

Phonetic realizations of /h/ after a sonorant in Korean

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Um, Hye-Young. 2014. Phonetic realizations of /h/ after a sonorant in Korean. *Studies in Phonetics, Phonology and Morphology*. 20.3. 357-377. In Korean /h/ is known to be optionally deleted between a voiced segment and a vowel or a glide. The current study investigates the phonetic realization of Korean /h/ occurring after a sonorant consonant, questioning the validity of complete /h/ deletion and raising the issue of possible influence of /h/ on the preceding sonorant. In the production experiment with two-syllable minimal pairs where one member contains a sonorant followed by /h/ and the other contains only a sonorant, such as /kamhi/ 'dare' and /kami/ 'persimmon-nom', it was found that the duration of the sonorant preceding underlying /h/ is shorter than that of the sonorant not followed by /h/ even when /h/ itself is not acoustically manifested. The results suggest that /h/ usually considered to be deleted in casual speech is in fact not completely deleted in the sense that it affects the preceding sonorant. (Myongji University)

Keywords: Korean /h/ deletion, optional /h/ deletion, nasal duration, breathy sonorant, phonation, aspiration merger

1. Introduction

/h/ is a segment that lacks specification for place of articulation. As such, it is typically represented as having only a laryngeal feature [spread glottis], lacking supralaryngeal feature (Lombardi 1991 among others). SPE even categorizes /h/ as [-consonantal] since it has no constriction within the oral cavity unlike other consonants. Korean /h/ seems to reflect this 'placeless' characteristic in its phonological behavior and is frequently deleted or merges with other consonants. For example, a coalescence of lax stops and /h/ results in aspirated stops as exemplified in (1) (Iverson and Kim-Renaud 1998: 37).

(1) Aspiration Merger

/ip+hak/	→	[ip ^h ak]	'admission'
/cap+hi/	→	[cap ^h i]	'hold-Passive'
/sip+ho/	→	[sip ^h o]	'ten-number'
/k'oc+hi/	→	[k'oc ^h i]	'insert-Passive'
/sok+hi/	→	[sok ^h i]	'fast'

/h/ is also susceptible to deletion in contexts where other consonants resist deletion. Korean /h/ is frequently deleted in intervocalic position. When /h/ is the final segment in a verb stem, it is obligatorily deleted as shown in the following (Kim-Renaud 1986: 79).

(2) Obligatory h-deletion

/nah-ina/	[naina]	*[nahina]	‘bears but’
/coh-ato/	[coado]	*[cohado]	‘though it is good’
/nolah-imjən/	[noramjən]	*[norahimjən]	‘if it is yellow’

However, an underlying phoneme /h/ in the following examples is optionally deleted between a voiced segment and a vowel or glide depending on the degree of formality and/or speed (Kim-Renaud 1986: 78).

(3) Optional h-deletion

	<i>Careful</i>		<i>Casual</i>	
a. /ahop/	[ahopʰ]	~	[aopʰ]	‘nine’
b. /sahara/	[sahara]	~	[saara]	‘Sahara’
c. /kjo-hwan/	[kjohwan]	~	[kjowan]	‘exchange’
d. /isaŋ-ha-ta/	[isaŋhada]	~	[isaŋada]	‘is strange’
e. /kaman-hi/	[kamaŋhi]	~	[kamaŋi]	‘quietly’
f. /sil-həm/	[širhəm]	~	[širəm]	‘experiment’
g. /ka:m-hjəŋ/	[ka:mhjəŋ]	~	[ka:mjəŋ]	‘remission’

Kim-Renaud (1986) calls it ordinary h-deletion rule and says it is a prevalent, automatic process that applies even when pronouncing loanwords, as in the pronunciation of ‘Sahara’ in (3b). While there has been much attention given to stem-final obligatory deletion phenomena, relatively few studies have been conducted on the optional /h/ deletion phenomena. Especially, studies based on the phonetic data are rare and Cha et al. (2003) seems to be the only one.

One question that arises in connection with this optional /h/ deletion is whether /h/ is completely deleted when deletion occurs. /h/ is not reliably detected in the speech stream: since /h/ manifests itself acoustically as the voiceless counterpart of the following vowel, it is not as distinct from the corresponding voiced vowels as are other consonants (Ladefoged 2001). In addition, /h/ is a perceptually weak segment and hard to hear. Therefore, when the phonetic study is conducted on the deletion of /h/, special attention needs to be given. Another important question that must be asked is whether /h/ affects only the following voiced segment (by being realized as the voiceless counterpart of the following vowel), and not the preceding voiced consonant - in this case only sonorant consonants due to Korean phonotactics, we might assume Aspiration merger as in (1), which typically occurs when /h/ appears after an obstruent, can extend to the case where /h/ occurs after a sonorant as in the following examples.

(4) Aspiration merger

/samho/	→	[sam ^h o]	‘three-number’
/punhal/	→	[pun ^h al]	‘division’

/kaŋha/	→	[kaŋ ^h a]	‘falling’
/silhjaŋ/	→	[ʃir ^h jaŋ]	‘loss of hometown’

The possibility of extending the aspiration merger to the sonorant has been given little attention. Part of the reason might be that aspirated sonorants do not exist in the Korean consonant inventory. While most languages have voiced sonorants only, there are also languages with contrastive sonorants that are produced with a laryngeal setting other than voice. One of them is breathy voiced sonorants which are not distinguished from aspirated sonorants in literature.

In this paper, I examine the phonetic realization of the cluster of a sonorant plus /h/ occurring in the phonological context where /h/ is reported to be deleted and see if /h/ is completely deleted and if there is any influence on the preceding sonorant. For this purpose I examine the two-syllable minimal pairs in casual/fast speech where one member contains a sequence of a sonorant plus /h/ between vowels/glides and the other contains only a sonorant. If a complete /h/ deletion occurs, /silhjaŋ/ ‘realization’ and /siljaŋ/ ‘broken heart’ would be realized identically as [ʃirjaŋ]. My hypothesis, however, is that there might be a possibility that the preceding sonorant consonant is affected by the presence of /h/, especially when the preceding sonorant consonant is realized as the onset of the following syllable and as a result constitutes the onset with /h/.

The organization of this paper is as follows. In section 2, I review previous literature on the descriptions of phonetic properties of /h/ in general and those of Korean sonorant clusters with /h/. In section 3, I present the experiment on the phonetic realization of the sonorant+/h/ cluster in Korean. Section 4 and 5 are devoted to discussion and conclusion.

2. Background and previous research

2.1 Phonetic characteristics of /h/ in general

The acoustic description of /h/ is especially dependent on the context of its occurrence. Whether /h/ is voiced or voiceless is determined in part by the voicing feature of the adjacent segments. The spectrogram of intervocalic /h/ in English shows that the distinct region of /h/ is differentiated from the vowel by the high frequency noise component and a lack of periodicity in the high frequency regions (Olive et al. 1993). Some Korean linguists’ description of Korean [h] as lenition to [ɦ] between voiced segments is in line with this characteristic. According to Lee (1996) and Kim-Renaud (1986), [ɦ] lenited or voiced from [h] is further weakened to be deleted as in (5).

(5) h-deletion (Lee 1996)¹

- | | | | | |
|-----------------|---------------|---|-------------|---------------|
| a. /we:halmaɲi/ | [we:ɬialmaɲi] | → | [we:almaɲi] | ‘grandmother’ |
| b. /jaŋhjaŋ/ | [jaŋɬjaŋ] | → | [jaŋjaŋ] | ‘influence’ |
| c. /munhwa/ | [munɬwa] | → | [munwa] | ‘culture’ |

On the other hand, Kim (1985) states that /h/ devoices the following vowel when it follows a voiced segment. According to him, /ka-ha-ta/ ‘inflict (damage)’, /palhɛ/ (name of a country), /kamhwa/ ‘be touched’, and /sonhɛ/ ‘damage’ are realized as three phonetic forms [kahada, kaãda, kaada], [palhɛ, paɾɛ, paɾɛ], [kamhwa, kamɰwa, kamwa] and [sonhɛ, sonhɛ̃, sonɛ], respectively (Shin and Cha 2000). According to Ladefoged (2001), [h] acts like a consonant in English, but from an articulatory point of view, it is simply the voiceless counterpart of the following vowel. That is, it does not have a specific place of articulation, and its manner of articulation is the same as that of a following vowel with only the state of glottis being different. Kim’s (1985) view of devoicing of the vowel following /h/ is in line with this description.

2.2 Phonetic descriptions of Korean sonorant clusters with /h/

According to Kim (1987), /h/ after a sonorant consonant /m, n, l/ merges with the preceding sonorant, becoming the onset of the following syllable. He says it can be referred to as the voicing/aspiration of the sonorant.² He says, however, that /h/ is pronounced as [ɬ] after /ŋ/ since [ŋ] occurs only in coda position. The examples are given in (6) (Kim 1987: 22).

(6) Aspiration merger

- | | | | |
|-------------------------------|---------------------------------------|--------------|---------------------------|
| a. n + h → [n ^h]: | /kan.hok/ → [ka.n ^h ok] | ³ | ‘sometimes’ |
| | /jən.hɛ/ → [jə.n ^h ɛ] | | ‘coastal waters’ |
| b. m + h → [m ^h]: | /kam.hiŋ/ → [ka.m ^h iŋ] | | ‘a sensation of pleasure’ |
| | /nam.hɛ/ → [na.m ^h ɛ] | | ‘southern sea’ |
| c. l + h → [l ^h]: | /kjəl.hon/ → [kjəl.r ^h on] | | ‘marriage’ |
| | /jəl.hil/ → [jəl.r ^h il] | | ‘ten days’ |
| d. ŋ + h → [ŋ.ɬ]: | /taŋ.hɛ/ → [taŋ.ɬɛ] | | ‘concerned (authorities)’ |

Iverson and Kim-Renaud (1998) also notice the influence of /h/ on the preceding sonorant. In their discussion of the aspiration adjustment, which applies to the cluster of an obstruent plus /h/, they say that the aspiration merger is also relevant to clusters involving /h/ and a sonorant consonant. For example, an underlying sequence of liquid plus /h/ as in /mal+ha+ta/

¹ Lee (1996) states, however, that the pronunciation with /h/ deletion is considered non-standard.

² He seems to see this as voiced [ɬ] surrounded by voiced segments being laid upon the preceding sonorant and making it aspirated.

³ The symbol ‘.’ symbolizes syllable boundary.

‘speak’ emerges with the liquid properties having extended into the /h/, as in [mall^hada] = [mal^hada]. Simplifying further, the geminate liquid may reduce to a single consonant resyllabifying as onset of the following syllable as in [maɾada] in casual speech. Similarly, the realization of /sil-hjən/ ‘realization’ can be [ʃirjən] in casual speech, with aspiration merged into the liquid now occupying syllable-initial position. They represent voiceless sonorants in terms of the feature [spread glottis], like aspiration. That is, they view the [spread glottis] feature of /h/ causes the preceding sonorant to become voiceless, or ‘aspirated’. The following summarizes this aspiration process of sonorants.

(7) Sonorant clusters with /h/ (Iverson and Kim-Renaud 1998: 47)

- a. /mal+ha+ta/ → [malhada] ~ [mall^hada] = [mal^hada] ~ [maɾada]
‘language+do+Declarative’
- b. /sil-hjən/ → [ʃil^hjən] ~ [ʃill^hjən] = [ʃill^hjən] ~ [ʃirjən]
‘realization’
- c. /an+ha+ko/ → [anhago] ~ [ann^hago] = [an^hago] ~ [aɳago]
‘Negative-do-and’

The phonetic description of these segments such as ‘aspiration merged into the liquid’ is parallel to that of the breathy voiced sonorants. Gordon and Ladefoged (2001) describe breathy phonation as vocal cords that are fairly abducted resulting in some turbulent airflow through the glottis and the auditory impression of “voice mixed in with breath”.

Though both Kim (1987) and Iverson and Kim-Renaud (1998) identify sonorant clusters with /h/ as being realized as aspirated sonorants in casual speech, there has been little attention given to this phenomenon in the literature on Korean phonology probably because Korean does not contrast voiced sonorants with voiceless or aspirated sonorants. Shin and Cha (2000) point out that this view of devoicing or aspiration of sonorants is abstract and problematic because there are no examples of voiceless/aspirated sonorants in actual Korean phonetic data and it is very rare for aspiration and voicing (of sonorants) to co-occur due to the physiological reason. That is, the state of glottis when producing a sonorant sound where the spontaneous voicing is possible is not compatible with the state of glottis where vocal folds spread in a configuration for aspiration. However, their argument is not also based on the actual phonetic data. In addition, though limited, less common non-modal phonation also exists in the languages of the world (Maddieson 1984).⁴ Shin and Cha (2000) argue instead that /h/ realized as [h̥] after a sonorant is phonetically a sound laid on the following vowel, but that it is phonologically a glide (e.g. /kjalhon/ ‘marriage’ → [kjal.h̥on]; [\$sonorant-glide]) because Korean does not allow consonant clusters in onset position.

⁴ In modal phonation, there is ‘regular, efficient vibration of the true vocal folds, without audible friction.’ Variation from this setting is known as non-modal phonation, of which breathy is one form (Harris 2009).

However, although their phonological interpretation of /h/ as a glide working as a member of a syllable nucleus may provide some explanation for the problem confronted by Korean phonotactics, they have to modify Korean phonotactics to allow double glides in nucleus position in order to account for the cases like /silhɔn/ 'realization' → [ʃi.rɦjɔn] and /pulhwaŋ/ 'depression' → [pu.rɦwaŋ].

This disagreement on the interpretation or phonetic description of /h/ is not surprising, considering the phonetic property of /h/ functioning as phonation feature. For example, while Ladefoged (2001) suggests that Hindi makes a breathy contrast in its nasals, Esposito et al. (2005) state that it is not clear, in fact, whether /N/ + /h/ sequences in Hindi are breathy nasals or simply /Nh/ clusters. According to Esposito et al. (2005), in Bengali and Hindi where the aspiration contrast is only in the oral stops, it is not certain if the sequences of a nasal consonant followed by /h/ are breathy nasals /N^h/ or simply [Nh] clusters.

2.3 Study on Korean /h/ deletion/realization between voiced segments

There has been little study of Korean /h/ realization or deletion conducted on the basis of the phonetic data. Cha et al. (2003) seems to be the only study using phonetic data. They try to make phonological interpretation for Korean optional /h/ deletion after examining the aspects of phonetic realization or deletion of /h/ between voiced segments⁵. In their study of ten subjects, they found out that the relative frequency of /h/ deletion is determined by speech rate, the number of syllables within the domain of AP, and the distance from the AP-initial position. Specifically /h/ is deleted most frequently after laterals and then after nasals. /h/ deletes less frequently after vowels than after sonorant consonants.

In their phonetic study, they distinguish the cases of voicing of /h/ to [ɦ], devoicing of the following vowel, and complete deletion. Their description of these three cases is summarized as follows.

(8) Phonetic realization/deletion of /h/ between voiced segments (Cha et al. 2003)

- a. Voicing of /h/ to [ɦ]: Similar formant structure as the following vowel with severe aspiration is observed. This realization is most frequently observed between vowels.
- b. Devoicing of the following vowel: /h/ is realized laid on the following vowel as aspiration, but with no severe aspiration as in the case of (a). /h/ is clearly heard, though, and noise is observed near high frequency region and there is no clear formant structure at the beginning of the following vowel. This occurs frequently after the sonorant consonants /m, n, ŋ/.

⁵ Their study uniquely includes vowels in the category of sonorants. Therefore, it is, in fact, the study on /h/ deletion between the voiced segments, rather than between sonorants.

- c. Complete deletion of /h/: No sign or trace of /h/ is observed and there appears the clear formant structure of the following vowel or glide. This complete deletion most frequently occurs after /l/.

They regard (c) as the deletion case and the other two cases (a) and (b) as /h/ being phonetically realized. However, the weak aspiration of the following voiced segment is hard to discern, especially when there comes a glide. And also the following glide or vowel can be realized as partially voiceless, which is not so clearly discernable just from the spectrogram and waveform. In addition, differently from their description of the case (b), it is not easy to perceive /h/, particularly after nasals and laterals in casual speech. /h/, in general, is considered a perceptually weak segment, vulnerable to misperception and deletion (Mielke 2008, among others). Even though their study is quite meaningful in that it is based on the phonetic data, it should be recognized that there could be some confusion among realization and deletion cases. My special concern is about the case (c) that they regard as complete deletion. While they focus on phonetic realization of /h/ in connection with /h/'s influence on the following segment, they did not pay attention to the influence of /h/ on the preceding consonant. That is, they did not consider the possibility that /h/ is phonetically realized through some change of the preceding sonorant. If /h/ somehow has influence on the preceding sonorant, the seeming complete /h/ deletion case in Cha et al.'s (2003) study in fact may not be the case of "complete" deletion, in the sense that /h/ might be at least partially realized on the preceding sonorant.

2.4 Phonetic realizations of the sonorant+/h/ sequence in Korean

The spectrograms and waveforms of clearly pronounced /h/ in sonorant plus /h/ sequences are shown in Figure 1.

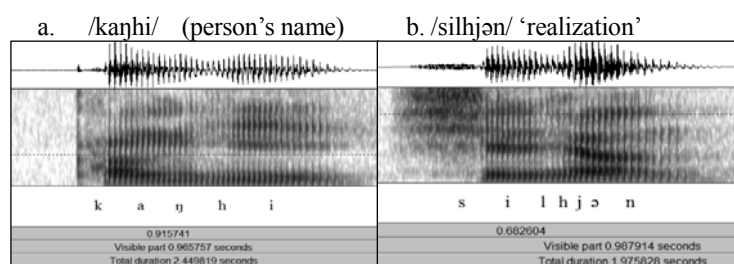


Figure 1. Spectrogram and waveform of /kaŋhi/ and /silhjon/

In both (a) and (b), /h/ is clearly realized with similar formant structures to the surrounding segments and with aspiration noise especially in the higher frequency region. It appears that the nasal followed by /h/ is also affected by

some high frequency noise of /h/ in (a). In (b) the glide preceded by /h/ does not have clear formant structure at the beginning. Figure 2 compares clearly pronounced /konhi/ with /koni/. Although a full manifestation of /h/ as in Figure 1 (a) is not observed, /h/ is clearly realized as aspiration noise at high frequency regions in /konhi/. Interestingly in this case as well, the preceding nasal appears to have some influence from /h/ as can be seen from the unclear formant structure (indicated by the arrow).

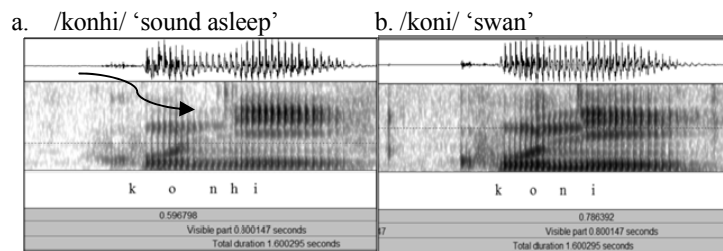


Figure 2. Spectrogram and waveform of /konhi/ and /koni/

It is very hard to fully investigate glottal gestures from acoustic data alone, in the case of unclearly pronounced casual speech. The glottal pattern might be very complicated, especially when it is combined with the sonorant consonant which manifests itself with spontaneous voicing. Therefore, signals from Electrolaryngograph (ELG) that measures time variation of the degree of contact between the vibrating vocal folds or fiberscopic analyses are used for the measurement of breathiness/aspiration of sonorants (Harris 2009; Esposito et al. 2005).

The purpose of this paper is to suggest the possibility that there is certain influence of /h/ on the preceding sonorant consonant though it is not clearly visible on the usual acoustic data of waveforms and spectrograms. In order to do this, I use the speech materials produced with rather casual rate that causes the weak /h/ consonant to be almost deleted and examine the possibility that complete deletion does not occur even when one does not hear any trace of /h/.

3. Experiment

3.1 Participants

Three male and three female speakers, aged 20 to 25, who are college students, participated in the production experiment. All six speakers are from Seoul or Gyeonggi Province.

3.2 Materials

In order to see if there is a complete /h/ deletion occurring after the sonorant consonant and before a vowel or a glide, as discussed in the previous studies on Korean /h/ deletion, the following 16 pairs of two-syllable minimal pairs are examined.

(9) a. sonorant + h cluster ⁶ (Pre-h condition)		b. sonorant between voiced segments (Non-h condition)	
kimhɛ	(city name)	kimɛ	'seaweed-loc.'
kamhi	'dare'	kami	'persimmon-nom.'
namha	'moving south'	nama	'man'
camhjəl	'occult blood'	camjəl	'self-destruction'
cinhiŋ	'promotion'	ciniŋ	'intelligence'
konhi	'sound asleep'	koni	'swan'
cənhu	'postwar period'	cənu	'fellow soldier'
sənhjəl	'fresh blood'	sənjəl	'patriotic martyrs'
paŋhan	'visit to Korea'	paŋan	'plan'
koŋhe	'pollution'	koŋɛ	'ball-loc.'
kaŋhi	(person's name)	kaŋi	'river-nom.'
toŋhjaŋ	'trend'	toŋjaŋ	'the Orient'
pʰilhi	'surely'	pʰili	'pipe'
palhan	'perspiration'	palan	'suggestion'
pulhə	'disapproval'	pulə	'French'
silhjən	'realization'	siljən	'broken heart'

To minimize prosodic differences, target words were presented in carrier sentences. Two kinds of carrier sentences are used, one for a casual/natural speech rate and the other for a faster speech rate.

- (10)
- a. Ice _____ palimhamnida. – casual/natural speech rate
 now _____ *pronounce-dec.*
 (Now I pronounce _____.)
- b. P'ali _____ palimhamnida. – faster speech rate
 fast _____ *pronounce-dec.*
 (I pronounce _____ fast.)

⁶ Due to Korean phonotactics that allows /h/ only in syllable-initial position, the sequence of a sonorant plus /h/ only occurs after a vowel and before a vowel or a glide. But in the actual pronunciation, except in very emphatic, slow speech, the sonorant resyllabifies as an onset of the following syllable as can be seen in the pronunciation of /silhjən/ 'realization' as [ʃi.rɦjən]. /l/ is realized as flap (tap) in syllable onset position (Lee 1996).

It is generally assumed that speech rate is the usual predictor of deletion. Casual/natural speech rate sentences are intended to elicit tokens of /h/ deletion, and faster speech rate sentences are to see how speech rate affects the possible influence of /h/ on the preceding sonorant. Casual speech rate might be fast enough to elicit /h/ deletion but the faster rate sentences are added to see the effect of the very fast speech rate on the /h/ deletion phenomenon.

It is hypothesized that members of the minimal pair in (9a) and (9b) show almost, though not exactly, the same phonetic realizations if a complete /h/ deletion occurs.

3.3 Procedures

Participants were asked to read the materials written in Korean orthography twice at a natural/casual speaking rate and twice at a faster rate. The test sentences were presented in separate cards and randomized in different orders for each repetition. For the natural/casual speech rate sentences subjects were instructed to read them as naturally as possible as if they pronounced them in the casual conversation with their friends. For the faster speech rate sentences they were directed to read considerably faster than the natural/casual speech rate sentences. Recordings were made using Edirol recorder, via SONY microphone in a quiet room. Spectrograms and waveforms are processed using Praat software.

3.4 Measurements

Based on the hypothesis that /h/ affects the preceding sonorant without manifesting itself on the spectrogram, the qualities of the preceding sonorants were measured and compared to those of the sonorant not followed by /h/. Two qualities, sonorant duration and spectral tilt, were measured.

3.4.1 Sonorant duration

The duration of the sonorant consonant was measured from spectrograms, wave forms and amplitude curves. On the spectrogram and waveform, nasals appear with greatly reduced energy compared to adjacent vowels or glides. Therefore, their onset and offset are marked by an abrupt change in intensity. I did not include lateral duration measurements in the analysis because the lateral sound, which is resyllabified as an onset of the following syllable, is realized as a tap which has a short overall duration and a very brief closure period. The following figure shows the nasal duration measurement.

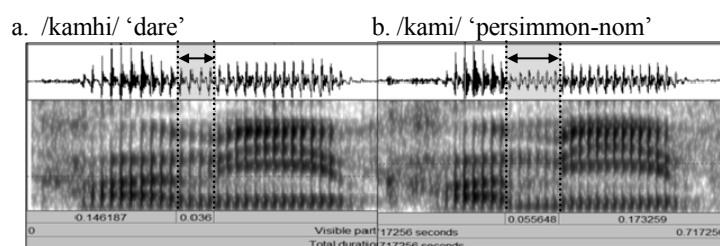


Figure 3. Nasal duration measurement for /kamhi/ and /kami/

3.4.2 Spectral tilt – H1-F3

Based on the hypothesis that /h/ preceded by a sonorant consonant affects the sonorant in the way that makes the sonorant breathy voiced, breathiness is measured by way of spectral tilt. Spectral tilt is the degree to which intensity drops off as frequency increases and is one of the common ways to measure phonation differences (Gordon and Ladefoged 2001). It can be quantified by comparing the amplitude of the fundamental (H1) to that of higher frequency harmonics. According to Gordon and Ladefoged (2001), subtracting the amplitude of higher harmonics from the amplitude of the fundamental yields larger values for breathy vowels than modal vowels. While various spectral tilt measures have been used in the former studies of phonation, I used H1 - F3 (the amplitude of the highest harmonic near the third formant) as used in Esposito (2003) and Harris (2009)⁷.

Measurements were taken manually from the spectral slices performed on the Fast Fourier Transform (window length of 25 ms.).⁸ The average spectral slice is taken at the mid-point of each nasal. In the case of lateral, it is pronounced as flap or tap in many cases, and thus, there is a closure which makes it impossible to measure spectral tilt. For this reason, spectral slices were taken just after the first full glottal pulse of the following vowel onset in the waveform. Examples of H1 and F3 on the spectral slices are shown in Figure 4.

⁷ While the spectral measure H1-H2 has been used to measure the phonation differences in various languages (Wayland and Jongman 2003 among others), the question of the reliability of this measure has been raised. Simpson (2012) points out that H1 and H2 are inappropriate reference points to measure sex-specific differences in breathiness with the possibility of nasality being present in some vowels produced by female speakers. According to him, due to the complexity of the nasal cavity, it is hard to accurately predict many details of the acoustic output of a vocal tract that is coupled with the nasal cavity. For more detailed discussion, see Simpson (2012).

⁸ Measurements of spectral tilt were taken from the natural speech production since the possibility of the sequence of sonorant and /h/ showing breathiness is higher when it is produced slower than when /h/ is completely deleted.

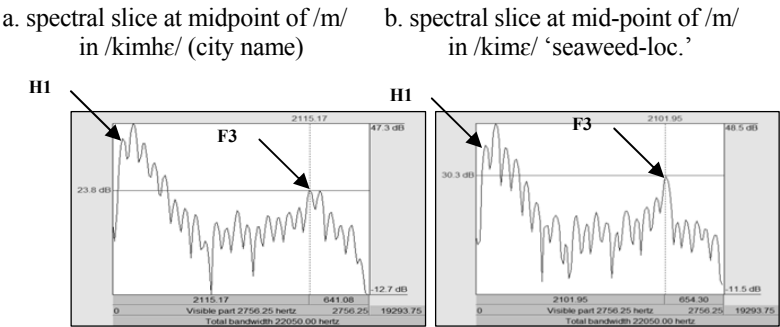


Figure 4. Demonstration of H1 and F3 values on the spectral slice

3.5 Results

3.5.1 Nasal Duration

In both of the casual/natural speech production and the faster speech production, acoustic manifestation of /h/ in the spectrogram and waveform was not observed, i.e., there was no visible or audible sign of /h/ in the target words.

In order to compare the durations of nasal sonorants preceding /h/ (e.g., /n/ in /konhi/: Pre-/h/ Condition) and those not preceding /h/ (e.g., /n/ in /koni/: Non-/h/ Condition), data obtained from the subjects were entered into the paired *t*-tests. Table 1 shows the mean duration of nasal consonants in the Pre-/h/ and Non-/h/ conditions in casual/natural speed production and the results of the paired *t*-tests.

Table 1. Mean duration of nasals in casual/natural speech rate (ms.) and paired *t*-test comparison

		Mean (SD)*	<i>t</i>	<i>p</i>
/m/	Pre-/h/	55.42 (14.74)	-10.446	.000
	Non-/h/	69.75 (14.19)		
/n/	Pre-/h/	48.71 (16.95)	-5.248	.000
	Non-/h/	61.42 (12.68)		
/ŋ/	Pre-/h/	40.67 (13.18)	-6.136	.000
	Non-/h/	60.38 (18.33)		
Nasals Total	Pre-/h/	48.26 (16.13)	-10.814	.000
	Non-/h/	63.85 (15.77)		

*(): Standard Deviation

For all three nasal consonants /m/, /n/, and /ŋ/, the duration was shorter when they were placed in the Pre-/h/ condition than when they were in the Non-/h/ condition (55.42 ms. vs. 69.75 ms. for /m/; 48.71 ms. vs. 61.42 ms. for /n/; 40.67 ms. vs. 60.38 for /ŋ/). Paired *t*-tests conducted for each consonant confirmed that these differences were statistically significant. ($t=-10.446$, $p<.001$ for /m/; $t=-5.248$, $p<.001$ for /n/; $t=-6.136$, $p<.001$ for /ŋ/). In total, the nasal consonants in the Pre-/h/ condition were significantly shorter than those in the Non-/h/ condition (Pre-/h/ condition: 48.26 ms., Non-/h/ condition: 63.85 ms., $t=-10.814$, $p<.001$).

The analysis with individual subjects showed that the above results were consistent across all six subjects. Table 2 shows the nasal duration produced by six subjects.

Table 2. Mean nasal duration in casual/natural speech rate by each subject (ms.)

		Subjects					
		A	B	C	D	E	F
/m/	Pre-/h/	71.50	64.25	42.00	34.75	60.50	59.50
	Non-/h/	85.25	81.50	54.50	50.75	72.75	73.75
/n/	Pre-/h/	73.75	57.50	36.75	29.25	50.00	45.00
	Non-/h/	80.25	65.00	52.50	48.25	57.50	65.00
/ŋ/	Pre-/h/	57.25	39.25	36.75	25.00	34.00	51.75
	Non-/h/	74.00	68.09	45.00	41.00	49.50	84.75
Nasals Total	Pre-/h/	67.50	53.67	38.50	29.67	48.17	52.08
	Non-/h/	79.83	71.50	50.67	38.75	59.92	74.50

All six subjects consistently produced the nasals in the Pre-/h/ condition shorter than the ones in the Non-/h/ condition. Repeated measure ANOVAs found the main effect of the Condition (Pre-/h/ or Non-/h/) on nasal duration for all three consonants ($F=92.258$, $p<.001$ for /m/; $F=28.387$, $p<.001$ for /n/; $F=42.210$, $p<.001$ for /ŋ/), but no interaction effect was found between the Condition and Subject for all three nasals ($F=.289$, $p>.05$ for /m/; $F=1.141$, $p>.05$ for /n/; $F=1.557$, $p>.05$ for /ŋ/), confirming that the main effect of the Condition was consistent across all subjects. These results suggest that the existence of /h/ causes changes in the duration of the preceding nasal consonants for all subjects.

We also measured the nasal duration in the faster speech rate. Table 3 shows the mean duration of three nasal consonants produced in faster speech and the results of the paired *t*-tests.

Table 3. Mean duration of nasals in faster speech (ms.) and paired *t*-test comparison

		Mean (SD)	<i>t</i>	<i>p</i>
/m/	Pre-/h/	48.67 (11.33)	1.616	.120
	Non-/h/	46.71 (12.63)		
/n/	Pre-/h/	40.79 (13.82)	-.434	.669
	Non-/h/	41.29 (11.66)		
/ŋ/	Pre-/h/	39.71 (7.54)	.517	.610
	Non-/h/	39.38 (7.70)		
Nasals Total	Pre-/h/	43.06 (11.75)	.993	.324
	Non-/h/	42.46 (11.17)		

The results showed that, for all three nasals in faster speech production, no significant difference was found in duration between the Pre-/h/ condition and the Non-/h/ condition ($t=1.616$, $p>.05$ for /m/; $t=-.434$, $p>.05$ for /n/; $t=.517$, $p>.05$ for /ŋ/). Total mean duration of the three nasal consonants was 43.06 ms. in the Pre-/h/ condition and 42.47 ms. in the Non-/h/ condition, showing no significant difference between the two conditions ($t=.993$, $p>.05$). The analysis with individual subjects on the faster speech rate indicated that these results were consistent across all six subjects.⁹ Repeated measure ANOVAs found that there was no main effect of the Condition on nasal duration for all three nasals ($F=2.688$, $p>.05$ for /m/; $F=.237$, $p>.05$ for /n/; $F=.328$, $p>.05$ for /ŋ/), and no interaction effect between the Condition and Subject for all three nasals ($F=.1137$, $p>.05$ for /m/; $F=2.201$, $p>.05$ for /n/; $F=2.035$, $p>.05$ for /ŋ/). These results suggest that when subjects pronounced the target words in faster speech, /h/ might be completely deleted without

⁹ The following table shows the nasal duration in faster speech rate by six subjects.

Mean nasal duration in faster speech rate by each subject (ms.)

		Subjects					
		A	B	C	D	E	F
/m/	Pre-/h/	62.50	57.00	43.75	37.25	47.50	44.00
	Non-/h/	60.25	58.50	38.75	31.00	48.00	43.75
/n/	Pre-/h/	54.75	53.75	29.75	31.00	33.25	42.25
	Non-/h/	55.75	47.00	31.50	34.00	33.75	45.75
/ŋ/	Pre-/h/	40.75	39.50	41.75	34.00	35.75	46.50
	Non-/h/	43.75	37.50	41.75	31.25	36.25	45.75
Nasals Total	Pre-/h/	52.67	50.08	38.42	34.08	38.83	44.25
	Non-/h/	53.23	47.67	37.33	32.08	39.33	45.08

affecting the preceding nasal.¹⁰

3.5.2 Spectral tilt –H1-F3

Again, paired *t*-test was used to compare the spectral tilts of sonorants in the Pre-/h/ condition and the Non-/h/ condition. Table 4 shows the mean value of H1-F3 and the results of the paired *t*-test.

Table 4. Average H1-F3 value of sonorants (dB) and paired *t*-test comparison

		Mean (SD)	<i>t</i>	<i>p</i>
/m/	Pre-/h/	28.70 (7.70)	.743	.465
	Non-/h/	27.97 (8.77)		
/n/	Pre-/h/	32.65 (8.48)	1.292	.209
	Non-/h/	31.09 (9.75)		
/ŋ/	Pre-/h/	26.74 (8.68)	1.569	.130
	Non-/h/	25.20 (9.13)		
/l/	Pre-/h/	19.53 (8.18)	2.368	.027
	Non-/h/	17.51 (7.16)		

The results showed that, for three nasal sonorants, no significant difference was found in H1-F3 value between the Pre-/h/ condition and the Non-/h/ condition ($t=.743$, $p>.05$ for /m/; $t=1.192$, $p>.05$ for /n/; $t=1.569$, $p>.05$ for /ŋ/). However, for liquid sonorant /l/, H1-F3 value in the Pre-/h/ condition was significantly larger than its counterpart in the Non-/h/ condition ($t=2.368$, $p<.05$).

Table 5 shows the average H1-F3 values of sonorants by each of six

¹⁰ To ensure that our subjects produced genuinely faster speech in the faster speech rate experiment, paired *t*-test was conducted to compare the durations of the nasal consonants in the casual/natural speech experiment and faster speech experiment. The following table shows the average duration of the nasal consonants in different speech rate conditions and results of the paired *t*-test comparison.

Mean duration of nasals in casual and faster speech and paired *t*-test comparison

	Casual/natural	Faster	<i>t</i>	<i>p</i>
/m/	62.58 (16.04)	47.69 (11.91)	7.532	.000
/n/	55.06 (16.14)	41.04 (12.65)	7.388	.000
/ŋ/	50.52 (19.01)	39.54 (7.54)	4.119	.000
Total	55.80 (17.87)	42.67 (11.51)	10.126	.000

Results of the *t*-tests indicate that durations of all three consonants in the faster speech experiment were significantly shorter than their counterparts in the casual speech condition, indicating that our subjects indeed made a faster speech in faster speech production experiment.

subjects.

Table 5. Average value of H1-F3 by each subject (dB)

		Subjects					
		A	B	C	D	E	F
/m/	Pre-/h/	39.35	34.05	20.98	23.58	24.33	29.90
	Non-/h/	36.93	37.58	15.20	23.63	25.53	28.95
/n/	Pre-/h/	39.93	39.20	20.80	29.50	27.63	38.85
	Non-/h/	37.78	40.08	16.15	29.60	25.85	37.10
/ŋ/	Pre-/h/	34.23	37.03	16.43	20.40	22.20	30.15
	Non-/h/	30.80	37.05	13.13	21.25	21.00	28.00
/l/	Pre-/h/	18.38	31.83	13.50	20.65	11.38	21.45
	Non-/h/	17.65	29.48	12.20	18.48	11.05	16.20
Total	Pre-/h/	32.97	35.53	17.93	23.53	21.39	30.09
	Non-/h/	30.79	36.05	14.17	23.24	20.86	27.56

In five subjects (subjects A, C, D, E, and F), total average value of H1-F3 in the Pre-/h/ condition was larger than its counterpart in the Non-/h/ condition. However, when repeated measure ANOVA was conducted for each consonant, no main effect of Condition was found for three nasal consonants ($F=.700$, $p>.05$ for /m/; $F=1.441$, $p>.05$ for /n/; $F=2.179$, $p>.05$ for /ŋ/). The main effect of Condition was found only for /l/ ($F=5.198$, $p<.05$). These results were consistent with the result of the paired *t*-test that, only for /l/, H1-F3 value in the Pre-/h/ condition is significantly larger than its counterpart in the Non-/h/ condition. Interaction effect between the Condition and Subject was found for none of the four sonorants ($F=.2231$, $p>.05$ for /m/; $F=.369$, $p>.05$ for /n/; $F=.473$, $p>.05$ for /ŋ/; $F=.663$, $p>.05$ for /l/).

4. Discussion

The results of the experiment can be summarized as follows: 1) The duration of the nasals followed by underlying /h/ is shorter than that of the nasals not preceding /h/ in the natural/casual rate speech where there is no visible or audible sign of /h/ occurring; 2) In faster rate speech, there is no difference in duration between the nasals followed by underlying /h/ and those not followed by /h/; and 3) As for the value of H1-F3 that is measured to test for the breathiness of the sonorant consonants, there is no difference in the value of H1-F3 between the sonorants followed by underlying /h/ and those not in that condition, except for /l/.

The results of the nasal duration suggest that in faster speech where no difference was found in the duration of nasals in pre-/h/ and non-/h/

conditions, /h/ preceded by the nasal is completely deleted. On the other hand, in natural/casual speech where the difference in the nasal duration was observed, /h/ might affect the preceding nasal in the way that it shortens the preceding nasal. Therefore, this case may not be considered “complete” deletion in the sense that /h/ is realized somehow on the preceding sonorant. In other words, this case may be seen as showing that nasals merged with /h/ go through a change in duration.

Two different speculations might be given to the reason for this phenomenon of nasal shortening. First, articulatorily when nasals, normally accompanied by spontaneous voicing in which the vocal folds are closed together vibrating, meet with the following /h/ whose glottal state is such that vocal folds are pulled apart with considerable airflow coming through, there will be some confusion or complication in the state of glottis. This confused or complicated glottal state between the closing gestures and opening gestures might result in terminating the voiced nasal sound earlier than usual. In this sense, this phenomenon might be seen as a kind of anticipatory process. Although not in line with this articulatory explanation I provided here, Ohala and Busà (1995) report many cases of nasal loss before voiceless fricatives. According to them, voiceless fricatives as well as voiced fricatives are implicated in endangering “spontaneous” nasalization and are the optimal environment for preceding nasal loss.¹¹

Another speculation might be that the reduction in nasal duration is due to some change in the nasal quality – according to my assumption, ‘breathiness’ of the nasals – influenced by the following /h/. Though not about breathy/aspirated sonorants, there is a study that duration differs depending on the laryngeal feature realized on sonorants. Um (1998) found that word-initial glottalized sonorants are shorter in duration than their plain counterparts in Gitksan, a language spoken in Northern America. In this language, the only difference between word-initial glottalized sonorants and word-initial plain sonorants is their duration, and there is no other acoustic manifestation of glottalization observed. Without many acoustic cues, it is hard to distinguish word-initial glottalized sonorants from their plain counterparts. Gitksan shows an instance that laryngeally specified sonorants are shorter than plain sonorants. Considering breathy voice/aspiration is a kind of laryngeal feature, the shortening of nasal duration before /h/ can be accounted for in the same line: both glottalization of sonorants in Gitksan and breathy voice/aspiration of sonorants in Korean are a kind of realization of laryngeal feature on sonorants, which is related to the shortening of duration. Of course, the idea that realization of laryngeal feature is associated with the shortened duration is a pure postulation and further evidence and discussion

¹¹ In his study on Burmese voiceless nasals, Dantsuji (1984) found out that a reduction in duration takes place in case of the voiced portion of the voiceless nasals. Such a reduction can also be observed in the case of nasals in consonant clusters including a voiceless fricative in English (recited from Dantsuji 1984).

are needed.¹² This interpretation of a sonorant followed by /h/ as breathy voiced/aspirated sonorant provides a parallel explanation for the aspiration merger phenomenon. Aspiration merger is usually considered to apply when an obstruent is followed by /h/ as in /ip+hak/ → [ip^hak] ‘admission’. If we admit the presence of aspirated sonorants, aspiration merger can extend to both sonorants and obstruents. That is, /h/ merges into the preceding consonant, making it aspirated and working as a laryngeal feature regardless of whether the consonant is an obstruent or a sonorant.¹³

The result of the measurement of spectral tilt H1-F3 suggests that a sonorant followed by /h/, except for /l/, does not have the quality that breathy voiced segments are reported to have. I assumed that if the sonorants were breathy, the values of H1-F3 for the sonorant followed by /h/ would be bigger than those for plain sonorants. The present result shows that this characteristic of higher H1-F3 value is found only in liquid sonorant /l/, but not in nasals. While this result clearly indicates that one of the important acoustic characteristics for breathy voice is not present in all target sonorants, some explanation may be needed on why nasals, but not the liquid, do not show the acoustic characteristics. One methodological consideration might be that acoustic characteristics of nasals are particularly difficult to capture. One of the reasons is that the spectral characteristics of nasal sonorants are very complicated due to the complexity of nasal cavity, which is related to spectral zero or anti-resonance. Berkson (2013) points out that breathy phonation is not cued by nasal sonorants as it is by obstruents. In addition, according to her, for sonorants, cues that are strong in one context can be weaker in another context. For example, cues that work for males are not necessarily the same as those that work for females. In fact, most studies on acoustic characteristics of breathy segments have been conducted on vowels, not on sonorants. Many questions about breathy voiced sonorants remain unanswered and further studies are required in the area.¹⁴

While the present study does not confirm the existence of breathiness of sonorants followed by /h/, there still is a possibility that the sonorants are influenced by the following /h/ in a way that they are devoiced. In Korean, /h/ is known to devoice the following voiced segment, and we can also conjecture that /h/ can devoice the preceding voiced segment. In fact, Ahn (2013) relates the weakening or devoicing of nasals with their duration.

¹² While there have been some studies on the duration of non-modal vowels such as glottalized or breathy voiced vowels (e.g., Gordon and Ladefoged 2001), there have not been many studies on the duration of breathy sonorants. Esposito et al. (2005) and Harris (2009) examined the duration, but those cases are the ones where there can be a debate whether the segments in question are single breathy sonorants or the sequences of sonorant plus /h/.

¹³ If we assume that aspiration merger applies when the sonorant, as well as the obstruent, is followed by /h/, the cases like /silhjon/ ‘realization’ → [ʃi.ɾijon] can be explained without postulating the special phonological status of /h/ as a glide. See section 2.2.

¹⁴ Harris (2009) reports that correlates of breathy voice were more easily observed in the articulatory signal, not in the acoustic signal.

According to her, nasals which are reported to be frequently weakened or denasalized have shorter duration and are more frequently devoiced. This phenomenon probably might be seen the other way around: the shorter duration of sonorants in the pre-/h/ condition in our study may be related to the devoicing of sonorants. That is, though it might not be a change in terms of breathiness, there might be a change in the sonorant quality in terms of voicing. Although this study did not examine whether the target sonorants are actually devoiced, a further research will have to include the voicing of sonorant as a possible candidate for sonorant quality change.

5. Conclusion

In this paper, I examined the phonetic realization of the cluster of a sonorant and /h/ occurring in the phonological context where /h/ is reported to be deleted. I specifically asked whether or not /h/ is completely deleted without influencing the preceding sonorant. In the experiment carried out with the two-syllable minimal pairs where one member contains the sequence of a sonorant+/h/ between voiced segments and the other contains only a sonorant, it was found that the duration of the sonorant preceding underlying /h/ is shorter than that of the sonorant not followed by /h/. While the quality of breathiness was not clearly observed in the sonorants, the difference found in the duration of the sonorant consonant suggests that /h/ in fact is not completely deleted. While it is presumed that /h/ affects the preceding sonorant in terms of duration change, a question remains whether there was a change in the quality of the preceding sonorant. A further research may be needed to investigate the possible quality change(s) in the sonorant followed by /h/. Analyses on the articulatory signal and the refined experiment on perception probably provide interesting insights on the influence of /h/ on the preceding sonorant.

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