# The Phonetic Nature of the Phonological Contrast between the Lenis and Fortis Fricatives in Korean

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## 1. Introduction

Korean has two alveolar fricatives: lenis /s/ and fortis /s*/. The lenis fricative /s/ has been described as unaspirated and unlaryngealized and /s*/ as laryngealized. Korean alveolar fricatives are different from stops and affricates in that they do not show the typical three-way distinction (aspirated vs. lenis vs. fortis); instead, a gap occurs in phonemic structure.

The phonetic nature of the contrast between the lenis and fortis fricatives has been less intensively studied relative to that of stops and affricates. It has been assumed that /s/ is similar to lenis stops or affricates with respect to laryngeal settings and /s*/ to fortis stops or affricates. This assumption seems to be due to the influence of Korean orthography, where the letter for /s*/ comes from juxtaposition of the letter standing for /s/, as is the case for stops and affricates.

The phonetic nature of the two fricatives has been investigated in various aspects. First, aspiration is observed between the frication noise and the subsequent vowel [2, 6, 10, 11]. Second, a systematic difference in glottal width at the point of release of the tongue constriction was found between the lenis and the fortis fricatives as well as in stops and affricates in Korean [6]. It was claimed that glottal width at the articulatory release should be considered as one of the determining factors for VOT. Third, the VOT value of /s/ is very similar to that of the aspirated stops while that of /s*/ is similar to that of the lenis stops [10]. Fourth, no significant difference is observed between the frictions of the two fricatives [10, 11]. Fifth, f0 at the onset of the vowel after the fortis fricative is higher than that of the vowel after the lenis fricative [2, 6, 10, 11]. Finally, there is no significant difference in duration between /s/ and /s*/ in VCV context [7].

To sum up, a clear and substantial aspiration occurs in the lenis fricative, which leads to higher values in glottal width, VOT, and f0 at the onset of the vowel. It is natural that the lenis fricative be transcribed as [$s^h$].

Perception tests also demonstrate that aspiration in the lenis fricative is substantial and of the same kind as is shown in aspirated stops [10, 11]. It was reported that a signal with the preceding frication cut away from [$s^h$ada], that is [hada], was perceived as [phada], [thada], or [khada] [11]. It was also noted that the stimuli, made by incrementally cutting 10 ms away from the onset of the frication noise of /sal/ flesh , were perceived as [$s^h$al], [thal], [thal], and [phal] [10]. What is clear from the two perception tests is that there is a clear aspiration in the lenis fricative. However, it seems that the crucial cue to distinguish the two fricatives does not lie in aspiration but in the subsequent vowel, since the subjects' responses coincide with the identity of the subsequent vowel regardless of aspiration. The stimuli, 4 tokens made by splicing, and responses are given in (1) [11].

Stimuli and responses in perception test

| | Stimuli | Responses |
|---|---|---|
| (a) | [s1a1da] | [$s^h$ada] |
| (b) | [s1ha2da] | [s*ada] |
| (c) | [s2a1da] | [$s^h$ada] |
| (d) | [s1a2da] | [s*ada] |

[s1] and [a1], [s2] and [a2] stand for the friction and the subsequent vowel in [$s^h$ada] and [s*ada], respectively. The fact that (a), a signal with aspiration cut away from [$s^h$ ada], was perceived as [$s^h$ada] implies that aspiration is not the only cue to distinguish the two fricatives. The fact that (b), a signal with friction and aspiration of [$s^h$ada] attached to the subsequent vowel of [s*ada], was perceived as [s*ada] implies that the subsequent vowel is a more important factor in perception than aspiration.

Another perception test was conducted to examine how aspiration and the subsequent vowel are related to the distinction of the two fricatives [11]. Recorded signal was [$s^h$ ada], where friction lasted for about 100 ms, aspiration for about 50 ms, and the subsequent vowel for about 150 ms. Fifteen tokens were made by cutting 10 ms away incrementally backward from the 50 ms vowel point. Subjects were asked to judge whether each token was perceived as [$s^h$ada] or [s*ada].

The result of the perception test showed a categorical perception, as illustrated in Figure 1.

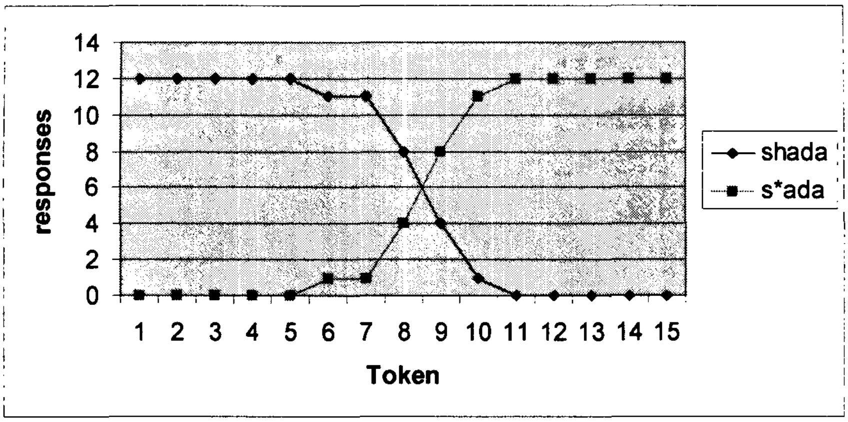



Figure 1. The result of the perception test

All subjects reported that the played signals sounded like [sʰada] until token 5, where all the vowel portion of the signal was cut away. At token 9, consisting of friction and 20 ms of aspiration, more subjects started to report it as [s*ada]. All subjects report the played signal sounds like [s*ada] at token 11, where neither aspiration nor the vowel section are present. The result of this perception test tells us that a considerable amount of aspiration (about 25 ms.) and the earlier portion of the subsequent vowel are responsible for identification of the lenis fricative.

It was made clear that the subsequent vowel is related to the distinction of the two fricatives. The present study provides more detailed information about the characteristics of the subsequent vowels in distinguishing the two fricatives. Spectral analyses of the vowels following the frication noise are conducted to specify the phonetic nature of the two fricatives.

## 2. Spectral analyses

The characteristics of the three phonation types (laryngealized, modal, breathy) have been specified with respect to glottal opening, volume velocity waveform, and spectral structure of the voicing source [8, 12]. The characteristics of a modal phonation are characterized by the nearly approximated vocal folds, leading to a typical volume velocity waveform with an open quotient of about 50% or 60% of the period, the slightly skewed shape during the open phase, and the spectrum of the normal voicing source with an average falloff of about 12 dB per octave.

The characteristics of a laryngealized phonation are characterized by the arytenoid cartilages positioned so as to close off the glottis, the relatively short duration of the open portion of a fundamental period, and the substantially lowered fundamental frequency during laryngealization. Possible perceptual cues to laryngealization are a reduction in the relative amplitude of the fundamental component in the source spectrum and a lowered fundamental frequency contour.

The characteristics of a breathy phonation are characterized by the well separated arytenoid cartilages at the back but sufficiently approximated vocal folds, the volume velocity waveform with a rounded corner at closure leading to a very strong fundamental component, and the substantially attenuated amplitudes of higher harmonics. Possible perceptual cues to a breathy vowel are thus an increase of the relative amplitude of the fundamental component in the spectrum and replacement of higher harmonics by aspiration noise.

H1-H2 (value obtained by subtracting amplitude of the second harmonic from that of fundamental frequency) was employed as a metric for breathy voice [4]. Vowels with such non-modal properties as breathiness and laryngealization were investigated across languages [1]. H1-H2 and H1-F2 (value obtained by subtracting amplitude of the second formant from that of fundamental frequency) were measured across vowels.

Those researches mentioned above provide a rationale for the employment of H1-H2 as a metric for difference of voice quality of the vowel after the two Korean fricatives.

## 2.1. Experiment I

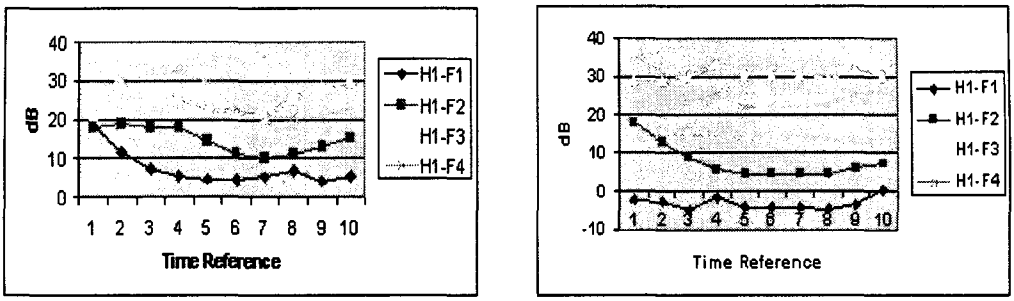
### 2.1.1. Method

The amplitude of the fundamental frequency and the first four formants were measured in the average spectrum of 20 ms windows every 10 ms from the onset to the midpoint of the vowel.

### 2.1.2. Result

The values obtained by subtracting the amplitude of each formant frequency from that of the fundamental frequency are illustrated in Figure 2.

In the vowel following the friction of the lenis fricative, H1 dominates the four formants throughout the time points. This configuration is similar to that of lax voice, where F1 and F2 are attenuated relative to the first harmonic [3]. In the vowel following the friction of the fortis fricative, F1 dominates H1 and the other formants throughout the frames. This configuration is also similar to that of tense voice, where F1 and F2 are comparatively boosted relative to the first harmonic so that the spectrum is dominated by F1 [3]. It is clear that the vowels following the friction of the two Korean fricatives show a difference in voice quality.




[sʰada] [s*ada]

Figure 2. H1-F1, F2, F3, F4

## 2.2. Experiment II

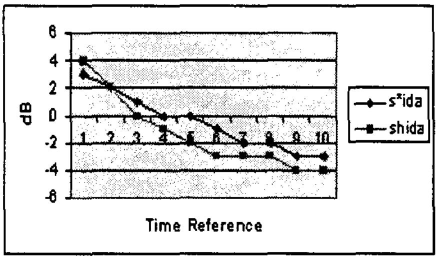
### 2.2.1. Method

The values of H1-H2 across 8 Korean vowels were plotted against time to specify what difference exists in the vowels following the friction. H1 is more variable than H2 in both [sʰVda] and [s*Vda]. The high variability results from the fact that H1 is readily affected by phonation types while H2 is more constant, which is one of the reasons why H1-H2 can be effective in determining the difference in voice quality between the vowels after the friction. Data analyzed here consist of 8 Korean monophthongs in [sʰ Vda] and [s*Vda].

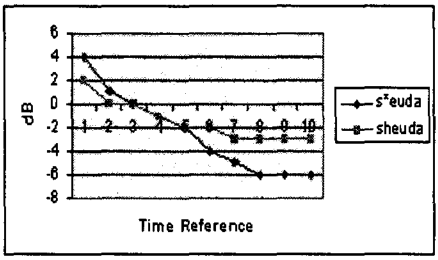
### 2.2.2. Result

The results are illustrated in Figure 3.

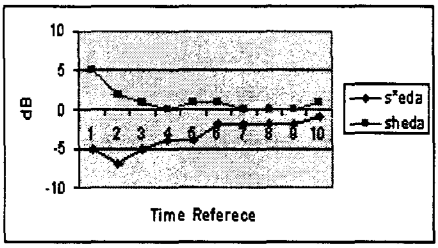
The three graphs for the high vowels commonly show that H1-H2 in both [sʰVda] and [s*Vda] decreases over time from the onset. On the other hand, the five graphs for the lower vowels commonly show a very sharp contrast in the earlier time reference: H1-H2 in [sʰVda] decreases over time from the onset while that in [s*Vda] increases over time.



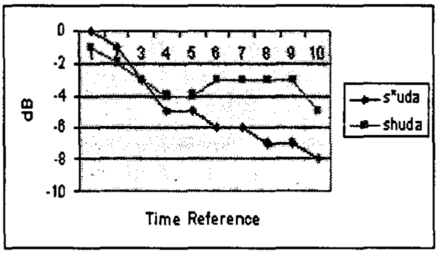

H1-H2 in /i/



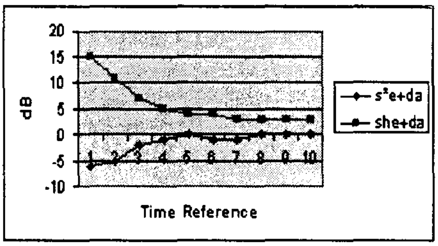

H1-H2 in /ɯ/



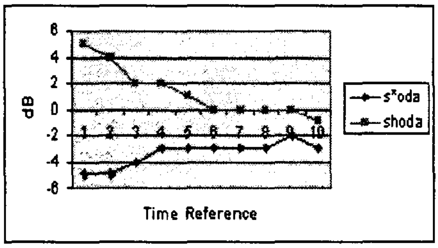

H1-H2 in /e/



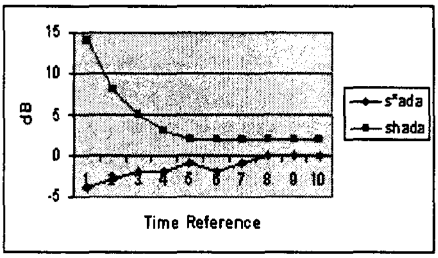

H1-H2 in /u/



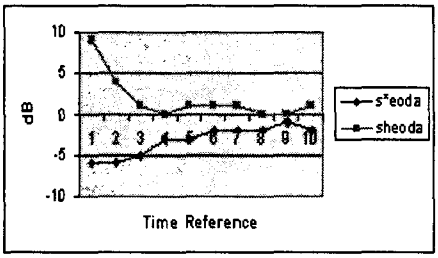

H1-H2 in /ɛ/




H1-H2 in /o/




H1-H2 in /a/




H1-H2 in /ʌ/

Figure 3. Comparison of H1-H2 in 8 vowels

Another higher order difference in H1-H2 between [$s^h$Vda] and [s*Vda] can be drawn. The values obtained by subtracting H1-H2 in [s*Vda] from that in [$s^h$Vda] are plotted against time in Figure 4.

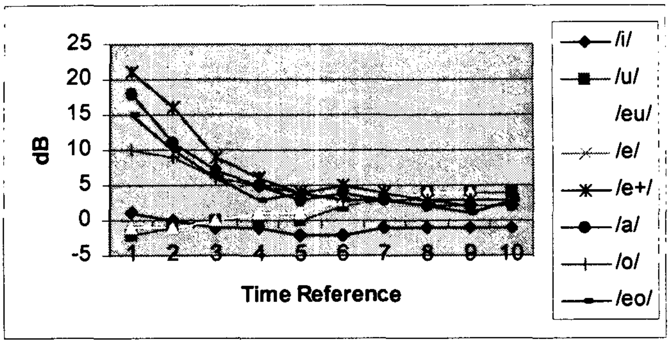



Figure 4. Comparison of 8 vowels

Difference in H1-H2 between [$s^h$Vda] and [s*Vda] across 8 Korean monophthongs are ordered as follows:

Order of the difference

ε > a > ʌ > e = o > i > ɯ > u

The bigger the difference is, the lower the vowel is. This difference seems not to be significant among high vowels or among lower vowels. Whether this difference is constant and consistent in all the situations must be clarified to give a generalization. If this difference is constant and consistent, it can be used as an indicator of vowel difference in the same context.

## 3. Discussion

Difference in H1-H2 between [$s^h$Vda] and [s*Vda] roughly corresponds to difference in vowel height. This difference is due to characteristics of the filter. The spectral shape is the sum of the source characteristics and the filter characteristics. The amplitude of each harmonic is affected by both the filter and the source. The closer the first formant peak is to the fundamental frequency, the more the second harmonic is boosted, which results in a reduction of the value of H1-H2. The amplitude of the second harmonic for the high vowels is much bigger than that of the lower vowels, since the peak of the first formant of the high vowels occurs near the second harmonic.

The results, nevertheless, showed that the vowels following the friction in [$s^h$Vda] are significantly different in voice quality from those in [s*Vda].

# 4. Conclusion

It was noted that there is a clear and substantial aspiration in the lenis fricative while not in the fortis fricative and that there is no significant difference between the frictions of the two fricatives. Those observations imply that aspiration may be a crucial acoustic cue that distinguishes the two fricatives. Another perception test, however, demonstrates that aspiration alone plays no crucial role in distinguishing the two fricatives. It is apparent that significant acoustic cues lie in the vowel following friction.

Acoustic experiments were conducted to specify what difference exists in the vowels following friction. The values obtained by subtracting the amplitude of each formant frequency from that of the fundamental frequency demonstrated that there is a notable difference in voice quality between the subsequent vowels of the two fricatives. A comparison of H1-H2 across 8 Korean vowels, especially for non-high vowels, confirmed that there is a sharp contrast in the onset of the vowel following friction between the lenis fricative and the fortis fricative.

H1-H2 in the unfiltered spectra was measured in the present study. It is necessary, however, to investigate genuine source spectra to give a more accurate description of the difference between the vowels following friction. The present study is also restricted to fricatives. A study of stops and affricates as well as fricatives would do justice to the nature of the three-way distinction of Korean obstruents. Such works remain to be done.

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