

First, if we assume the ranking of [μμ]σ, NOCODA >> DEP-IO($^{\mu}$V) >> DEP-IO($^{\mu}$C), then we can prevent a *pure* onset from becoming a coda by gemination.

(20) /t^hak^ha/ → [t^ha:.k^ha] 'take'

μ | /t^ha k^ha/	[μμ]σ	NOCODA	DEP-IO($^{\mu}$V)	DEP-IO($^{\mu}$C)
a. μ | t^ha. k^ha	*!			
b. μ μ | |/ t^ha k^ha [t^hahka]		*!		*
c. ☞ μμ |/ t^ha. k^ha			*	

In this tableau, the first candidate (a) is ruled out because of the crucial violation of [μμ]σ. Candidate (b) is also ruled out because of the crucial violation of NOCODA. On the other hand, candidate (c) violates only DEP-IO($^{\mu}$V). Thus, between the three candidates (a), (b) and (c), candidate (c) is selected as the optimal output. Consequently, in an open stressed syllable, vowel lengthening is preferred to consonant gemination to satisfy the bimoraic requirement for stressed syllables in Icelandic.

This contrasts sharply with the closed syllable case in which coda consonant gemination is preferred to vowel lengthening as shown in (17) and (18) above. However, in order to ensure the preservation of the input coda consonant, we need to assume that MAX-IO must dominate NOCODA: MAX-IO >> NOCODA. The following tableau shows this aspect:

(21) /rakna/ → [ra<u>kk</u>.na] ‘curse, swear’

<table>
<tr><th>/rakna/</th><th>MAX-IO</th><th>[μμ]σ</th><th>NO
CODA</th><th>DEP-IO
($^{\mu}$V)</th><th>DEP-IO
($^{\mu}$C)</th></tr>
<tr><td>a.
μ
|
rak.na</td><td></td><td>*!</td><td>*</td><td></td><td></td></tr>
<tr><td>b.
μμ
|/
ra.na</td><td>*!</td><td></td><td></td><td>*</td><td></td></tr>
<tr><td>c.
μμ
|/
rak.na</td><td></td><td></td><td>*</td><td>*!</td><td></td></tr>
<tr><td>d. ☞
μμ
| |
rak.na</td><td></td><td></td><td>*</td><td></td><td>*</td></tr>
</table>

First, candidate (a) crucially violates [μμ]σ because the initial syllable has just one mora. Thus, it is eliminated. The above tableau shows that we cannot remove the input coda consonant to satisfy NOCODA because that will cause a worse violation of MAX-IO (b). Candidate (c) violates NOCODA and DEP-IO($^{\mu}$V). On the other hand, candidate (d) violates NOCODA and DEP-IO($^{\mu}$C). Between the two candidates (c) and (d), candidate (d) is correctly selected as the optimal output because DEP-IO($^{\mu}$C) is lower ranked than DEP-IO($^{\mu}$V).

Thus far we have accounted for the complementary distribution of consonant gemination and vowel lengthening through the interaction of the constraints. Especially, we have seen that lengthening is enforced by the compulsion of the high ranked constraint [μμ]σ. Also, we have observed that MAX-IO and NOCODA play a key role for the precise description of consonant gemination and vowel lengthening.

3.2.3.3 An Apparent Counterexample to Vowel Lengthening

The following examples are exceptional to our hypothesis on vowel lengthening in Icelandic (cf. (6b) and (10b)).

(22) Vowel Lengthening: /V.CV/ → [V:.CV]

mein	[mei:n]	'damage'
sem	[se:m]	'as, like'
$\acute{u}t^h$	[$\acute{u}$:t^h]	'out'

Here, we need to note that these examples occur in word-final environments. Since alignment comes into play as an additional factor, it is not surprising that we can find some exceptional cases in word-final position. We will show, however, that even these exceptional cases are not a problem in our system and can be accounted for neatly through constraint interaction.

In general, vowel lengthening occurs in an open stressed syllable in Icelandic. However, the above examples do not have open syllables, and yet vowel lengthening has occured. In monosyllabic words, vowels are lengthened instead of consonants geminating, even in a closed syllable. In rule-based approaches, these cases were explained with the notion of extrametricality. In this analysis, we use the constraint ALIGN(WD-R, M-R) to explain word-final exceptional cases without turning to the notion of extrametricality. Originally, ALIGN(WD-R, M-R) was proposed to have the standard meaning: *The right edge of every word coincides with morpheme-final elements* (McCarthy and Prince 1993a, b and c). Here, however, I extend this to the prosodic structures, so that if a mora is added, then that mora interrupts the satisfaction of ALIGN(WD-R, M-R). That is, even though singleton consonants and geminates have the same segment in final position, they are not well-aligned with respect to the prosodic structures (i.e. C] vs. $^{\mu}$C]). In (23), I show 3 relevant pictures. I assume the input is (23a):

```
(23) a. Input              b. [se:m]          c. [semm]
        /sem/                  σ                  σ
                              /|\\                /|\
          μ                   /μμ\               / μμ
          |                   / |/ \             / | \
        s e m]Morpheme        s  e  m]Word       s  e  m]Word
```

(23b) shows that a mora is added to the vowel /e/. Here, there is no ALIGN(WD-R, M-R) violation because the vocalic mora can be added to the left of the input mora. On the other hand, (23c) shows a mora is added to /m/, interrupting satisfaction of ALIGN(WD-R, M-R). Here, the ALIGN(WD-R, M-R) violation is necessarily incurred since the coda mora can only be added to the right of the input mora.

Concerning the ranking of the constraints, we can infer that ALIGN(WD-R, M-R) must dominate DEP-IO($^{\mu}$V) since DEP-IO($^{\mu}$V) is violated to satisfy ALIGN(WD-R, M-R).

As an illustration, let us consider the following tableau.

(24) /sem/ → [se:m] ‘as, like’

μ | /s e **m**/	[μμ]σ	ALIGN (WD-R, M-R)	DEP-IO($^{\mu}$V)	DEP-IO($^{\mu}$C)
a. μ | s e **m**	*!			
b. μ *μ* | | s e **m**		*!		*
c. ☞ *μ*μ |/ s e **m**			*	

In the above tableau, candidate (a) violates [μμ]σ since the stressed syllable has only one mora. Word-final gemination in (b) causes ALIGN(WD-R, M-R) violation as well as DEP-IO($^{\mu}$C) violation. Finally, candidate (c) violates DEP-IO($^{\mu}$V) due to the lengthening of the vowel to satisfy bimoraic requirement of the stressed syllable. Since [μμ]σ and ALIGN(WD-R, M-R) are higher ranked than DEP-IO($^{\mu}$V), candidate (c) is selected as the optimal output form. Thus, vowel lengthening occurs in a closed syllable if the word is monosyllabic.

The examples in (11c), however, show an obstruent gemination in a closed syllable (e.g. /eikn/ → [eik:n] ‘property’, /fukl/ → [fIk:l] ‘bird’, etc). In this case, sonorants are not geminated. In order to explain this pattern, I treat word-final sonorants as syllabic (cf. Hermans 1985). Resonants can be syllabic in many languages, thereby causing a violation of PEAK which requires a vowel in the syllable.

(25) PEAK: Every syllable has a vowel (Archangeli 1997)

Then, in the above examples, obstruents (e.g. [k]) become a syllable-final consonant of the initial syllable, and thus the obstruent will be lengthened to meet bimoraic requirement of the initial stressed syllable (e.g. /eikn/ → [eikk.N]). However, this also causes a violation of ALIGN(WD-R, M-R) because of the new mora ($^{\mu}$n) added to the right of the input mora. Tableau (26) shows this point:

(26) a. Input b. [eikk.N]

```
   /eikn/                 σ   σ
                          |\  |
    μ                     μ μ μ
    |                     | | |
    eikn]Morpheme         ei k  n]Word
```

Compare this with the following two forms: [eikkn] and [ei:kn]. In the above, we have established the ranking ALIGN(WD-R, M-R) >> DEP-IO($^{\mu}$V) >> DEP-IO($^{\mu}$C) (cf. figure (24)). The form [eikkn] also violates ALIGN(WD-R, M-R) due to the new mora ($^{\mu}$k) added to the right of the input mora. Then, the form [ei:kn] must be chosen as the optimal one against the fact, since it does not violate high ranked ALIGN(WD-R, M-R) as we have demonstrated in (23b).

In explaining the problem raised above discussion, I turn to the constraint Sonority Sequencing Principle (SSP):

(27) Sonority Sequencing Principle (SSP): Within a syllable, onsets are required to rise in sonority toward the nucleus and codas to fall in sonority from the nucleus (cf. Clements 1990)

It is generally agreed on that syllabification crucially refers to sonority (Vennemann 1972, Selkirk 1982, Clements and Keyser 1983, Clements 1990, among others). Obviously, the word-final resonants of the examples in (9 & 11c) are more sonorant than the preceding obstruent. Thus, this sequence violates SSP. If we assume that SSP dominates ALIGN(WD-R, M-R), then we can explain why obstruent-resonant sequences are not allowed in syllable final positions and why word-final sonorants are syllabic. (I assume PEAK is low ranked to allow syllabic sonorants in Icelandic). For an illustration, consider the following tableau.

(28) /eikn/ → [eikk.N] 'property'

μ | /eik**n**/	SSP	[μμ]σ	ALIGN (WD-R, M-R)	DEP-IO($^{\mu}$V)	DEP-IO($^{\mu}$C)	PEAK
a. μ | eik**n**	*!	*				
b. μ μ | | ei k**n**	*!		*		*	
c.	*!			*		

μμ |/ eik**n**						
d. ☞ μ μ μ | | | ei k . **n**			*		*	*

In the above tableau, candidates (a), (b) and (c) are all eliminated by crucially violating SSP due to the obstruent-sonorant sequence in the coda. By contrast, candidate (d) satisfies SSP because word-final sonorant [n] is not in the coda any more, but forms a new syllable. Thus, candidate (d) is chosen as the optimal output, resulting in obstruent gemination, instead of vowel lengthening.[12]

3.2.3.4 Fake Geminates

Now, let us see what happens in the case of fake geminates with respect to preaspiration. In this case, additionally the OCP and NOFUSION play a role in producing optimal output form.

(29) a. OCP: At the melodic level, adjacent identical elements are prohibited
b. NOFUSION: No element of the output has multiple correspondents in the input (McCarthy and Prince 1995)

I rank the OCP at the top and NOFUSION at the bottom considering the fact that fake geminates also undergo preaspiration just as in underlying true geminates. Thus, the final ranking of the constraints in Icelandic will be like (30):

(30) OCP, MAX-IO, SSP >> [μμ]σ, NOCODA, ALIGN(WD-R, M-R), >> DEP-IO(^{μ}V) >> DEP-IO(^{μ}C), PEAK, NOFUSION

[12] We can insert an epenthetic vowel word finally to make the coda [n] an onset of the new syllable (i.e. [eikk.n*V*]). That will, however, incur worse constrain violations: ALIGN(WD-R, M-R) (**) and DEP-IO. Here, ALIGN(WD-R, M-R) is violated twice since vowel epenthesis causes both segmental and prosodic misalignment. Thus, regardless of the ranking of DEP-IO, this form will be ruled out because the competing form [eikk.N] has less constraint violation. For this reason, we omit this form from the tableau analysis.

Now, the following tableau helps to illustrate the behavior of fake geminates with regard to preaspiration.

(31) /feit^h-t^h/ → [feiht] 'fat(neut.sg.)'

/feit^h-$\mathbf{t}^{h}$/	OCP	MAX -IO	[μμ] σ	ALIGN (WD-R, M-R)	DEP-IO($^{\mu}$V)	NO FUSION
a. μ | feit^h$\mathbf{t}^{h}$	*1		*			
b. μμ |/ feit^h$\mathbf{t}^{h}$	*!				*	
c. μμ |/ fei$\mathbf{t}^{h}$		*!			*	
d. μμ*μ* |/ | fei $\mathbf{t}^{h}$				*	*!	*
e. ☞ μ *μ* | | fei $\mathbf{t}^{h}$				*		*

Candidates (a) and (b) are first excluded by crucially violating the top ranked constraint OCP. Here, the OCP violation is incurred because the two identical segments come together side by side without fusing into one segment. Candidate (c) also crucially violates MAX-IO due to the underparsing of the stem-final segment /t^h/. Between the two candidates (d) and (e), candidate (e) is selected as the optimal output, because candidate (d) has worse violation of DEP-IO($^{\mu}$V).

As in the true geminate case, fake geminates also satisfy the bimoraic requirement for the stressed syllable just by fusing the two identical segments into one. That is, we get a mora by fusion. This operation is facilitated because the constraint NOFUSION is lowest ranked and the OCP is top ranked . Thus, the form (e) [feit^{h}t^h] (→ [feiht]) is selected as the optimal output form in underlying fake geminates.

From above discussion, it is shown that there is no difference between true and fake geminates in Icelandic preaspiration. This partly results from the fact that NOFUSION is lowest ranked, which ensures the fusion of /C-C/ into [$^{\mu}$C]. Because of this, both true geminates and fake geminates are preaspirated by the phonetic manifestation of aspirated geminate stops.

4. Summary and Conclusion

In this paper, we have investigated aspects of phonetics and phonology of Icelandic preaspiration. We have shown that different strategies are employed in Icelandic preaspiration to meet the bimoraic requirement of the initial stressed syllable: vowel lengthening and consonant gemination. These aspects are shown to be effectively captured by the constraints interaction model of OT.

We have argued that phonologically derived aspirated geminates (either underlying or derived by gemination) undergo preaspiration later in the phonetic component. (cf. Preaspiration Hypothesis (1)). We have also demonstrated that looking at preaspiration in this way can also explain other related phonological processes like vowel lengthening and consonant gemination, in a surprisingly simple and systematic way.

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