The Acoustics of Korean Fricatives Revisited

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1 Introduction

The three-way laryngeal contrast in Korean among lenis, fortis, and aspirated[1] plosives and affricates has been the subject of much phonetic research. In contrast, the two-way distinction between fortis and non-fortis[2] fricatives has received relatively little attention despite its typological rarity. This paper presents the results of two production experiments focusing on these fricatives, part of ongoing phonetic research with two main objectives. The first is to arrive at an analysis of laryngeal contrast in Korean fricatives on the basis of phonetic data. The second is to put this analysis in typological perspective. What do phonetic data suggest about the proper classification of the fricatives? Within the scope of the Korean sound system, is the non-fortis fricative lenis, aspirated, both, or neither? Finally, what category does the non-fortis fricative exemplify in the broader scope of universal laryngeal features? Here I report acoustic data on the fricatives in two different vowel environments and suggest that the non-fortis fricative instantiates the category of aspirated voiceless lenis.

2 Background

Korean laryngeal contrast has been the subject of a great deal of linguistic research. A variety of previous studies have shown that the three laryngeal series differ from each other in initial position along several dimensions: linguopalatal contact (Cho and Keating 2001), glottal configuration (Kim 1970, Kagaya 1974), subglottal and intraoral pressure (Dart 1987), laryngeal and supralaryngeal articulatory tension (Kim 1965, Hardcastle 1973, Hirose et al. 1974, Dart 1987), voice onset time (Lisker and Abramson 1964, Han and Weitzman 1970, Hardcastle 1973, Hirose et al. 1974, Han 1996, Cho et al. 2002, Kim 2004), fundamental frequency of vowel onset (Han 1996, Kim 2004), intensity of vowel onset (Han and Weitzman 1970), and voice quality of vowel onset (Abberton 1972, Han 1998, Kim and Duanmu 2004).

While much of the literature has concentrated on the nature of the three-way contrast among the plosives, comparatively few studies have investigated the two-way contrast between the fricatives. The identification of the first fricative as a fortis sibilant /s*/ has been relatively uncontroversial, but there is disagreement over the proper analysis of the non-fortis fricative. In some phonological processes such as Post-Obstruent Tensing (Kim 2003), it patterns with the lenis plosives (becoming fortis following an obstruent just as the lenis plosives do). However, in other processes such as Intervocalic Lenis Stop Voicing (Jun 1993), it patterns with the aspirated plosives (remaining voiceless intervocalically just as the aspirated plosives do).

The ambiguous nature of the non-fortis fricative in comparison to the fortis fricative is reflected in several aspects of its phonetic realization. Some bear more similarities to the features of the aspirated plosives than the lenis plosives. For instance, the fundamental frequency (f_0) onset associated with the non-fortis fricative is close to that of the fortis fricative, in keeping with the closeness in f_0 onset between the fortis and aspirated plosives, and its initial duration is similar to that of the aspirated plosives (Kang 2000, though cf. Park 2002b). In addition, the glottal configuration associated with the non-fortis fricative is similar to that of the aspirated plosives (Kagaya 1974), with an opening that is significantly larger than that for the fortis fricative (Jun et al. 1998). The fricative is thus heavily aspirated like the aspirated plosives (Kang 2000, Cho et al. 2002). Yoon's (1999) acoustic analyses further suggest that before mid and low vowels the duration of the aspiration interval is the only consistent difference between the two fricatives; thus, he concludes that "the duration of the aspirated segment alone can act as the primary cue for the aspirated/[fortis] distinction" (*ibid.*: iv).

On the other hand, the non-fortis fricative has significantly less linguopalatal contact than the fortis fricative (Kim 2001), a difference similar to that between lenis and fortis plosives, and its shortened intervocalic duration is similar to that of the lenis plosives (Kang 2000, Cho et al. 2002). With respect to initial duration, Cho et al. (2002) report that including aspiration the non-fortis fricative is actually longer than the fortis fricative (which makes it seem more like the aspirated plosives than the lenis plosives); however, when aspiration is excluded it is much shorter than the fortis fricative (which makes it seem more like the lenis plosives than the aspirated plosives). Cho et al.'s (2002) data also show that the non-fortis fricative's f_0 onset is generally lower than that associated with the fortis fricative (which makes it seem like the lenis plosives vis-à-vis the fortis plosives), but this was not a statistically significant trend; when they compared its f_0 onset to the f_0 distributions of lenis and aspirated plosives, in fact they found that it was similar to neither and fell in between. Moreover, when the non-fortis fricative is flanked by voiced sounds, though it remains voiceless it undergoes vocal fold slackening similar to that seen in the lenis plosives in the same environments (Iverson 1983). Cho et al. (2002) go further in claiming that it even becomes voiced in this environment as often as 46% of the time, though the voicing they found was gradient and did not appear to be phonologized in the same way it is for lenis plosives (furthermore, this result has not been duplicated by other researchers).

Other dimensions of the fricative distinction appear to lie in the adjacent vowels (Park 1999), which contain many of the cues to the laryngeal contrast among the plosives. In fact, vowels carry so much of the information about the laryngeal distinction that perception of the contrast is quite good on the basis of vocalic information alone (Kim et al. 2002). Among the cues provided by the vowel as to the laryngeal state of a consonant are f_0, intensity, and voice quality, as discussed above. Kluender (1991) adds first formant (F1) onset to this list. In experiments with both human listeners and Japanese quail, he found that among the various aspects of the vowel onset related to F1, F1 onset frequency was the best predictor of voiced/voiceless labeling judgments. Later work by Benkí (2001, 2005) involving English and Spanish speakers confirmed the role of F1 onset frequency in the perception of voicing and emphasized the role of the F1 transition pattern as well.

In the case of a consonant articulated with the tongue body high and a vowel articulated with the tongue body low, a higher F1 onset and flatter F1 transition pattern are associated with the category having the longer VOT (i.e. the voiceless category in a voiced/voiceless contrast). Since F1 increases as the tongue lowers from the point of consonantal occlusion to the position for vocalic articulation, this correlation is the natural result of the longer delay between consonantal release and voicing onset. In other words, with a long VOT, the tongue has more time to get into position for the vowel and thus is closer to the target position by the time the vocal folds start vibrating. Conversely, when the VOT is short, the tongue has little time to get into position for the vowel and the vocal folds may start vibrating well before the tongue reaches its target position; thus, the F1 onset is lower and the F1 transition pattern steeper.

Park (2002a) investigated the time courses of F1 and F2 as realized in the three laryngeal types in some detail. His results indicated significant differences in F1 trajectory among the three laryngeal series. Specifically, F1 peaks earlier and higher in the aspirated series than in the fortis or lenis series (not an unexpected result, given that the aspirated series has the longest VOT). Data for F2 trajectories also showed some differences, but was less conclusive.

Finally, H1-H2 and H1-F2, measures of spectral tilt, are significantly higher for the non-fortis fricative than for the fortis fricative (Cho et al. 2002), which indicates breathy phonation similar to that seen after lenis plosives. However, it is not clear that breathy phonation can be said to exclusively characterize the lenis plosives. Cho et al. (2002) themselves demonstrate that while H1-H2 and H1-F2 are highest for the lenis plosives among the three series, these values are next highest for the aspirated plosives (with those for the fortis plosives being the lowest). Consequently, this sort of evidence has also been used to argue in favor of analyzing the non-fortis fricative as aspirated (Park 1999).

Not surprisingly, then, the non-fortis fricative has been analyzed in various ways in the literature—as aspirated by some (e.g. Kagaya 1974, Park 1999, Yoon 2002), as lenis by others (e.g. Iverson 1983, Cho et al. 2002), and as both aspirated and lenis by others still (e.g. Kang 2000, 2004).

3 Experiments 1a and 1b: Production

Given the conflicting results of some of the studies described above, as well as the fact that they have largely focused on the fricatives in the same vowel environment (namely, /a/), two experiments were conducted to reexamine the distribution of the Korean fricatives along the acoustic dimensions discussed above – fricative duration, aspiration duration, f_0 onset, F1 onset, intensity buildup, and voice quality – as well as length of the following vowel. Experiment 1a investigated the fricatives in the environment of /a/, while Experiment 1b investigated the fricatives in the high vowel environment of /u/.

3.1. Methods

3.1.1. Materials

A randomly ordered list of Korean CV monosyllables was constructed such that obstruents of all places of articulation and phonation types occurred before the three vowels /a, i, u/. The critical syllables/words in Experiment 1a were /Sa/ 'buy; four' and /s*a/ 'cheap; wrap', while those in Experiment 1b were /Su/ 'number' and /s*u/ 'cook'.

3.1.2. Speakers

The same five native speakers of Korean participated in Experiments 1a and 1b. They were three males and two females in their 20s and 30s with no articulatory or auditory impairments. The first and second male speakers (M1, M2) and first and second female speakers (F1, F2) were born and grew up in Seoul; the third male speaker (M3) was born and grew up in Daejeon. All speakers spoke relatively standard dialects containing the fortis/non-fortis fricative contrast.

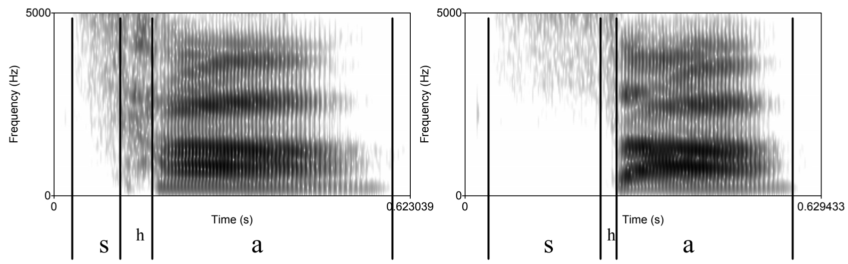
3.1.3. Procedure

The sound files for speakers F1, M1, and F2 were recorded in quiet rooms as mono sound files in Praat 4.2.17 (Boersma and Weenink 2004) using a Sony Vaio PCG-TR5L laptop computer and a Shure C608 microphone. The sound files for speakers M2 and M3 were recorded using a Marantz PMD660 solid state recorder and an AKG C420 microphone. For all speakers and target words, three tokens were recorded in isolation at 22.1 kHz and 16 bps.

All measurements were taken in Praat by hand. The spectrogram method used was Fourier, with a Gaussian window shape, window length of 5 ms, dynamic range of 70 dB, and pre-emphasis of 6 dB/octave. Fricative duration was measured from the onset of high frequency noise to the onset of periodicity in the vowel; aspiration duration was measured from the onset of a distributed spectrum with low frequency noise to the onset of periodicity; f_0 was measured over the first three pitch points in the vowel resulting from the default autocorrelation method used by Praat; F1 was measured at the first visible glottal cycle; intensity was measured at the beginning of each of the first ten glottal cycles as well as across the whole vowel; H1-H2 values were calculated across a spectrum of the first four glottal cycles; and vowel length was measured from the first glottal cycle to the end of visible periodicity.

Spectrograms of /Sa/ and /s*a/ are shown below in Figure 1, with the portions of the spectrogram corresponding to the sibilant fricative, aspiration, and vowel demarcated to illustrate the transition points used to measure the duration of these sections.

Figure 1. Wide-band spectrograms of /Sa/ (L) and /s*a/ (R) as spoken by M1.



3.2. Results

The acoustic data for all speakers' productions in Experiments 1a and 1b are summarized in Tables 1 and 2, respectively.

Table 1. Average acoustic measures (and standard errors) for /Sa/ vs. /s*a/.

Speaker	F1	F2	M1	M2	M3	
Fricative duration (ms)	110 (5)	109 (4)	153 (14)	167 (13)	153 (4)	/Sa/
	180 (20)	192 (13)	218 (26)	209 (25)	215 (8)	/s*a/
Aspiration duration (ms)	78 (10)	29 (8)	43 (6)	60 (3)	56 (9)	/Sa/
	14 (1)	14 (3)	9 (0)	9 (1)	11 (1)	/s*a/
f_0 onset (Hz)	245 (2)	296 (6)	162 (3)	136 (2)	164 (6)	/Sa/
	239 (5)	291 (5)	166 (3)	138 (1)	156 (6)	/s*a/
F1 onset (Hz)	918 (8)	1018 (92)	589 (58)	682 (36)	558 (30)	/Sa/
	539 (29)	575 (10)	420 (14)	448 (9)	555 (16)	/s*a/
ΔIntensity (dB/cycle)	0.8 (0.2)	1.1 (0.2)	1.5 (0.0)	0.9 (0.1)	1.3 (0.1)	/Sa/
	0.7 (0.2)	1.1 (0.1)	1.1 (0.1)	0.3 (0.2)	0.5 (0.1)	/s*a/
Average intensity (dB)	66.6 (0.2)	69.5 (0.1)	67.7 (0.5)	78.7 (0.2)	74.5 (1.2)	/Sa/
	66.4 (0.7)	72.2 (0.8)	67.3 (0.9)	77.8 (0.1)	75.6 (0.2)	/s*a/
Spectral tilt (dB)	23.6 (1.1)	9.4 (1.5)	8.7 (2.7)	2.2 (0.6)	11.3 (1.8)	/Sa/
	-0.7 (1.6)	-9.7 (1.3)	-0.4 (0.6)	-1.8 (0.3)	-2.1 (0.1)	/s*a/
Vowel length (ms)	425 (19)	387 (18)	357 (35)	268 (9)	235 (10)	/Sa/
	423 (15)	400 (23)	349 (22)	296 (5)	246 (21)	/s*a/

Table 2. Average acoustic measures (and standard errors) for /Su/ vs. /s*u/.

Speaker	F1	F2	M1	M2	M3	
Fricative duration (ms)	138 (7)	144 (7)	153 (3)	201 (16)	187 (6)	/Su/
	156 (7)	212 (18)	183 (18)	195 (7)	221 (16)	/s*u/
Aspiration duration (ms)	62 (8)	47 (7)	62 (3)	50 (3)	43 (1)	/Su/
	18 (6)	21 (4)	9 (1)	6 (1)	8 (2)	/s*u/
f_0 onset (Hz)	243 (1)	320 (11)	193 (5)	168 (2)	158 (3)	/Su/
	239 (2)	303 (7)	197 (11)	165 (4)	173 (5)	/s*u/
F1 onset (Hz)	293 (7)	350 (7)	284 (13)	359 (13)	327 (20)	/Su/
	351 (15)	385 (10)	286 (19)	308 (21)	373 (8)	/s*u/
ΔIntensity (dB/cycle)	1.9 (0.1)	0.6 (0.1)	1.7 (0.1)	0.5 (0.1)	1.1 (0.3)	/Su/
	1.2 (0.1)	1.2 (0.1)	1.3 (0.2)	0.9 (0.1)	0.9 (0.0)	/s*u/
Average intensity (dB)	66.3 (0.8)	66.8 (0.3)	67.3 (1.4)	80.0 (0.4)	74.5 (0.3)	/Su/
	66.3 (1.3)	65.0 (0.6)	67.0 (0.9)	79.6 (0.3)	78.2 (1.3)	/s*u/
Spectral tilt (dB)	33.4 (2.5)	29.4 (0.1)	25.9 (1.0)	0.2 (0.4)	0.7 (4.6)	/Su/
	22.4 (9.3)	18.7 (4.0)	19.5 (9.7)	-3.8 (0.2)	-3.0 (0.4)	/s*u/
Vowel length (ms)	405 (13)	328 (8)	278 (6)	275 (5)	227 (18)	/Su/
	389 (16)	301 (11)	282 (6)	262 (17)	227 (22)	/s*u/

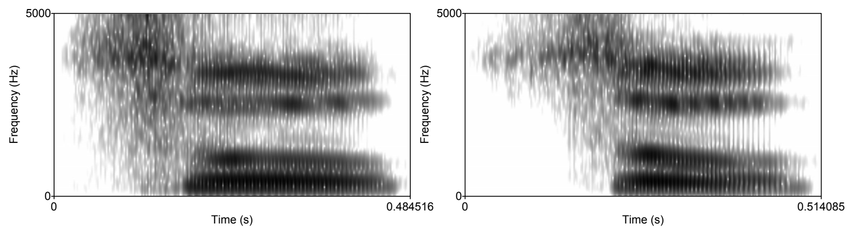
For all speakers the fortis fricative is significantly longer than the non-fortis fricative in the environment of /a/ ($F(1, 4) = 93.704$, $p = 0.001$); for most speakers the fortis fricative is also longer in the environment of /u/, with the difference approaching significance ($F(1, 4) = 5.735$, $p = 0.075$). These data contradict the results of Cho et al. (2002), who claimed that the non-fortis fricative including aspiration was longer than the fortis fricative. On the contrary, with the exception of M2's /Su/-/s*u/ contrast, the data in Table 1 and Table 2 indicate that the fortis fricative is much longer than the non-fortis fricative including aspiration; in some cases (e.g. F2's /Sa/-/s*a/ contrast), the fortis fricative is nearly twice as long as the non-fortis fricative.

With regard to aspiration, the data corroborate the results of previous studies. For all speakers the aspiration interval is significantly longer in the non-fortis fricative than in the fortis fricative. This is true both before /a/ ($F(1, 4) = 25.567$, $p = 0.007$) and before /u/ ($F(1, 4) = 77.500$, $p = 0.001$).

With regard to f_0, there is no significant difference between the two fricatives in the case of /a/ ($F(1, 4) = 1.216$, $p = 0.332$) or /u/ ($F(1, 4) = 0.036$, $p = 0.858$), much as in Cho et al. (2002), where there also was no significant difference found. Moreover, the general trend in Cho et al. (2002) for the non-fortis fricative to be associated with a lower f_0 than the fortis fricative is not reflected in these data, which fail to fall in the same direction across speakers.

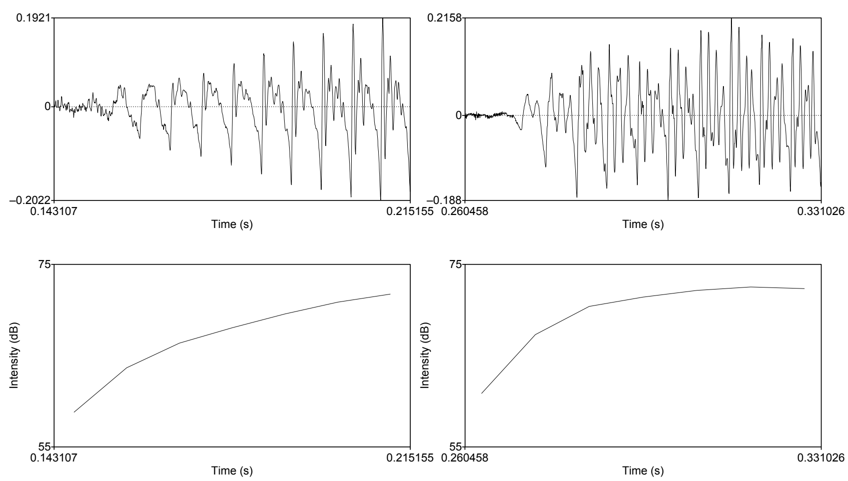
With regard to F1, the data in Experiments 1a and 1b corroborate the results of previous research in that for nearly all subjects the first formant starts significantly lower after the fortis fricative than the non-fortis fricative when the vowel is /a/ ($F(1, 4) = 9.919$, $p = 0.035$), a difference that approaches 500 Hz for some subjects (cf. F1, F2). On the other hand, when the vowel is /u/, this difference diminishes considerably and is no longer significant ($F(1, 4) = 0.843$, $p = 0.411$). This fact can be seen in Figure 2 (cp. Figure 1), from which it is apparent that there is little or no difference in F1 onset between /Su/ and /s*u/.

Figure 2. Wide-band spectrograms of /Su/ (L) and /s*u/ (R) as spoken by M1.



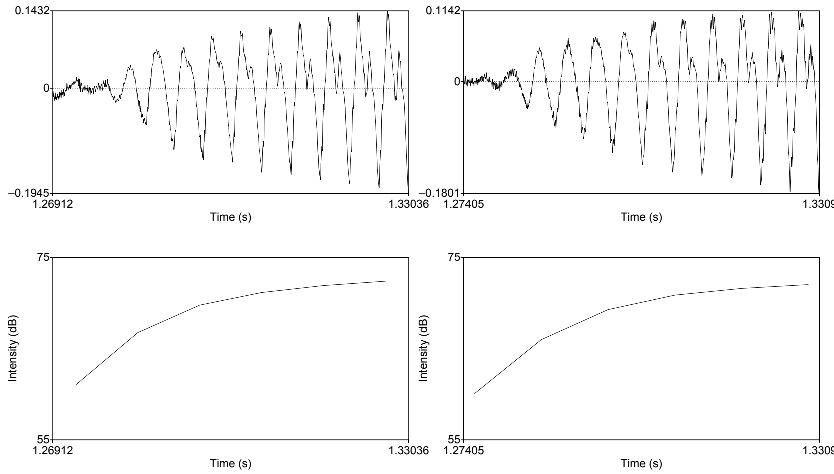
With regard to intensity buildup, the difference found by Han and Weitzman (1970) between the fortis plosives and the lenis and aspirated plosives is reflected in the intensity buildup following the two fricatives into /a/, as shown in Figure 3. As with the plosives, intensity increases more sharply and peaks earlier following a fortis fricative than following a non-fortis fricative.

Figure 3. Waveforms and intensity contours of vowels in /Sa/ (L) and /s*a/ (R).



The average change in intensity across the first four glottal cycles of vowel onset reveals differences approaching significance for /a/ ($F(1, 4) = 6.446$, $p = 0.064$), but not for /u/ ($F(1, 4) = 0.060$, $p = 0.818$). As shown in Figure 4, the intensity profiles of the two fricatives are virtually identical in the case of /u/.

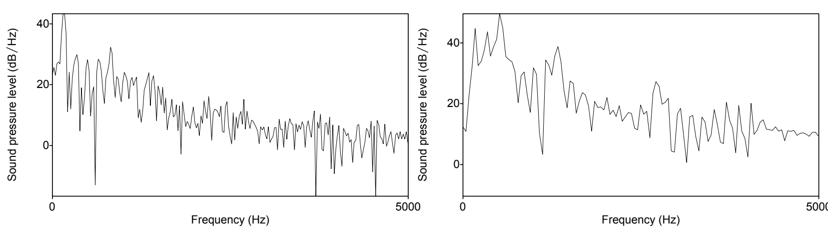
Figure 4. Waveforms and intensity contours of vowels in /Su/ (L) and /s*u/ (R).



In the /a/ environment, average change in intensity for these early periods is lower for /s*a/ because intensity levels off and begins decreasing sooner than in /Sa/. Although the data for intensity change show some differences between the two fricatives in the case of /a/, the data for average intensity across the whole vowel do not differentiate the fricatives in the /a/ environment ($F(1, 4) = 0.501$, $p = 0.518$) or the /u/ environment ($F(1, 4) = 0.068$, $p = 0.807$).

With regard to voice quality, differences between the first and second harmonics (H1-H2) of the spectrum of vowel onset agree with previous results: H1-H2 is more positive following non-fortis obstruents. H1-H2 values are thus more positive following the non-fortis fricative than following the fortis fricative (cf. Figure 5), and this difference is significant for /a/ ($F(1, 4) = 15.241$, $p = 0.017$), as well as for /u/ ($F(1, 4) = 20.584$, $p = 0.011$).

Figure 5. Spectra of vowel onset in /Sa/ (L) and /s*a/ (R).



The final acoustic dimension explored in Experiments 1a and 1b was vowel length. Although vowel length has not usually been claimed to differ following initial obstruents in Korean, some (e.g. Kang 2000) argue that the non-fortis fricative's shortened duration intervocalically triggers compensatory lengthening of the following vowel. In addition, studies such as Cho and Keating (2001) have shown that closure duration differs significantly between fortis and non-fortis plosives even in word-initial position; it follows that there could be a complementary effect of "compensatory shortening" resulting in significantly shorter vowels following the longer fortis fricatives than the shorter non-fortis fricatives. Nonetheless, similar to the data for f_0 onset, the data for vowel length do not show any trends. In some cases (e.g. F1 and M1 in Table 1), the vowel following the fortis fricative is slightly shorter than following the non-fortis fricative, while in other cases (e.g. F2, M2, and M3 in Table 1), the vowel following the fortis fricative is actually longer. Differences in vowel length between the two fricatives are not significant for /a/ ($F(1, 4) = 1.788$, $p = 0.252$) or for /u/ ($F(1, 4) = 3.438$, $p = 0.137$).

To summarize, acoustic data from Experiments 1a and 1b indicate that the two fricatives are produced with (i) different durations (the fortis fricative being longer), (ii) different aspiration intervals (the non-fortis fricative's being longer), (iii) different F1 trajectories into a low vowel (F1 after the fortis fricative starting lower), (iv) different patterns of intensity buildup into a low vowel (intensity increasing more rapidly after the fortis fricative), and (v) different voice onset qualities (a more breathy quality after the non-fortis fricative, as indicated by a more steeply declining spectral tilt). However, f_0 onset, average vowel intensity, and vowel length do not appear to be distinguishing factors.

4 Discussion

This study has yielded several major findings. Besides confirming and adding to previous results regarding aspiration duration, voice quality, F1 onset, and intensity buildup, Experiments 1a and 1b showed, contra Cho et al. (2002), that the fortis fricative is significantly longer in duration than the non-fortis fricative, and that there is no difference in f_0 onset between the two. The first finding favors a lenis categorization of the non-fortis fricative (cf. the difference in closure duration between the lenis and fortis plosives); on the other hand, the second finding favors an aspirated categorization (cf. the closeness in f_0 onset between the aspirated and fortis plosives).

Do the results of this study then support any particular categorization of the non-fortis fricative? The evidence previously marshaled in favor of the two possible analyses is summarized in Table 3. The findings of this study generally confirm these facts, or otherwise do not contradict them (in the case of the phonological evidence). One result of Experiment 1a adds to the body of acoustic evidence supporting the aspirated analysis: the non-fortis fricative shows a high F1 onset, a property of the aspirated plosives.[3] How can this finding be reconciled with the evidence favoring a lenis analysis?

Table 3. Evidence for lenis vs. aspirated analyses of the non-fortis fricative

Lenis Analysis	Aspirated Analysis
subject to post-obstruent tensing	not subject to intervocalic voicing
less linguopalatal contact than fortis	not subject to phonological aspiration
vocal fold slackening intervocalically	open glottal configuration
loss of aspiration intervocalically	heavy aspiration in initial position
shorter duration than fortis	duration similar to aspirated
shortened duration intervocalically	high f_0 onset similar to aspirated

The answer to this question may lie in the generality of these facts and the interpretation of their underlying causes. First, with respect to linguopalatal contact and durational properties, it is unclear how similar the aspirated plosives are to the fortis plosives. Cho and Keating (2001) found a significant difference between the contact for lenis plosives and that for aspirated and fortis plosives, but do not claim that the contact for aspirated and fortis is in fact the same. If anything, the subordinate relation of the aspirated plosives to the fortis plosives in closure duration would suggest a similar relationship in articulatory contact. [4] Thus, neither the fact that the non-fortis fricative has less linguopalatal contact than the fortis fricative, nor the fact that the non-fortis fricative is shorter than the fortis fricative may actually constitute evidence that can adjudicate between a lenis analysis and an aspirated analysis. However, even supposing that the aspirated and fortis plosives were the same in terms of linguopalatal contact and that a similar parallelism should exist between an aspirated and a fortis fricative, it is not unreasonable to predict the aspirated fricative would have less contact anyway due to coarticulatory assimilation with the following aspiration gesture (essentially a glottal fricative/voiceless vowel with no oral constriction).

With regard to the non-fortis fricative's intervocalic loss of aspiration, again it is not clear that this is evidence that can be said to support either analysis. As Han and Weitzman (1970) and others have shown, both the aspirated plosives and the lenis plosives lose a great deal of aspiration intervocalically. In addition, with regard to post-obstruent tensing, though it is true in standard Seoul Korean that the non-fortis fricative following obstruents is tensed like the lenis plosives, there are dialects (e.g. North Gyeongsang Korean) in which it is not and instead stays aspirated.

Nonetheless, Iverson (1983) provides some convincing arguments for the lenis analysis of the non-fortis fricative. He observes that the vocal fold slackening, or glottal width reduction, in intervocalic environments is similar in magnitude ("a reduction by 10 or 15 on the glottal width scale [of 30]") to that seen in intervocalic lenis plosives. Though it is debatable whether a narrowing of a partly open glottis to a fully adducted glottis (in intervocalic lenis plosives) and a narrowing of a fully open glottis to a partly open glottis (in intervocalic non-fortis fricatives) amount to parallel gestures, the narrowing is indicative of some assimilation to the glottal requirements of the adjacent voiced vowels (i.e. a "weakened" articulation). Both this fact and the fact that intervocalic non-fortis fricatives are significantly reduced in duration (Kang 2000) provide the strongest evidence in favor of the lenis analysis.

Thus, the results of this study generally support analyzing the fricative distinction as an aspirated/fortis contrast, but do not refute much of the independent evidence offered in favor of a lenis/fortis contrast. It may be that the ambivalent position of Kang (2000, 2004) is ultimately the most justified: with both lenis and aspirated features, the non-fortis fricative may simply be both lenis and aspirated. In fact, this position becomes quite reasonable in the context of the laryngeal typology proposed in Jansen (2004).

Jansen (2004) notes that plosives across a wide variety of languages seem to divide into four types – (unaspirated) *prevoiced lenis*, (unaspirated) *passively voiced lenis*, *unaspirated voiceless fortis*, and *aspirated voiceless fortis* – while fricatives generally come in only two types: (unaspirated) *prevoiced lenis* and *unaspirated voiceless fortis*. Jansen says that aspirated fricatives "only seem to occur in languages that already have distinctively voiced and plain voiceless fricatives" (*ibid.*: 56). This, however, is not an accurate characterization of the Korean fricative contrast, which appears to be typologically unusual (cf. Ladefoged and Maddieson 1996: 176-179). The 'fortis' fricative can indeed be labeled unaspirated voiceless fortis, but the 'non-fortis' fricative cannot be prevoiced lenis since it is neither prevoiced nor passively voiced. Moreover, as summarized above, there is considerable evidence grouping it with the lenis plosives. Therefore, it would appear that either we should look to the other plosive categories and paradoxically classify the 'non-fortis' fricative as aspirated voiceless fortis, or admit that this fricative does not fit into any of Jansen's four categories and classify it as something else. The latter analysis seems superior. The non-fortis fricative appears to exemplify a different category: *aspirated voiceless lenis*.[5] This analysis not only avoids classifying the 'non-fortis' fricative as fortis, it also resolves the issue of whether the 'non-fortis' fricative is 'lenis' or 'aspirated', since in this classification it is both.

5 Conclusion

In summary, this study examined the production of the two-way laryngeal contrast in Korean sibilant fricatives in two experiments covering low and high vowel environments. Acoustic analyses show that in a low vowel environment, the two fricatives differ from each other in fricative duration, aspiration duration, F1 onset, intensity buildup, and voice quality; however, the F1 and intensity differences disappear in a high vowel environment. In both environments, there are no differences in f_0 onset, average intensity, or vowel length. In having a fricative contrast without a voiced member, Korean constitutes an exception to Jansen's (2004) laryngeal typology. This contrast seems to be typologically unique and can only be accommodated by the addition of an aspirated voiceless lenis category to the set of possible laryngeal classifications.

Notes

* Research represented in this paper has been supported in part by a Jacob K. Javits Fellowship, a Gates Cambridge Scholarship, and a research grant from Trinity College, Cambridge. I am grateful to Andrew Garrett, Sharon Inkelas, Keith Johnson, Brechtje Post, Rachel Smith, and audiences at the Berkeley QP Fest 2006, LSA 2007, and HISOKL 2007 for helpful discussions and feedback. Any errors are my own.

1. These laryngeal series have acquired many names in the literature. The lenis series is also called 'lax', 'weak', 'plain', 'slightly aspirated', and 'breathy'; the fortis series is also called 'tense', 'strong', 'glottalized', 'long', 'unaspirated', and 'forced'; and the aspirated series is also called 'heavily aspirated', 'strongly aspirated', and 'super aspirated'. In this paper they will be referred to as lenis, fortis, and aspirated, respectively.

2. The latter fricative is usually called lenis or aspirated, depending on how it is categorized. Here it will be referred to as non-fortis and transcribed with /S/ (rather than /s/ or /s^h/) in order to remain neutral on its categorization.

3. Neither gradual intensity buildup nor positive H1-H2 is evidence that can be brought to bear here, since both lenis and aspirated plosives show more gradual intensity buildup than fortis plosives (Han and Weitzman 1970), as well as more positive H1-H2 values than fortis plosives (Cho et al. 2002).

4. Cho and Keating (2001) did not find a significant duration difference between aspirated and fortis plosive closures, but several other studies have found a difference (cf. Silva 1992, Kim 1994, Han 1996).

5. A somewhat separate issue is the fact that voiced aspirated ('breathy voiced') stops, a relatively common class of sounds across languages, also necessitate an additional category in Jansen's (2004) typology.

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