Perspectives on the Korean laryngeal contrast from cross-linguistic perceptual similarity*

Charles B. Chang
University of California, Berkeley

1 Introduction

The three-way laryngeal contrast in Korean among lenis, fortis, and aspirated plosives has been well-described in previous linguistic studies. The results of this research have shown that the three laryngeal series are differentiated from each other along a number of articulatory, aerodynamic, and acoustic dimensions word- and phrase-initially: linguopalatal contact (Cho and Keating 2001), glottal configuration (C.-W. Kim 1970, Kagaya 1974), subglottal and intraoral pressure (Dart 1987), laryngeal and supralaryngeal articulatory tension (C.-W. 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, J.-I. Han 1996, Cho et al. 2002, Choi 2002, M. Kim 2004), fundamental frequency of vowel onset (J.-I. Han 1996, Choi 2002, M. Kim 2004), intensity of vowel onset (Han and Weitzman 1970), and voice quality of vowel onset (N. Han 1998, Cho et al. 2002, Kim and Duanmu 2004).[1]

The majority of these previous studies analyze the contrast as one among "lax" (i.e. lenis), "tense" (i.e. fortis), and aspirated stops—all phonologically

* This work was conducted with the support of a Jacob K. Javits Fellowship from the U.S. Department of Education. I am grateful to Ian Maddieson, Keith Johnson, John Ohala, Larry Hyman, Sharon Inkelas, the Berkeley Phonetics and Phonology Forum, and the audience at WIGL 5 for helpful discussions and feedback. Naturally, any errors are mine.

[1] The somewhat complementary dimensions of closure duration and vowel length also appear to be important cues to the laryngeal distinction, but primarily in postvocalic/intervocalic environments (cf. Silva 1992, Kim 1994, Han 1996, Cho and Keating 2001). As this paper focuses on the laryngeal contrast in prevocalic position, these factors are not considered further, though closure duration does appear to play a role in the perception of initial voiced plosives (cf. §2.2).

LSO Working Papers in Linguistics 7: Proceedings of WIGL 2007, 55-69.

voiceless, although the lenis series typically becomes voiced intervocalically. These series have traditionally been transcribed as, respectively, /p, t, k/; /p*, t*, k*/ or /p', t', k'/; and /p^h, t^h, k^h/. Even when transcription conventions make use of symbols for voiced sounds to represent Korean stops, the analysis of the laryngeal contrast usually leaves voicing out of underlying representations. For instance, the transcription conventions of Lee (1999), which are used in many other phonetic studies of Korean, uses /b, d, g/ to indicate "voiceless unaspirated (or slightly aspirated) lenis plosives."

On the other hand, Kim and Duanmu (2004) have recently argued that the analysis of the Korean laryngeal system as having three kinds of voiceless consonants is problematic for phonological theory because, among other reasons, having to describe a "tense" series that appears to be phonologically distinct only in Korean (e.g. by positing a feature [tense]) overgenerates such unattested sounds as /b^h*/ or /p^h*/. Kim and Duanmu argue instead that the Korean stop contrast is more accurately characterized as one among voiced stops (which would then be analyzed as devoicing word-initially), voiceless unaspirated stops, and voiceless aspirated stops—a system of laryngeal contrast not uncommon in other languages of the world (e.g. Burmese, Thai, Hindi).

The present study contributes to the growing body of research on this unusual laryngeal contrast with a cross-linguistic perceptual survey of plosives from three other languages (Sindhi, Spanish, and Shanghainese) with different systems of laryngeal contrast. How do Korean speakers perceive phonation in these other languages in terms of the laryngeal categories of Korean? Do Korean speakers' perceptual patterns provide evidence in favor of a particular analysis of the Korean laryngeal system? What are the acoustic correlates of these perceptual patterns?

This paper is organized as follows. First, the results of a cross-linguistic perception experiment are described, and acoustic analyses are provided of some of the stimuli. The implications of the results are then discussed before the main conclusions are summarized.

2 Experiment 1: Cross-linguistic perception

2.1 Methods

2.1.1 Materials

Word lists were constructed for Korean, Sindhi, Spanish, and Shanghainese that included the laryngeal contrasts of interest: in Korean and Shanghainese, a three-way contrast between lenis/voiced, fortis/voiceless unaspirated, and voiceless aspirated; in Spanish, a two-way contrast between voiced and voiceless; and in

Sindhi, a four-way contrast between voiced unaspirated, voiced aspirated, voiceless unaspirated, and voiceless aspirated (with two words including implosives). Whenever possible, words were included that had the relevant consonants in both word-initial and word-medial positions and that were matched for vowel quality (i.e. containing /a/). Partial word lists for each language are given in Tables 1-4 below with fairly broad phonetic transcriptions.

Table 1: Partial Korean word list

WORD-INITIAL CONSONANTS		INTERVOCALIC CONSONANTS	
IPA	*Gloss*	*IPA*	*Gloss*
[**p**ɑrada]	'to hope for'	[ʧa**b**a]	'Grab (it)!'
[**p***ɑrɯda]	'to be fast'	[a**p***a]	'Dad'
[**pʰ**a]	'scallion'	[ka**pʰ**a]	'Pay (it) back!'
[**t**a⌋]	'moon'	[ta**d**a]	'Close (it)!'
[**t***ada]	'to pluck'	[pa**t***a]	'to receive'
[**tʰ**ada]	'to burn'	[pa**tʰ**aŋ]	'foundation'
[**k**ak*apta]	'to be close'	[ma**g**a]	'Block (it)!'
[**k***adɑropta]	'to be particular'	[a**k***apta]	'to be a waste'
[**kʰ**a⌋]	'knife'	[ʧo**kʰ**a]	'nephew'
[**ʧ**a]	'well then'	[ʧa**ʤ**aŋ]	'black bean sauce'
[**ʧ***a]	'to be salty'	[ka**ʧ***a]	'fake'
[**ʧʰ**a]	'tea'	[ʧ*o**ʧʰ**a]	'Follow!'
[**sʰ**ada]	'to buy'	[ha⌋a**sʰ**an]	'Mount Halla'
[**s***ada]	'to be cheap'	[a**s***a]	'Yes!!'

Table 2: Partial Shanghainese word list

IPA	*Gloss*	*IPA*	*Gloss*
[**b**aˬ]	'row of things'	[**ʥ**iaˬ]	'Jia' (surname)
[**p**a˩]	'stupid person'	[**ʨ**ia˩]	'good'
[**pʰ**a˩]	'to crouch'	[**ʨʰ**iaˊ]	'not straight'
[**d**aˬ]	'to wash'	[**g**aˬ]	'to cut'
[**t**aˊ]	'to take, bring'	[**k**a˩]	'family'
[**tʰ**a˩]	'Thailand'	[**kʰ**aˊ]	'card'

Table 3: Partial Spanish word list

IPA	*Gloss*	*IPA*	*Gloss*
[**b**aˈlon]	'ball'	[ˈ**g**ato]	'cat'
[ˈ**p**apa]	'potato'	[**k**anˈtar]	'to sing'
[ˈ**d**aɲo]	'damage'	[**dj**a] ~ [**ʤ**a]	'already'
[ˈ**t**apas]	'lids, covers'	[**ʧ**arˈlar]	'to chat'
[ˈ**s**anto]	'saint'		

Table 4: Partial Sindhi word list

IPA	*Gloss*	*IPA*	*Gloss*
[**b**abu]	'gentleman'	[**g**ano]	'song'
[**bʱ**alo]	'good'	[**gʱ**oɽo]	'horse'
[**p**anːu]	'leaf'	[**k**ano]	'straw (in a field)'
[**pʰ**alʊ]	'fruit'	[**kʰ**aɽə]	'salty water'
[**d**arũŋ]	'gunpowder'	[**ʤ**aro]	'niche, sill'
[**dʱ**arə]	'separate'	[**ʤʱ**anʤʱar]	'percussive instr.'
[**t**aɗo]	'mat'	[**ʧ**aɽə]	'four'
[**tʰ**alʱi]	'plate'	[**ʧʰ**ati]	'chest, breast'
[**s**ubʱu]	'morning'	[**z**amĩn]	'earth, soil'
[**ɗ**akʰɛ̃ɳə]	'south'		

2.1.2 Stimuli

Speakers were recorded saying their respective word lists in a sound-proof booth at the University of California, Berkeley, using a Marantz PMD670 solid state recorder and an AKG C420 condenser microphone. Three tokens of each word in isolation were recorded as mono sound files at a sampling rate of 44.1 kHz and a bit rate of 16 bps. Once the words were recorded, individual syllables were extracted from the multisyllabic words in Praat 4.2.17 (Boersma and Weenink 2004). The duration of these excised syllables as well as the monosyllabic words was normalized to 0.5 seconds. A perceptual test was then constructed mixing 120 originally word-initial and originally non-word-initial syllables from all four languages.[2]

2.1.3 Subjects

The five subjects who recorded the stimuli were all students in their 20s or 30s with no articulatory or auditory impairments. Speaker 1 (L1 = Korean) was a male born in Seoul, Korea and raised in the U.S.; Speaker 2 (L1 = Korean, L2 = Spanish) was a female born in the U.S. and raised in Santiago, Chile; Speaker 3 (L1 = Siraeki, L2 = Sindhi) was a male from Sindh, Pakistan; Speaker 4 (L1 = Spanish) was a male from Granada, Spain; and Speaker 5 (L1 = Shanghainese, L2 = Mandarin) was a female from Shanghai, China.

The 12 subjects who listened to the stimuli were native speakers of Korean who reported no cognitive or auditory impairments. They ranged in age from 18 to 64 and were all familiar with the standard *hangeul* orthography.

[2] Due to the regular intervocalic spirantization of voiced stops in Spanish, only word-initial Spanish syllables were used. In the case of Shanghainese, the isolating nature of the language made it difficult to find common non-word-initial syllables, so only word-initial syllables were collected.

2.1.4 Procedure

Subjects who participated in the perception experiment were told that they would be taking a test in which they would write down in *hangeul* a series of Korean syllables that had been modified in one or more ways in a speech synthesis program. The test lasted approximately 15 minutes, and all subjects listened to the 120 syllables in a random order on a laptop computer over headphones with an inter-stimulus interval of approximately 4.5 seconds. As they heard each syllable only once and were not allowed a break during the experiment, subjects were instructed to write down only their first impression of the syllable and not to worry about transcribing coda consonants (even if a syllable sounded like it was closed).

2.2 Results

In the response matrices below, the labels running vertically correspond to stimuli, while those running horizontally correspond to subjects' identification judgments. All data are presented in terms of the percentage of total responses to a particular stimulus, and the most common response to each stimulus is boxed off in bold.

Figure 1: Response matrix with originally word-initial stimuli from Korean

		…sounds like Korean:													
		p	pʰ	p*	t	tʰ	t*	ʧ	ʧʰ	ʧ*	k	kʰ	k*	sʰ	s*
Korean stimulus…	p	**58**	22	19											
	pʰ		**100**												
	p*		8	**92**											
	t				**58**	42									
	tʰ				4	**96**									
	t*			8	8		**83**								
	ʧ							**100**							
	ʧʰ					3		14	**83**						
	ʧ*							17		**83**					
	k										**61**	28	11		
	kʰ										8	**92**			
	k*										4	4	**92**		
	sʰ													**100**	
	s*													33	**67**

As seen in Fig. 1 above, subjects are very good at identifying Korean word-initial consonants correctly. The most misidentifications are of lenis plosives as aspirated plosives, which may be attributed to the overlap in aspiration between these two series (cf. M. Kim 2004): both are aspirated, although the aspirated series tends to be more heavily aspirated than the lenis series. On the whole, however, perception is generally quite accurate, a fact that is represented visually by the perfect diagonal of most common responses in Fig. 1.

Figure 2: Response matrix with originally intervocalic stimuli from Korean[3]

		…sounds like Korean:													
		p	pʰ	p*	t	tʰ	t*	ʧ	ʧʰ	ʧ*	k	kʰ	k*	sʰ	s*
Korean stimulus…	b	17		83											
	pʰ	33	63			4									
	p*	21		75			4								
	d	2			17	2	79								
	tʰ		13		58	29									
	t*				17		83								
	ʤ							37		62					
	ʧʰ							46	54						
	ʧ*									100					
	g			8							50		25		
	kʰ										67	33			
	k*						8				11	3	78		
	sʰ								4					92	4
	s*													4	96

In the perception of originally intervocalic consonants that have been moved to initial position, there is much more divergence from this diagonal. This divergence shows some clear patterns. First, intervocalic lenis obstruents (which are allophonically voiced) are generally perceived as fortis. This is not so in the case of the velar, but even here a large percentage of responses identify the stop as fortis. Second, intervocalic aspirated plosives and the aspirated affricate are not perceived with nearly the same amount of veridicality seen in Fig. 1. For the alveolar and velar, the majority of responses are in favor of lenis, and there are large numbers of responses in this direction for the bilabial and the post-alveolar affricate as well.

[3] Other responses to [g] stimulus: [l] = 8%, [ʔ] = 8%.

These perceptual patterns may again be understood in terms of aspiration. When intervocalic lenis obstruents become voiced, they lose the aspiration they have word-initially. Thus, when originally intervocalic lenis obstruents are made to be word-initial, a critical cue to their identity in word-initial position – namely, aspiration – is missing, and they are consequently identified as fortis. This sort of aspiration reduction may also underlie the perceptual confusion of aspirated and lenis obstruents seen in Fig. 2. While aspirated obstruents are not voiced intervocalically like lenis consonants, they are indeed significantly less aspirated intervocalically than word-initially. It follows that this relatively shortened aspiration may be perceived as closer to the lighter aspiration of the lenis obstruents than the heavier aspiration of the aspirated obstruents (cf. §3.2).

Figure 3: Response matrix with Sindhi stimuli[4]

		…sounds like Korean:													
		p	pʰ	p*	t	tʰ	t*	ʧ	ʧʰ	ʧ*	k	kʰ	k*	sʰ	s*
Sindhi stimulus…	p	2	3	95											
	pʰ		100												
	b	79		21											
	bʱ	67	17	8							6				
	t				12	4	79								
	tʰ					92						8			
	d	33		12	37		17								
	dʱ	2			75	4									
	ʧ							29	25	46					
	ʧʰ							6	94						
	ʤ							92		6					
	ʤʱ							65	6						
	k			3							17		78		
	kʰ											100			
	g										75		25		
	gʱ										83	8	8		
	z				8		8	75		8					
	ɗ	4		4	12		46								

[4] Other responses to [bʱ] stimulus: [ʔ] = 2%. Other responses to [t] stimulus: [ʔ] = 4%. Other responses to [dʱ] stimulus: [n] = 4%, [l] = 21%, [ʔ] = 4%. Other responses to [ʤ] stimulus: [j] = 3%. Other responses to [ʤʱ] stimulus: [ç] = 15%, [j] = 15%. Other responses to [k] stimulus: [ʔ] = 3%. Other responses to [ɗ] stimulus: [n] = 12%, [l] = 8%, [ʔ] = 12%.

Subjects' perception of Sindhi consonants is very consistent, as seen in the similar pattern of bolded cells at each place of articulation in Fig. 3 above. First, voiceless aspirated obstruents are generally perceived as aspirated, while voiceless unaspirated obstruents are generally perceived as fortis.

Second, all voiced obstruents, both aspirated and unaspirated, are perceived as lenis, the latter result standing in contrast to the perception of the allophonically voiced lenis obstruents of Korean, which, as seen in Fig. 2, are most often perceived as fortis and occasionally as lenis (with the exception of the velar, for which the pattern goes in the other direction). Fig. 3, on the other hand, shows voiced unaspirated obstruents being perceived most often as lenis, with a significant minority of fortis identifications for plosives at all places of articulation (bilabial: 21%, alveolar: 17%, velar: 25%). In short, even though in both cases subjects are hearing voiced unaspirated obstruents, the perceptual patterns in Fig. 2 and those in Fig. 3 are essentially the reverse of each other. These results are most likely attributable to differences in strength of voicing (Sindhi's voiced plosives being more robustly voiced, even slightly pre-nasalized) as well as differences in closure duration (Sindhi's phonemically voiced plosives being longer than Korean's allophonically voiced plosives). Note, however, that the general pattern for Sindhi plosives is reversed for the implosives, which are most often perceived as fortis but occasionally perceived as lenis as well.

Finally, the perception of the voiced alveolar fricative is somewhat surprising. It is not perceived as either of the voiceless fricatives, but instead as the lenis post-alveolar affricate, suggesting that listeners are sensitive to the vocal fold vibration that occurs over the duration of the segment.

Figure 4: Response matrix with Spanish stimuli[5]

		…sounds like Korean:													
		p	pʰ	p*	t	tʰ	t*	ʧ	ʧʰ	ʧ*	k	kʰ	k*	sʰ	s*
Spanish stimulus…	p	**58**		42											
	b	**92**		8											
	t	8		4	42	4	42								
	d				**100**										
	ʧ							**83**	8	8					
	ʤ							**58**							
	k										**54**		46		
	g										**92**		8		
	s													33	**67**

[5] Other responses to [ʤ] stimulus: [tʲ] = 25%, [lʲ] = 17%.

The perception of Spanish consonants shows some patterns similar to the perception of Sindhi consonants. Like Fig. 3, Fig. 4 shows voiced obstruents generally being perceived as lenis. On the other hand, the perception of voiceless plosives is split between lenis and fortis. In contrast to the perception of Sindhi voiceless plosives, Spanish voiceless plosives are perceived as fortis less than half of the time; perception instead slightly favors lenis for the bilabial and velar and heavily favors lenis for the post-alveolar affricate. The voiceless alveolar fricative, however, is perceived most often as fortis.

Figure 5: Response matrix with Shanghainese stimuli

		…sounds like Korean:													
		p	p^h	p*	t	t^h	t*	ʧ	$ʧ^h$	ʧ*	k	k^h	k*	s^h	s*
Shanghainese stimulus…	b	100													
	d	33			67										
	ʤ							83		17					

The perception of Shanghainese voiced obstruents is similar to that of Spanish and Sindhi voiced obstruents. Like Fig. 3 and Fig. 4, Fig. 5 shows that subjects generally identify voiced obstruents as lenis (even when they misidentify the place, as with the alveolars).

2.3 Summary

In general, Korean word-initial obstruents are perceived accurately, as are originally intervocalic aspirated and fortis obstruents. Originally intervocalic (and thus allophonically voiced) lenis obstruents, however, are usually perceived as fortis instead of lenis. Sindhi voiceless aspirated obstruents are perceived as aspirated; voiceless unaspirated as fortis; and both voiced aspirated and voiced unaspirated as lenis. The Sindhi voiced fricative /z/ is also perceived as lenis, but the (voiced) implosive is more often perceived as fortis. Unlike Sindhi, Spanish voiceless obstruents are perceived slightly more often as lenis, but similar to Sindhi, Spanish voiced obstruents as well as Shanghainese voiced obstruents are perceived as lenis.

3 Experiment 2: Acoustic analysis

As noted in §1, the Korean lenis, fortis, and aspirated consonants have been observed to differ from each other in a number of ways, but the two most well-documented differences have been in voice onset time (VOT) and fundamental frequency (f_0) of voice onset. To examine acoustic correlates of the perceptual patterns observed in Experiment 1, the Korean stimuli used were analyzed with respect to both VOT and f_0.

3.1 Methods

Measurements of VOT and f_0 were all taken in Praat 4.2.17. VOT was measured from the beginning of the consonant burst (or, in the case of the fricatives, the end of noise concentrated in the high-frequency range) to the onset of periodicity. Measurements of f_0 at vowel onset were taken across the first 25 ms of the vowel.

3.2 Results

Table 1 presents the results of analysis of Speaker 1's word-initial obstruents before the vowel /a/.

Table 1: Acoustic measures for Korean word-initial consonants

Consonant	VOT (ms)	f_0 (Hz)
p	61	97
pʰ	100	92
p*	26	133
t	41	91
tʰ	160	126
t*	18	117
ʧ	79	94
ʧʰ	140	113
ʧ*	55	134
k	40	96
kʰ	130	108
k*	32	122
sʰ	91	125
s*	18	133

These data are consistent with previous acoustic generalizations about Korean. First, VOT of the fortis series is significantly shorter than that of the lenis series, which in turn is significantly shorter than that of the aspirated series (lenis vs. fortis: $t(3) = 4.058$, $p < 0.05$; fortis vs. aspirated: $t(3) = -6.689$, $p < 0.01$; lenis vs. aspirated: $t(3) = -6.689$, $p < 0.01$). Second, f_0 of the lenis series is significantly lower than that of the fortis and aspirated series, though it does not differ appreciably between the latter two series (lenis vs. fortis: $t(3) = -8.991$, $p < 0.01$; fortis vs. aspirated: $t(3) = 2.151$, n.s.; lenis vs. aspirated: $t(3) = -4.318$, $p < 0.05$).

Table 2: Acoustic measures for Korean intervocalic consonants

Consonant	VOT (ms)	f_0 (Hz)
b	8	99
p^h	72	106
p*	26	94
d	14	88
t^h	58	86
t*	14	87
ʤ	43	87
ʧ^h	110	87
ʧ*	57	89
g	27	97
k^h	57	86
k*	35	105
s^h	42	89
s*	14	102

On the other hand, intervocalic obstruents differ dramatically from word-initial obstruents, as seen in Table 2 above. In intervocalic position, distinctions among the three series are greatly diminished in both VOT and f_0. VOT of the lenis series shrinks such that VOT serves only to distinguish aspirated from lenis and fortis (lenis vs. fortis: $t(3) = -2.554$, n.s.; fortis vs. aspirated: $t(3) = -6.156$, $p < 0.01$; lenis vs. aspirated: $t(3) = -5.870$, $p < 0.05$). In the case of f_0, intervocalic position erases all significant differences among lenis, fortis, and aspirated (lenis vs. fortis: $t(3) = -0.365$, n.s.; fortis vs. aspirated: $t(3) = 0.393$, n.s.; lenis vs. aspirated: $t(3) = 0.405$, n.s.).

These results are informative with regard to interpreting the perceptual patterns shown in Fig. 1 and Fig. 2 for Korean stimuli and provide likely acoustic causes underlying the change in perceptual patterns across stimulus type. First, it

seems that a reduction in VOT of the lenis series to a level similar to that of the fortis series is sufficient to create the percept of fortis, even when f_0 remains well below the typical value of word-initial fortis. As shown in Table 2, the f_0 of intervocalic lenis consonants ranges from 87-99 Hz, about 30 Hz lower than the f_0 of word-initial fortis consonants (117-134 Hz); nevertheless, the decreased range in VOT of 8-43 ms, which is closer to the VOT range of word-initial fortis (18-55 ms) than of word-initial lenis (40-79 ms), appears to be enough to steer perceptual judgments towards fortis. Second, the VOT range of intervocalic aspirated (42-110 ms), which is much lower than that of word-initial aspirated (91-160 ms), approaches the VOT of word-initial lenis (40-79 ms). It follows that intervocalic aspirated would be confusable with word-initial lenis (especially when f_0 is also lower in comparison to word-initial position, approaching the values of word-initial lenis).

4 Discussion

The findings of this study have implications both for a map of cross-linguistic perceptual similarity as well as for the analysis of Korean laryngeal contrast. First, it was observed that (i) Sindhi, Spanish, and Shanghainese voiced obstruents are perceptually similar to Korean lenis obstruents, (ii) Sindhi and Spanish voiceless unaspirated obstruents are perceptually similar to Korean fortis obstruents,[6] and (iii) Sindhi voiceless aspirated obstruents are perceptually similar to Korean aspirated obstruents.

In this way the data are consistent with an interpretation of the Korean laryngeal contrast along the lines of Kim and Duanmu (2004), who use the f_0 difference between lenis and fortis/aspirated along with other arguments to group the Korean contrast with the familiar voicing and aspiration contrasts found in other languages of the world. Korean speakers' perception of voiced unaspirated obstruents in particular indicates that they are attuned to voicing in initial position; such a fact is easily accounted for by positing that Korean contains a phonologically voiced category.

However, even though the data overall do not contradict an analysis of Korean laryngeal contrast along the lines of Kim and Duanmu (2004), they also point out the inadequacy of simply calling the lenis series "voiced", since aspiration (i.e. a VOT lag) appears to be an important cue in Korean speakers' percept of word-initial lenis. "Voiced" consonants from other languages are

[6] Chang (2006) also points out the perceptual similarity between Korean fortis consonants and other languages' voiceless unaspirated consonants. In fact, in this study it is found that Korean speakers are unable to distinguish between Korean fortis consonants and voiceless unaspirated consonants in Chinese, Spanish, and English – a result that is consistent with the arguments of Kim and Duanmu (2004).

indeed perceived as lenis most of the time, but when there is no VOT lag, voiced plosives and implosives are often perceived as fortis (cf. the minority responses to voiced Sindhi obstruents in Fig. 3 and the majority responses to allophonically voiced Korean lenis obstruents in Fig. 2). Note that this perceptual pattern arises even in the face of conflicting cues: allophonically voiced intervocalic Korean lenis obstruents are perceived as fortis even though their duration is much shorter than that typical of fortis obstruents.

Thus, these facts suggest that a VOT lag is an integral part of word-initial lenis consonants in Korean. In contrast, voiced consonants cross-linguistically are characterized precisely by the lack of such a lag (or, for that matter, a "negative lag" – vocal fold vibration prior to the release of closure). It seems, then, that in spite of the fact that Korean lenis obstruents are perceptually similar to the voiced obstruents of other languages, the Korean lenis category remains different from the prototypical voiced category.

5 Conclusion

This study reexamined the typologically unusual three-way laryngeal contrast in Korean among lenis, fortis, and aspirated voiceless obstruents in light of a recent proposal by Kim and Duanmu (2004) that the contrast is really among voiced, voiceless unaspirated, and voiceless aspirated categories. The results of a cross-linguistic perception experiment conducted with 12 native Korean speakers are generally consistent with Kim and Duanmu's analysis. The data show that Korean speakers are attuned to voicing in initial position, and while this is naturally accounted for by a Korean laryngeal system containing a phonologically voiced category, the data also suggest that an important factor in Korean speakers' perception of word-initial lenis obstruents is a feature atypical of voiced obstruents: namely, aspiration. Thus, even if the lenis series were to be analyzed as voiced, it would differ in a fundamental way from the phonetic character of other languages' voiced plosives, a finding that severely weakens the cross-linguistic thrust of Kim and Duanmu's argument.

References

Boersma, Paul, and David Weenink. 2004. Praat: Doing phonetics by computer. http://www.praat.org.

Chang, Charles B. 2006. Tense consonants in Korean revisited: A crosslinguistic perceptual study. In *CamLing 2006: Proceedings of the Fourth University of Cambridge Postgraduate Conference in Language Research*, 35-42, ed.

Charles Chang et al. Cambridge, UK: Cambridge Institute of Language Research.

Cho, Taehong, and Patricia Keating. 2001. Articulatory and acoustic studies of domain-initial strengthening in Korean. *Journal of Phonetics* 29(2):155-190.

Cho, Taehong, Sun-Ah Jun, and Peter Ladefoged. 2002. Acoustic and aerodynamic correlates of Korean stops and fricatives. *Journal of Phonetics* 30(2):193-228.

Choi, Hansook. 2002. Acoustic cues for the Korean stop contrast – dialectal variation. *ZAS Papers in Linguistics* 28:1-12.

Dart, Sarah. 1987. An aerodynamic study of Korean stop consonants: Measurements and modeling. *Journal of the Acoustical Society of America*, 81(1):138-147.

Han, Jeong-Im. 1996. The phonetics and phonology of "tense" and "plain" consonants in Korean. Ph.D. dissertation, Cornell University.

Han, M. S., and R. S. Weitzman. 1970. Acoustic features of Korean /P, T, K/, /p, t, k/, and /p^h, t^h, k^h/. *Phonetica* 22:112-128.

Han, Namhee. 1998. A comparative acoustic study of Korean by native Korean children and Korean-American children. M.A. thesis, University of California, Los Angeles.

Hardcastle, W. J. 1973. Some observations on the *tense-lax* distinction in initial stops in Korean. *Journal of Phonetics* 1:263-272.

Hirose, H., C. Y. Lee, and T. Ushijima. 1974. Laryngeal control in Korean stop production. *Journal of Phonetics* 2:145-152.

Jun, Sun-Ah. 1993. The phonetics and phonology of Korean prosody. Ph.D. dissertation, Ohio State University.

Kagaya, Ryohei. 1974. A fiberscopic and acoustic study of the Korean stops, affricates and fricatives. *Journal of Phonetics* 2:161-180.

Kim, Chin-Wu. 1970. A theory of aspiration. *Phonetica* 21:107-116.

Kim, Midam. 2004. Correlation between VOT and F0 in the perception of Korean stops and affricates. In *INTERSPEECH 2004*, 49-52.

Kim, Mi-Ryoung. 1994. Acoustic characteristics of Korean stops and perception of English stop consonants. Ph.D. dissertation, University of Wisconsin, Madison.

Kim, Mi-Ryoung, Patrice Speeter Beddor, and Julie Horrocks. 2002. The contribution of consonantal and vocalic information to the perception of Korean initial stops. *Journal of Phonetics* 30:77-100.

Kim, Mi-Ryoung, and San Duanmu. 2004. Tense and lax stops in Korean. *Journal of East Asian Linguistics* 13:59-104.

Kim, Sahyang. 2001. The interaction between prosodic domain and segmental properties: Domain initial strengthening of fricatives and post obstruent tensing rule in Korean. M.A. thesis, University of California, Los Angeles.

Kim, Sahyang. 2003. The Korean post-obstruent tensing rule: Its domain of application and status. In *Japanese/Korean Linguistics* 11, ed. P. Clancy. Stanford, CA: Center for the Study of Language and Information.

Lee, Hoyoung. 1996. *Gugeo Eumseonghag* [Korean Phonetics]. Seoul: Taehagsa.

Lee, Hyun Bok. 1999. Korean. *Handbook of the International Phonetic Association*. Cambridge: Cambridge University Press, 120-123.

Lisker, Leigh, and Arthur Abramson. 1964. A cross-language study of voicing in initial stops: Acoustical measurements. *Word* 20(3):384-422.

Park, Hansang. 1999. The phonetic nature of the phonological contrast between the lenis and fortis fricatives in Korean. In *Proceedings of the 14th International Congress of Phonetic Sciences* (ICPhS99) 1:424-427.

Park, Hansang. 2002. The time courses of F1 and F2 and a descriptor of phonation types. *Eoneohag* [Linguistic Sciences] 33:87-108.

Silva, David. 1992. The phonetics and phonology of stop lenition in Korean. Ph.D. dissertation, Cornell University.

University of California, Berkeley
Department of Linguistics
1203 Dwinelle Hall
Berkeley, CA 94720-2650

cbchang@post.harvard.edu