Phonation effect of stops on vowel F_0 in South Kyungsang Korean*

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This paper examines the interactions between phonation type of stops and the fundamental frequency (F_0) of the following vowel in a tonal dialect of Korean. Korean has three-way contrasts in voiceless stops and there is a well-documented effect of phonation type on F_0 in word-initial position. In standard Korean, the aspirated (p^h, t^h, k^h) have higher F_0 value than the fortis (p*, t*, k*), while both stops have higher value than the plain stops (p, t, k). However, the current paper shows that F_0 after the aspirated and the fortis is not significantly different from each other when a low tone is present. A total of 600 tokens by five female speakers were digitized and then analyzed for pitch tracking. The results indicate that there is an interaction between phonation type and tone, and phonation type in this dialect may be produced by a different mechanism than that of standard Korean.

1 Introduction

This paper examines interactions between phonation types of voiceless stops, tones and the fundamental frequency (F_0) of the following vowel in South Kyungsang Korean. It is well known that Korean has three-way phonemic contrasts of voiceless stops. They are distinguished by different laryngeal settings and often described as being aspirated, unaspirated lax, and unaspirated fortis (Kim 1970, Halle & Stevens 1971, Iverson 1983, Ladefoged & Maddieson 1996).

(1) Three-way contrasts in stops[1]

	Bilabial	Alveolar	Velar
Aspirated	p^hul 'grass'	t^hal 'mask'	k^hɨn 'large'
Lax	pul 'fire'	tal 'moon'	kɨn 'weight unit'
Fortis	p*ul 'horn'	t*al 'daughter'	k*ɨn 'rope'

(Ladefoged and Maddieson 1996)

* I would like to thank Bryan Gick for his patience and encouragement as well as his helpful suggestions. Many thanks to Henry Davis, Rose-Marie Déchaine, and Douglas Pulleyblank for their comments and support. Without these people, I would not have completed this work. I want to thank my colleagues at Dept. of Linguistics, UBC and the audience at NWLC 2001. This paper is a modified version of my generals paper. This research was supported in part by CKR Grant for Graduate students in 2000. All errors are mine.

[1] For unaspirated fortis stops, * will be used in this paper to differentiate them from glottalized stops.

1.1 Previous studies

1.1.1 Phonation type and F_0

The literature on Korean has shown that phonation type of consonants has an effect on adjacent vowels. For example, vowel F_0 following either an aspirated stop or a fortis stop is higher than that following a lax stop, although the difference between F_0 after the aspirated stops and the fortis stops is much smaller (Kim 1965, Han and Weitzman 1970, Kagaya 1974, Dart 1987). While these previous studies have shown that phonation type has an effect on the F_0 of the following vowel, their findings were based on the analysis of one speaker or non-homogeneous speakers, who were speaking different dialects.

The speech of five male speakers of standard Korean was studied by Silva (1998) to show the phonation effect on the F_0 of the following vowel. He looked at F_0 after bilabial stops in three prosodic positions, phrase-initial, word-initial, and word-internal (intervocalic/ postnasal) and showed that the aspirated stops have a higher F_0 value than the fortis stops in three prosodic positions, while both of them have higher F_0 than the lax stops. The relative F_0 values of phonation type are summarized in (2):

(2) Phonation effect on vowel F_0 in standard Korean (Silva 1998)

	Lax	Aspirated	Fortis
High F_0		√	
Mid F_0			√
Low F_0	√		

1.1.2 Phonation type and tone

There is only one study available on the interaction between phonation type and tone in Korean. Oh (1999) firstly examined lexical tones in South Kyungsang Korean (henceforth SK) by eliciting 350 nouns from three native speakers of SK (two female and one male) and found that the fortis stops occur highly with a High tone in this dialect.[2] The results of the tonal pattern regarding phonation type of stops indicates that the fortis stops are strongly correlated with a High tone, the aspirated stops with a Mid or Low tone, and the lax stops with a Low tone, as in (3).[3]

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[2] The phonemic inventory of consonants in SK is the same as in standard Korean, but the vowel inventory is rather simplified: Mid front vowels /e/ and /ɛ/ in standard Korean are merged to /e/, a low back vowel /a/ is centered, and a high back vowel /ɨ/ is fronted as /ə/.

	Front	Mid	Back
High	i		u
Mid	e	ɨ	o
Low		a	

[3] Kyungsang dialects are spoken in the southeast region of Korea. They are distinguished as northern and

(3) Distribution of lexical tones by phonation type of stops in SK (Oh 1999)[4]

	Lax	Aspirated	Fortis
High tone	26.2%	23.2%	**59.3%**
Mid tone	21.5%	**39.4%**	30.5%
Low tone	**52.2%**	**37.9%**	10.2%

The fortis and lax stops have one predominant tone that occurs more that 50%: 59.3% of the words begin with fortis stops are High-tone words, and 52.2% of the lax stops are Low-tone words. However, no tone is predominant for the aspirated stops: about 40% of the aspirated stops are with a Mid tone, followed by 37.9% of Low-tone words. The predominant tone per phonation type is summarized as in (4):

(4) Predominant tone by phonation type of stops

	Lax	Aspirated	Fortis
High tone			√
Mid tone		√	
Low tone	√	(√)	

1.2 Questions

It has been argued that there is a universal correspondence between phonation type and pitch (F_0). In section 1.1, we have seen that in standard Korean, the aspirated stops induce higher vowel F_0 than the fortis stops, whereas the F_0 value of the lax stops is lower than both stops. On the other hand, in SK we have seen that the fortis stops are highly associated with a High tone, while the aspirated stops are likely to occur with either a Mid or Low tone. The lax stops occur mostly with a Low tone in SK. Assuming a High tone induces higher F_0 than a Mid or Low tone, the tonal pattern in SK (see (4)) does not pattern with the F_0 value by phonation type (see (2)) in standard Korean. Between standard Korean and SK, only the lax stops are consistent in terms of pitch: they

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southern dialects by different tones and/or vowel length. South Kyungsang has three lexical tones (High, Mid, and Low), whereas North Kyungsang has two lexical tones (High and Low) and a vowel length distinction. While most eastern dialects have tones, vowel length is distinctive in western dialects of Korea. Only South Kyungsang is examined in this paper.

	Standard Korean	**South Kyungsang**	North Kyungsang
mal 'horse'	Short	**H**	H
mal 'measure unit'	Short	**M**	L short
mal 'language, word'	long	**L**	L long

Korean lexical tones are different from the tones of Chinese, where tones represent a pitch contour of each monosyllable. The pattern of Korean tones can spread over and be realized in polysyllables.

[4] Oh (1999a) also looked at words in alphabetic order from randomly chosen pages in a dictionary, and found the similar distribution of tones. Vowel quality did not play much role in the tonal pattern.

have a low F_0 value, as in (2) and occur mostly with a Low tone, as in (4). The mismatch between F_0 and the tonal pattern of the fortis and aspirated stops will be focused in the current paper.

1.3 Hypothesis

Given the correlation between phonation type and lexical tones, we first ask whether the tonal pattern in (4) is a result of a corresponding phonetic effect on F_0. The phonation effect of stops on F_0 in SK will be tested to see if phonation type of stops has the same effect on vowel F_0 as is standard Korean. If the result patterns with the findings in standard Korean, then the effect of phonation type of stops is consistent regardless of the presence of a tone. In that case, there is no interaction between phonation type and tone, and we need another explanation for the tonal pattern. On the other hand, if the results are different from standard Korean, then SK stops must be produced by a different mechanism and have different effects on vowel F_0, and it may have affected the tonal pattern.

2 Experiment

An experiment was conducted in order to test the hypothesis that phonation type of stops has the same effect on vowel regardless of the existence of a lexical tone. To minimize the differences between these two dialects, this experiment followed the methods used for standard Korean in Silva (1998), if possible. The F_0 values after stops in SK were compared with those of standard Korean shown in Silva (1998).[5]

2.1 Participants

Five female native speakers of SK participated in the experiment: they are graduate students of the University of British Columbia (UBC) or family members either of students or visiting scholars from Korea, staying at UBC. Four speakers were at between 35 and 40 and one speaker was at 64. All speakers have lived in their hometowns for at least 20 years. In order to make sure that all speakers use a dialect with the same tones, only for those who had passed a pre-test were selected as participants. Two out of initial seven speakers were excluded from the study as they did not pass the pre-test.[6]

2.2 Materials

An Aiwa portable tape recorder with an Aiwa microphone was used to record the stimuli at a standard tape speed. The recordings were played on a Teac cassette tape recorder and then were digitized using PCQuirer and MacQuirer signal analysis software

[5] Silva examined bilabial stops, but the current study examined stops in four places of articulation (bilabial, alveolar, post-alveolar, velar) in the word initial position.

[6] In South Kyungsang, there are three main sub-dialects, east, north, and south due to tonal pattern. The speakers for this study were all from south dialects.

in the Interdisciplinary Speech Research Laboratory at UBC. For the statistical analysis, Statview and MS Excel were used.

2.3 Methods

Recording was done in each speaker's house. Participants were asked to read randomly mixed sentences and each target sentence was repeated 10 times. A total of 120 usable tokens per speaker was collected for the analysis (4 places x 3 phonation type x 10 tokens x 5 speakers = 600).[7] The first and last sets of sentences and the first and last sentences of each set were discarded. The data were digitized at a sampling rate of 11025 (Hz), and for each token waveforms, spectrograms, and pitch track were created on the software. The F_0 measurements were taken at vowel onset following each stop.[8] The F_0 values were calculated by means of an automated pitch-tracking algorithm, using a frame size of 5/1000 second.

2.4 Stimuli

Tone was controlled to L tone and verbal minimal pairs of each stop series with were used as the stimuli.[9] The target segment was each stop followed by a low vowel /a/ in word-initial position in a form of a carrier sentence, as in (5). In SK, the interrogative ending suffix *–na* is used instead of *–ni* in standard Korean, and with – *na* suffix, it is mandatory to use tone even though it is given in a written text. Thus, interrogative was used in order to produce tones that are more natural.[10] The stimuli is listed in Appendix.

(5) *Chelswu-ka* _____ *kko ha-ass-na?*
Chelswu-NOM _____ that say (do)-Past-Q
'Did Chelswu say that (he) is/feels _____?'

3 Results

ANOVA of the pooled data showed that there were no significant between-speaker effects for the F_0 values ($p = 1.00$) but that within-speaker effects were very significant, $F(2, 117) = 65.446$, $p = .0001$.[11] This indicates that the phonation effect on the vowel F_0 is consistent across all five speakers, and hence it is possible to observe within-speaker effects.

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[7] 1040 tokens were collected from five speakers.

[8] Vowel transition (e.g. 10% into the vowel, 50% of the vowel) was not measured this time but it will be considered in future research.

[9] Both Silva (1999) and Oh (1999) used noun categories for their research. However, it was hard to find noun minimal pairs of three phonation types with a L tone, hence verbal minimal pairs were used instead.

[10] Generally speaking, the declarative ending *–ta* is only used in a written form and many different mood ending suffixes are used instead in colloquial form. Moreover, standard Korean is used for a written text, and people are taught to use standard Korean when they read a text. Thus, when a sentence is declarative, tone cannot be observed although some speakers still have a sentential pitch. All subjects mentioned that the tone is not required when they read.

[11] In statistics, P-value indicates the results of tests of significance. The difference between two items is significant only if the P-value is less than .05 ($p \leq .05$).). Speaker 2,3,4,5, $p < .0001$; Speaker1, $p = .0006$.

Table 1 Mean values of F_0 after each phonation type of stops
(^{n}= 40, Numbers in italics = standard deviation)

	F (2, 117)		Mean		
	F	p	Lax^n	Aspirated^n	Fortis^n
Speaker 1	7.999	.0006	196.1	205.0	203.5
			8.78	*5.81*	*4.47*
Speaker 2	51.523	< .0001	167.2	202.0	205.4
			6.37	*8.54*	*12.5*
Speaker 3	91.140	< .0001	168.7	207.9	193.5
			11.13	*7.62*	*8.25*
Speaker 4	68.535	< .0001	170.7	190.6	184.7
			7.97	*2.59*	*9.74*
Speaker 5	107.924	< .0001	182.9	210.6	205.6
			4.12	*5.98*	*7.44*
Average (pooled)	65.446	0.0001	180.97	203.74	199.65
			10.34	*6.38*	*7.94*

3.1 Overall results

The aspirated and fortis stops consistently had higher F_0 values than the lax stops in the speech of all speakers. However, interaction between the phonation type and F_0 did not clearly reflect the tonal pattern that we have seen in (3-4). That is, the fortis stops did not predominantly enhance a higher F_0 value than the aspirated stops. Nevertheless, the F_0 values of these stops did not reflect the pattern in standard Korean (see (2)) either, where the aspirated stops have higher F_0 values than those of the fortis. As in Table 1, the F_0 values of these two stops are not different much, and F_0 after the fortis stops is almost as high as that of the aspirated stops. An ANOVA ad hoc test showed that the difference between the aspirated and fortis stops was not significant ($p = .4561$), whereas the differences between these stops and the lax stops were significant at $p = .001$ and $p = .0042$.

Table 2 Fisher's PLSD for significance of phonation effect on F_0

Between	P-Value
Lax, Aspirated	.0010***
Lax, Fortis	.0042**
Aspirated, Fortis	.4561

(** p < .01, *** p < .001)

The mean F_0 values following each phonation type is shown in Figure 1.

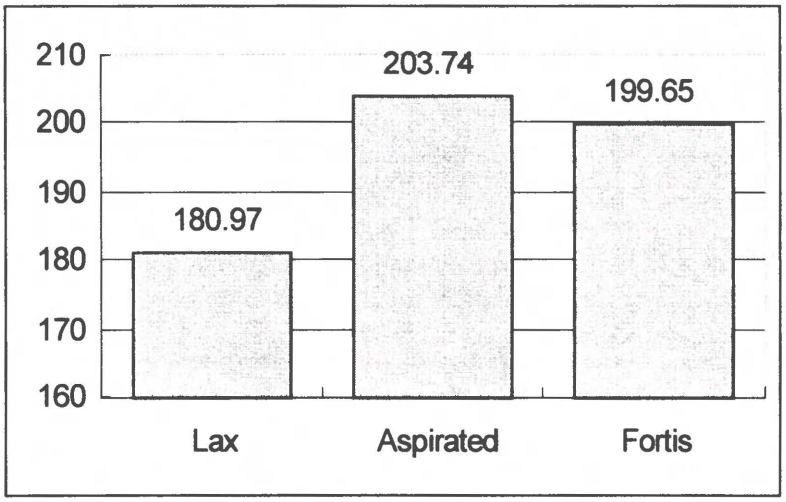

Figure 1. Mean F_0 values after each stop in all speakers

3.2 Individual results

The results from each speaker were consistent with the pattern shown in Figure 1 except for one speaker: the speech of four speakers showed that there was no significant difference in F_0 values between the aspirated and fortis stops. One the other hand, the F_0 values in the speech of one speaker (speaker 3) were similar to those in standard Korean rather than the rest of the speakers': the F_0 after the aspirated stops was higher than that of the fortis stops, followed by the lax stops, and the difference between each stop was statistically significant.

Table 3 Fisher's PLSD for significance of phonation effect on F_0 for speakers

Phonation effect	*P Value*				
between	Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
Lax, Aspirated	.0056**	< .0001****	< .0001****	< .0001****	< .0001****
Lax, Fortis	.0186*	< .0001****	< .0001****	.0002***	< .0001****
Aspirated, Fortis	.6159	.4299	.0015	.0867	.0736

(*p < .05, **p < .01, ***p < .001, ****p < .0001)

Speaker 1 had a relatively higher pitched voice than other female participants, and the F_0 after the lax stops was almost as high as the aspirated or fortis stops in other subjects' speech. The difference between the aspirated and fortis stops was not significant ($p = .6159$), whereas P-values between the aspirate and lax stops ($p = .0056$) and between the fortis and lax stops ($p = .0186$) were all significant.

The F_0 value after the fortis stops in the speech of Speaker 2 were higher than that of the aspirated stops, yet the difference was not significant ($p = .4299$). The P-values between the aspirated and lax stops and between the fortis and lax stops were highly significant at $p < .0001$. The results for Speaker 2 are summarized in Figure 2:

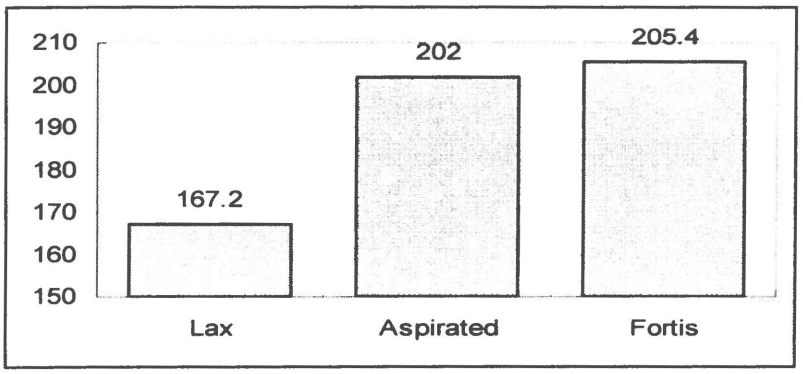

Figure 2. Mean F_0 values in Speaker 2

On the other hand, the speech of Speaker 3 showed that F_0 after each phonation type f stops was significantly different from each other, similar to that of standard Korean. P-value between the aspirated and the lax as well as P-value between the fortis and the lax were highly significant at $p < .0001$, as in speaker 2, but the difference between the aspirated and the fortis was very significant at in the speech of Speaker 3 ($p = .0015$).

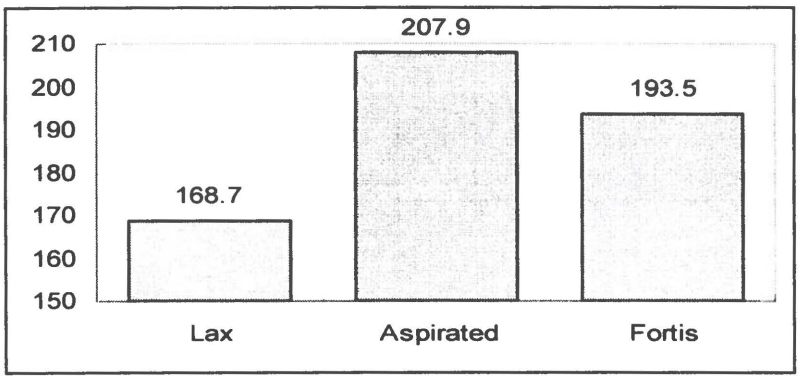

Figure 3. Mean F_0 values in Speaker 3

Lastly, the speech of Speaker 4 and 5 patterned similarly with that of Speaker 1 and 2: there was no significant difference between the aspirated and the fortis (Speaker 4, $p=.0867$; Speaker 5, $p = .0736$), whereas the differences between these stops and the lax stops were highly significant at $p < .0001$.

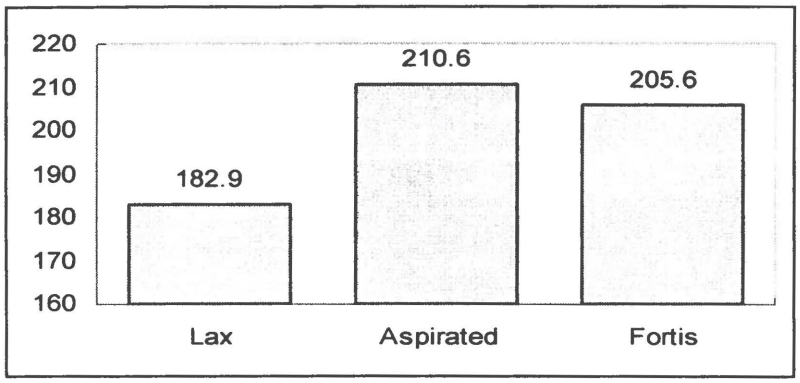

Figure 4. Mean F_0 values in Speaker 5

To sum, we have seen the phonation effect on vowel F_0 in SK and observed that F_0 following the fortis can be as high as that of the aspirated stops, at least in the speech of four speakers. In other word, the phonation effect of the fortis is not much different from that of the aspirated stops.

4 Discussions

As presented in the previous section, F_0 after the aspirated stops is not higher than the fortis stops in SK: there was no significant difference between the aspirated and the fortis for four speakers, while the difference between the lax stops and the aspirated and/or the fortis was significant. However, it contrasts with the standard Korean data (Silva 1998), where all three phonation types of stops are significantly different from each other: the F_0 values after the lax stop are the lowest, the fortis stops with mid-range values, and the aspirated stops with the highest values. If phonation type of stops were produced by the same mechanism in SK as well as in standard Korean, the phonation effect on F_0 would be identical in both dialects, and the aspirated stops would induce higher F_0 than the fortis. However, the findings in the current paper do not coincide with the prediction above. Thus, it implies that there are variables that affect the phonation effect of stops in SK and phonation type of stops should be distinguished by another cue.

In addition, it is not clear which phonation type behaves differently. It has been claimed that lax stops are associated with relatively lower F_0 values and aspirated and fortis stops are with relatively higher F_0 values, where F_0 values of the latter two are much smaller (Kim 1965, Han and Weitzman 1967). Thus, the results in SK could be one of the two possibilities: it is the fortis stops that have a higher F_0 effect than in standard Korean; or the aspirated stops have a lower F_0 effect than in standard Korean. Note that the phonation effect of lax stops is consistent in both dialects, with a lower F_0 value, but the phonation effects of the other two have opposite results in each dialect. This implies that the phonation effects of either aspirated or fortis stops can be affected by other factors and may have more than one directional effect. In the following sections, conflicting phonation effects found in other languages will be discussed.

4.1 Conflicting F_0 effect

Some conflicting results with regard to the effect of stops on F_0 of the following vowel have been brought in the literature. For instance, Zee (1980) cited a couple of research on this regard in the following languages: It has been reported that, in Thai, a vowel following the aspirated stops can have a higher F_0 value (Erickson 1975, Ewan 1976) or have a lower F_0 value than following an unaspirated stop (Erickson 1975, Gandour 1974). In addition, the vowel F_0 following the aspirated stops of a Hindi speaker was also slightly lower than the unaspirated counterparts (Kagaya and Hirose 1977, cited Zee 1980). These results suggest that the F_0 effect of the aspirated stops on the following vowel can be either higher or lower than their counterparts due to various factors even in a single language.

In addition, the different F0 effects of the ejectives in two languages have been observed by Kingston (1982, cited 1985). In the speech of one speaker of Tigrinya (Semitic and Quiché (Mayan) showed that F0 of the following vowel was higher in

Tigrinya, whereas it was lower in Quiché.

Even in Korean, the speech of one speaker in standard Korean had a higher F_0 value after the fortis stops than the aspirated stops, contrast to the results from four other speakers, where the aspirated stops have a higher F_0 value than the fortis (Silva 1998). On the other hand, the speech of one speaker in SK had a higher value after the aspirated, while other four speakers had opposite results as we have seen in section 3. Thus, the results found in this study also provide evidence that more than one-way phonation effect of stops is possible.

4.2 Tonogenesis

In SK, the fortis stops are highly associated with H tone and the aspirated stops with M and L tones (see section 1.1.2). If this tonal pattern is the result of the corresponding phonetic effects on F_0, then stops in this dialect must be produced by a different mechanism than that of standard Korean. It has been known that lexical tones in dialects are originated from the 15 C. Middle Korean tone (Martin 1992).

Table 4 Tonogenesis in Korean

	Middle K	St.Korean	**SK**	Hamkyung
mal 'horse'	L	Short	**H**	L
mal 'measure unit'	H	Short	**M**	H
mal 'word'	R(LH)	long	**L**	H/R

Middle Korean had three tones, H, R (rising) and default tones. These tones are realized in vowel length in standard Korean, where R tone becomes long.[12] While Hamkyung dialect, which is spoken in the far north regions in North Korea, still preserve the Middle Korean tones, tones in Kyungsang dialects cognate with those of Middle Korean in absolutely opposite way.

There are two supporting evidences from other languages. First, in Athapaskan languages, tone has evolved from a postvocalic glottal consonant. Languages like Chipewayan and Hare have H tone, while Kutchin, Navajo, and Sarcee have L tone from the same source or no tone in Hupa and Ahtna (Krauss 1979, cited Kingston 1985). Glottal consonants may have rise to just one tone originally, either H or L, and then reversed in some languages later. Another possibility is that a glottal consonant was articulated differently to elevate F_0 in some dialects and it lowered the F_0 of a preceding vowel in other dialects: a H tone would evolve in the former and L tone in the latter.

Second, laryngeal features of consonants determine tonal splits in Southeast Asian languages (Sinitic, Tibeto-Burman, Kam-Sui, Tai, Miao-Yao, Viet-Muong), and they are induced by syllable initial consonants (Kingston and Solnit 1989). In some languages, tensed consonants have H tone, whereas aspirated consonants have H tone in other languages.

So far, we have seen that phonation effect of consonants on F_0 may not be

[12] Many younger generation can no longer identify words by vowel length.

consistent among dialects, and the aspirated or fortis stops can either elevate or depress F_0 values. However, it is not clear which phonation type of stops in SK triggers the conflicting F_0 effect. The interaction between tone and phonation type of stops in SK needs further research.

5 Conclusion

This paper has examined the phonation effect on vowel F_0 after stops in a tonal dialect (SK) of Korean and showed that the phonation effects of the aspirated and the fortis stops are not significantly different in this dialect as opposed to standard Korean. The speech of four out of five speakers has indicated that three-way contrasts in stops may not be accounted for by the F_0 value of the following vowel. The high tendency of the fortis stops with a H tone has also indicated that there is a possibility that the fortis stops in SK are produced using different mechanisms. Conflicting results regarding the F_0 effect of stops are evident in other languages, and hence there should be at least one more cue other than F_0 necessary to distinguish three-way contrast in phonation type of stops in Korean.

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Appendix: Stimuli

Chelswu-ka _____ *hatak*o hass-na?* 'Did Chelswu say _____?'

1.	**panpan**	'good looking'
	p^{h}anp^{h}an	'flat'
	p*anp*an	'impudent'
2.	**tantan**	'solid, steady'
	t^{h}ant^{h}an	'stable'
	t*ant*an	'hard'
3.	**cancan**	'calm'
	c^{h}anc^{h}an	'patient'
	c*anc*an	'miser'
4.	**kamkam**	'uncertain'
	k^{h}amk^{h}am	'dark'
	k*amk*am	'black out'

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