

## The domains of laryngeal feature lenition effects in Chonnam Korean

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### Abstract

This paper investigates the domain of two aspects of laryngeal features (voicing and voicing onset time) in the Chonnam dialect of Korean. In Korean, voiceless lenis stops, /p, t, k/, sometimes become voiced between voiced segments. Traditionally, this voicing has been discussed as occurring "within a word". Recently, Cho (1989) suggested that lenis stop voicing happens within a phonological phrase. To test this, utterances of various constructions (mostly from Cho 1989) were produced by three Chonnam speakers at three different tempi (slow, normal, fast) with three repetitions. An electroglottograph (EGG) was recorded simultaneously with an audio wave. The results show that word initial lenis stops were almost always voiced within the "accentual phrase" but not within the Phonological Phrase. A second experiment was run for the other laryngeal feature, VOT, to see whether the domain is an accentual phrase as in the case of lenis stop voicing or something else. One, two, or three-syllable words, where a test syllable [p<sup>h</sup>a] was either at a word initial or medial position and phrase initial or medial position, were put in the frame sentence. Sixty four sentences were read with two different accentual phrasings. The result shows that VOT durations of [p<sup>h</sup>] are significantly different between word initial and medial as well as accentual phrase initial and medial. This suggests that there is a hierarchy of prosodic level in Chonnam Korean: a prosodic word and an accentual phrase.

### Introduction

Phonetic studies show that the pronunciation of segments depends on word and phrase level prosody (e.g., Lehiste, 1960). Many of these effects can be subsumed under the notion "lenition". For example, Pierrehumbert and Talkin (1989) found that the 'gestural magnitude' of /h/ is less in 'weak' positions, word medially or in deaccented words; (overall amplitude is smaller, energy is more concentrated in the first harmonic).

Keating et al. (1983) survey phonetic studies to show that many languages have different allophones of voiced or voiceless stops depending on position within a word or a phrase and on degree of stress. A cross linguistic tendency seen in these phonetic studies is that voicing-related phonetic features, such as the glottal opening gestures for voicelessness or aspiration, become lenited or weakened depending on position at some prosodic level.

Thus, in languages with voiceless stops only, voiceless unaspirated stops tend to be voiced word medially (e.g., Mandarin, Choctaw, Cuna, Korean, Tamil, cited in Keating et al.). In addition, in languages whose initial stop contrasts involve short lag with long lag VOT values, there is a common pattern of medial

deaspiration of initial voiceless aspirated stops (e.g., Lisker & Abramson 1964 for English). A question that arises in looking at these studies is what is the domain of the lenition effects. Clearly it is not always the word. Word-initial voiceless stops in Burmese becomes voiced in phrases, especially after a "weakened" (toneless and reduced) syllable. In Polish, word final stops become voiced before a vowel-initiated word (Keating et al., 1983). That is, the domain of the lenition effects can be larger than a word.

This paper investigates the domain of two phonetic aspects of laryngeal features (voicing during closure and VOT after release) in the Chonnam dialect of Korean. Korean has no voicing contrast for obstruents, but it has phonemically a 3-way contrast among voiceless obstruents.

Aspirated:	p <sup>h</sup>	t <sup>h</sup>	k <sup>h</sup>	tʃ <sup>h</sup>	
Fortis:	p'	t'	k'	tʃ'	s'
Lenis:	p	t	k	tʃ	s

As mentioned in Keating et al.(1983), Korean is believed to show some lenition phenomena word medially. That is, slightly aspirated voiceless stops (or lenis stops) become voiced intervocalically. Lisker and Abramson (1964), however, noticed that word-initial lenis stops are also voiced when preceded by a monosyllabic modifier which ends in a sonorant (e.g., {i} 'this' + {tal} 'a moon' => [idal] 'this moon').

Therefore, we must look to a larger unit as the domain of this effect. Recently, Cho (1989) suggested that, in the Seoul dialect of Korean, lenis stop voicing happens within a phonological phrase whose boundaries are determined by the syntactic structure of a sentence or constituent. Since Chonnam dialect is the same as Seoul in its syntactic structures (even though it differs from Seoul in its intonation patterns and by some lexical items), the domain of voicing, if we follow Cho's analysis, should be the same for both dialects. A pilot study showed, however, that the domain of voicing in the Chonnam dialect changed depending on speech rate and intonation pattern, suggesting that the domain cannot be a unit defined entirely by syntax.

In the Chonnam dialect of Korean, there is a phrase which can be defined by the tonal pattern, called "accentual phrases" by Jun (1989). An accentual phrase in Chonnam has either of two tonal patterns, Low-High-Low or High-High-Low, as determined by the laryngeal feature specification of the first segment of the phrase: if the segment is either [+constricted glottis] or [+spread glottis], the phrase has a High-High-Low accentual pattern and otherwise a Low-High-Low pattern. Figure 1 (from Jun, 1989) is an example of an utterance showing accentual phrases.

The second and the fourth accentual phrases have H-H-L accentual patterns since their phrase initial sounds are [+spread glottis] ([k<sup>h</sup>] and [s], respectively). The other accentual phrases have L-H-L patterns. (The final H-L pattern is a boundary tone(%) for the intonational phrase.)

An accentual phrase in Chonnam can contain more than one word. This can be seen later in figure 5. To determine whether the accentual phrase is the domain of lenis stop voicing, an experiment was designed in such a way that many sentences contain an accentual phrase having more than a word and, at the same time, most words begin with a lenis stop.

Since any word in a phrase did not have its own tonal pattern nor have any influence in the tonal pattern of the phrase, the lowest level of prosodic structure in Chonnam was claimed to be an accentual phrase. Therefore, the level of prosodic word was not motivated before. But it is possible that a prosodic word is a domain of other phonological features and becomes the lowest level of prosodic hierarchy.

As noticed by Lisker & Abramson (1964), cross-linguistically aspirated stops tend to be deaspirated word medially. Since Korean has voiceless aspirated stops word initially and medially, the duration of VOT after release was examined to see whether there is any similar lenition phenomenon depending on positions in a word or a phrase and, if there is, whether the domain of VOT lenition is also an accentual phrase or something else.

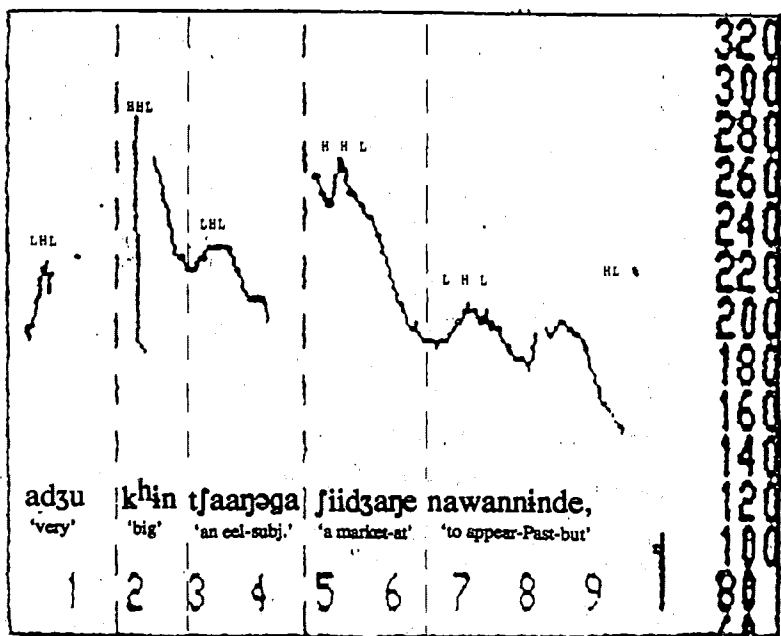


Figure 1. A pitch track of a phrase, {adzu} {k<sup>h</sup>in} {tʃaənəgə} {jiidzəŋe} {nawanninde},  
'very' 'big' 'an eel-subj.' 'a market-at' 'appeared-but'  
=> 'A very big eel came out at the market, but...'

## Experiment 1 : Lenis Voicing

### Methods

#### Subjects:

Two male speakers and one female speaker of Chonnam dialect participated. They were in their late twenties. Two of them, one male and one female, had lived

in Kwangju, the main city of Chonnam province, for 26 years and one other male had been in Kwangju for 19 years and moved to Seoul and lived there for 7 years until he came to the States. This last subject sometimes showed a mixed intonation pattern between Chonnam and Seoul intonation. Thus, to elicit the Chonnam intonation, about 30 minutes conversation was made between him and a native Chonnam speaker before recording, and contexts which include many lexical items typical of the Chonnam dialect were given for the test phrase or sentences. Recording was made when the intonation of his utterances was very close to that of a native Chonnam speaker's.

### Material

Thirty-four phrases or sentences with various syntactic structures were selected. Most of these were taken from Cho's (1989) corpus of examples. Most of the word initial segments were lenis obstruents to examine whether a lenis stop becomes voiced across word boundaries. Each subject was asked to read the phrases or sentences in their natural intonational phrasing. However, sometimes they were asked to read them in a specific accentual phrasing intended by the author. In this case, a corresponding meaning was given to help the appropriate accentual phrasing. Some of representative examples are as follows. (The full list of sentences or phrases is in the appendix). Word-medial lenis obstruents are spelled as a voiced one but every lenis obstruent is checked for its status of voicing. { } means an intended accentual phrasing that differs from the context-neutral "natural" phrasing.

1. abədʒi-ga paŋ-e tirəgasinda.  
'Father-subj. a room-to to enter-honorific ending'
2. abədʒi kabaŋ-e tirəgasinda.  
'Father-(subj.) a bag-to to enter-honorific ending'
3. a. {kəmin} {kojaŋi-e palmok} - 'a cat's ankle which is black'  
b. {kəmin kojaŋi-e} {palmok} - 'the ankle, not a tail, of a black cat'  
c. {kəmin} {kojaŋi-e} {palmok} - 'ambiguous'  
'black' 'a cat-Genitive' 'an ankle'
4. Kjuŋsu-ga ton paɲŋə pondʒəginnja?  
'Kyungsu-subj. money-obj. to get-Rel. to see-Rel.-experience-Question'  
=> 'Have you seen Kyungsu get or receive money?'
5. Uri sənseŋin Suni-hantʰe tʃəmsuril tʃal tʃuŋiŋət kat'ira.  
'our teacher-subj. Suni-to a score-obj. well to give-Rel. to seem.'  
=> 'It seems that our teacher gives a good score to Suni.'

### Procedure

Subjects were instructed to say each sentence or phrase in its 'natural' intonation pattern unless marked: they were asked to read a sentence as if they are talking to someone in a natural conversation. Subjects repeated each phrase three times at three self-selected rates, normal, slow, and fast, in a sound-attenuated room. Utterances were blocked by rate.

In order to ascertain more directly the intended voicing of a stop, an Electroglottograph (henceforth EGG) recording was made. For EGG, a high frequency electrical current is passed through the larynx, between electrodes placed on the neck surface on the left and the right sides. The electrical impedance (resistance) between the electrodes depends on the glottal area, being small when the vocal folds are pressed firmly against each other and large when the folds are completely separated. To get EGG data, The EGG band was held tightly around the subject's neck while he or she was reading. The audio wave and EGG signals were simultaneously tracked and digitized simultaneously. Using computer programs, the two signals were separated and viewed synchronically.

For every lenis obstruent position, the two signals were checked for sinusoidal periodicity, indicative of voicing. The voicing status of each lenis obstruent was ascertained independently from the audio and the EGG signal. Almost all of the time, the two signals agreed in voicing status: either both showed periodicity or neither did. However, there were a few cases when the two disagreed; either the audio showed voicing and the EGG did not, or (very rarely) the EGG showed voicing and the audio did not. Figure 2 shows sample traces for each type of case.

In Figure 2, (a) + (b) are taken from two utterances of the same sentence with different accentual phrasings: 1. {Kjungsu-ga} {tonil} {} {pondzəginnja}? 2. {Kjungsu-ga} {tonil badingə} {pondzəginnja}? For each picture, the upper two windows are for Audio signals and the lower two windows are for EGG signals and they are synchronized. The second and the fourth windows are expanded views beginning from the small tick points in the first (Audio wave) and the third (EGG wave) window, respectively. The horizontal dimension in each window indicates the time dimension and the vertical dimension indicates the amplitude of signal. In Figure 2(a), the verb-initial lenis stop, /p/ of {padi-ngə}, is voiceless as shown by the circles of both Audio and EGG wave forms, whereas it is voiced by both signals in Figure 2(b). Figure 2(c) is part of sentence 5 above, 'Uri sənsegin Sunihan<sup>the</sup> tʃəmsuril tʃal tʃuningət kat'ira'. The second and the fourth window show an expanded view for {tʃəmsuril}; as shown by the waveforms inside the circle, the fricative has a voiced Audio signal but a voiceless EGG signal.

For these few cases where the two signals disagreed, the EGG signal was assumed to indicate the speaker's intention, since it can give information about glottal adduction and abduction unfiltered by the vocal tract. It is already noticed in the literature that the same glottal configuration can produce voiced or voiceless sounds depending on the vocal tract function and air pressure difference. That is, when vocal folds are abducted and supraglottal air pressure is higher due to some constriction within a vocal tract, then vocal folds are not vibrating and a voiceless sound occurs. On the other hand, when there is a high subglottal air pressure and a vocal tract is open, then vocal folds can vibrate while abducted. A good example is a breathy or murmured /h/ and figure 3 shows this. The sentence is: *Youngsunin Hekjungiril tʃoahə* 'Youngsu likes Hekjung.'

In Figure 3, the second (Audio) and fourth (EGG) window show waveforms around [h]. The EGG signal shows low-amplitude vibrations for an open glottis while the Audio signal shows high-amplitude vibrations continuously through the /h/. Thus, it is the EGG signal which gives more reliable information about glottal adduction and abduction.

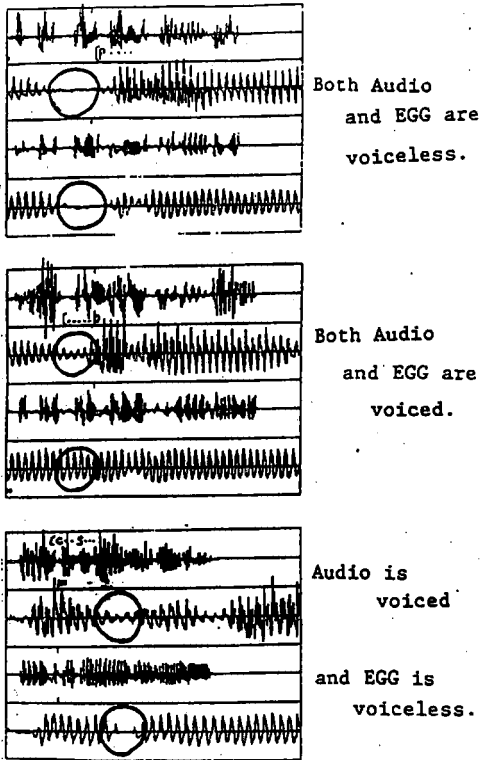


Figure 2. Audio & EGG wave forms: (a) When both are voiceless (b) When both are voiced (c) When audio is voiced and EGG is voiceless.

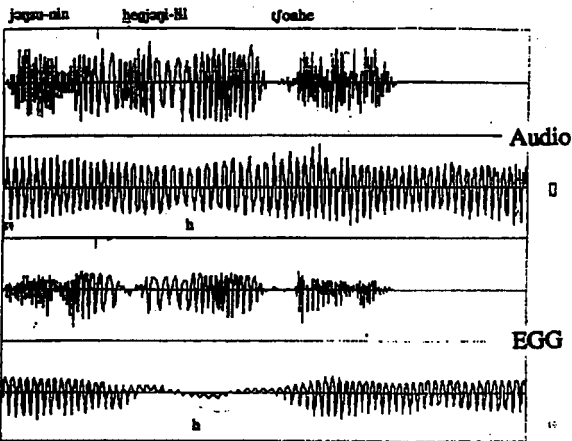


Figure 3. Audio and EGG waveforms of *yaŋsunin heŋjəŋŋi tʃo:he*. The second and fourth window shows waveforms around underlined part of the sentence.

## Results and Discussion

Both EGG and Audio wave form data showed that lenis obstruents in word initial position between voiced segments become voiced almost all the time in accentual phrase medial position but not at accentual phrase initial position. Figure 4 and 5 illustrate these contrasting positions.

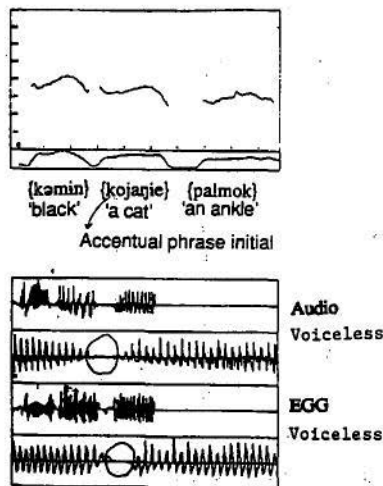


Figure 4. Pitch tracks of *kəmin kojaɲie palmok* "a black cat's ankle" uttered in three accentual phrases. Audio & EGG waveforms show a voiceless /k/ of *koyaɲie* at an accentual phrase initial position.

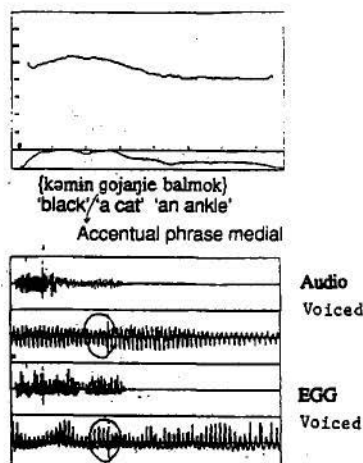


Figure 5. Pitch tracks of *kəmin kojaɲie palmok* "a black cat's ankle" uttered in one accentual phrase. Audio & EGG waveforms show a voiced /k/ of *koyaɲie* at an accentual phrase medial position.

They show pitch tracks and Audio/EGG waveforms for 'kəmin koyaɲie-palmok' example phrase 3 above in the material section. Figure 4 shows an utterance in which the phrase is broken into three accentual phrases, {kəmin} {koyaɲie} {palmok}, while Figure 5 shows an utterance where the whole phrase forms one accentual phrase, {kəmin gojaɲie balmok}. When the lenis stop, /k/ of /koyaɲie/ "a cat" is in accentual phrase initial position in figure 4, it is voiceless in both waveform signals, but as an accentual medial /k/ in figure 5, it is voiced.

For cases where there was a discrepancy between signals, the EGG showed what was expected from the position in terms of accentual phrasing. The following two tables show the frequencies of occurrence of lenis obstruent voicing for each speaker for three speech rates: Table I is that of word-initial & accentual phrase-medial position and Table II is that of word-initial & accentual phrase-initial position. A total of 195 tokens (three repetitions of 65 word) were examined for each signal. Due to some missing tokens for each speaker, the sum of totals in

tables I & II are not exactly 195. Ambiguous cases are where the signal shows so weak vibration that the decision of voicing was difficult.

**Table I: Frequency of voicing (word-initial and accentual phrase-medial)**

Speaker	Rate	signal	Clearly voiced	Clearly voiceless	Ambig- uous	total
1	fast	Audio	63	0	3	66
		EGG	62	0	4	66
	normal	Audio	33	0	11	44
		EGG	36	0	8	44
	slow	Audio	18	0	1	19
		EGG	18	0	1	19
2	fast	Audio	77	3	6	86
		EGG	77	1	8	86
	normal	Audio	45	1	3	49
		EGG	45	1	3	49
	slow	Audio	9	1	0	10
		EGG	8	1	1	10
3	fast	Audio	24	1	6	31
		EGG	24	1	6	31
	normal	Audio	11	0	2	13
		EGG	11	0	2	13
	slow	Audio	12	1	0	13
		EGG	12	0	1	13

**Table II: Frequency of voicing (word-initial & accentual phrase-initial)**

Speaker	Rate	signal	Clearly voiced	Clearly voiceless	Ambig- uous	total
1	fast	Audio	7	97	5	109
		EGG	8	94	11	113
	normal	Audio	1	124	6	131
		EGG	1	125	11	137
	slow	Audio	0	170	4	174
		EGG	0	173	1	174
2	fast	Audio	4	82	21	107
		EGG	4	96	7	107
	normal	Audio	1	137	2	140
		EGG	0	138	2	140
	slow	Audio	0	169	9	178
		EGG	0	168	10	178
3	fast	Audio	4	131	6	141
		EGG	4	131	6	141
	normal	Audio	2	151	4	157
		EGG	2	149	6	157
	slow	Audio	1	165	0	166
		EGG	1	165	0	166



As seen in Table I, voiceless lenis obstruents in word-initial position within an accentual phrase are mostly voiced and are rarely voiceless. At the same time, the total number of tokens which are both word-initial and phrase-medial tokens is smaller as the rate decreases from fast to slow, indicating faster speech contains fewer accentual phrases. This tendency is again shown in the Table II. The slower the rate, the more accentual phrases there are in an utterance. This tendency is very clear for the first two speakers, but less clear for the third speaker, whose general speech rate is very slow compared with others.

The observation that a fast rate utterance tends to have more voicing can be supported by the idea about phonetic representation expressed in Browman and Goldstein(1987). They assume that the gestures are invariant across different contexts. However, using the inherently spatiotemporal characteristics of gestures, they claim that "it is possible for gestures to overlap in time. Such overlapping activation of several invariant gestures results in context-varying articulatory trajectories when the gestures involve the same articulators, and in varying acoustic effects even when different articulators are involved. That is, much coarticulation and allophonic variation occur as an automatic consequence of overlapping invariant underlying gestures" (p.2).

Therefore, the intervocalic voicing in casual or fast speech may involve not only reduction of gestural magnitude of the glottal opening-and-closing gesture responsible for the voicelessness but also the blending of closely phased voicing gestures. Moreover, this intervocalic lenition is very highly likely to occur within an accentual phrase instead of across accentual phrases. This indicates that the magnitude of voicing gesture is reduced in the middle of an accentual phrase, but not reduced (maybe increased) at the accentual phrase initial position. This may be possible due to the existence of an accentual phrase boundary. That is, there would be enough time for the voicing gesture of the lenis stop to reach its target position at an accentual phrase initial position. (As will be shown in the next experiment, the duration of features is longer at an accentual phrase initial position than non-initial position.) As a result, it would be less likely that the voicing gesture of the preceding vowel and that of the following lenis stop are overlapping with each other.

This interpretation is supported by the results in Table II which shows the opposite pattern to table I. That is, most word-initial & phrase-initial lenis obstruents are voiceless and are rarely voiced. The results in these two tables constitute strong evidence that a word-initial voiceless lenis obstruent becomes voiced accentual-phrase medially but remains voiceless accentual phrase initially. Therefore, the domain of voicing is the accentual phrase in the Chonnam dialect.

## Experiment 2: VOT lenition

In this experiment, the VOT duration of /p<sup>h</sup>/ was measured to see whether there is any lenition effect at all and, if there is, what is the domain of lenition effect. Three outcomes are possible, with different interpretations:

*Outcome 1* : If there is no lenition effect of aspiration, there would be no significant difference in VOT duration depending on position.

*Outcome 2* : If there is a lenition effect of aspiration and if its domain is an accentual phrase, then there would be two significant groupings of the VOT duration; one group in accentual phrase initial and the other group in medial.

*Outcome 3* : If the domain is some unit smaller than an accentual phrase (such as the prosodic word), there would be at least two groupings of VOT duration within an accentual phrase.

## Method

### Subjects

The two speakers from the first experiment other than the male speaker who had been in Seoul participated in this second experiment.

### Material

1, 2, or 3 syllable words where /p<sup>h</sup>/ was either word initial onset or word medial onset were put in the frame sentence:

'igəsin \_\_\_\_ hago \_\_\_\_ gimən'  
'This is \_\_\_\_ and \_\_\_\_.'

Twenty-eight words were put in either position of the frame sentence which was read with either of the following accentual phrasings.

1. {igəsin} { \_\_\_\_ hago} { \_\_\_\_ gimən}
2. {igəsin} { \_\_\_\_ hago \_\_\_\_ gimən}

There were 32 frame sentences for each of the two accentual phrasings above. The first accentual phrasing above is often found in normal reading without focusing any special lexical item. The second accentual phrasing is found when the first conjunct is narrowly focused. To get this phrasing, each subject was told to emphasize (or to put a focus on) the first conjunct item before recording. The words with initial and medial /p<sup>h</sup>/ are shown in Table III:

Table III : Words with initial and medial /p<sup>h</sup>/

#### < 11 Words with initial /p<sup>h</sup>/ >

p <sup>h</sup> a	'green onions'	p <sup>h</sup> ado	'surge'
p <sup>h</sup> are	'sea lettuce'	p <sup>h</sup> adʒaŋ	'wave length'
p <sup>h</sup> ari	'a fly'	p <sup>h</sup> adʒən	'a grilled food with onions'
p <sup>h</sup> araŋse	'a blue bird'	p <sup>h</sup> atʃhuls'o	'a police station'
p <sup>h</sup> adʒama	'pajamas'	p <sup>h</sup> atʃhulpu	'a maid'
p <sup>h</sup> agimtʃhi	'pickled green onions'		

#### < 17 Words with medial /p<sup>h</sup>/ >

jaŋp <sup>h</sup> a	'onions'	tanp <sup>h</sup> a	'a short wave'
inp <sup>h</sup> a	'silvery waves'	tʃaŋp <sup>h</sup> a	'a long wave'
jəp <sup>h</sup> a	'aftershock'	kjəkp <sup>h</sup> a	'destruction'

sop <sup>h</sup> a	'ripples'	jaɲp <sup>h</sup> ak'aŋ	'onion snack'
tʃup <sup>h</sup> asʉ	'frequency'	hwip <sup>h</sup> acaram	'a whistle'
map <sup>h</sup> aram	'the south wind'	kodzup <sup>h</sup> a	'a high frequency'
tʃ <sup>h</sup> odanp <sup>h</sup> a	'ultra-sonic'	tʃəŋip <sup>h</sup> a	'defender of justice'
p <sup>h</sup> ump <sup>h</sup> ari	'street vender'	insap <sup>h</sup> a	'impressionist art'
naŋmanp <sup>h</sup> a	'romantic art'		

Depending on the position of /p<sup>h</sup>/ within a word and within an accentual phrase eight groups can be defined. These are shown in Table IV.

Table IV: 8 groups of prosodic positions

Group 1: { } {p <sup>h</sup> __} { }	} Word initial
Group 2: { } { } {p <sup>h</sup> __}	
Group 3: { } {p <sup>h</sup> _____}	} Accentual phrase initial
Group 4: { } {__p <sup>h</sup> __} --	
Group 5: { } {__p <sup>h</sup> __} { }	} Word initial
Group 6: { } { } {__p <sup>h</sup> __}	
Group 7: { } {__p <sup>h</sup> _____}	} Accentual phrase medial
Group 8: { } {_____p <sup>h</sup> __}	

#### Procedures

Subjects read each sentence five times at normal rate in a sound-attenuated booth. The sound was digitized and sound waveforms were displayed using a waveform editing program. The duration of VOT was measured from the release of stop to the beginning of complex waveform for the following vowel. The duration of VOT was measured using waveform editing program.

#### **Results and Discussion**

A one-way ANOVA was run on the VOT durations for the 8 groups and showed a significant main effect of group ( $p < .01$ ). A Tukey test was performed between groups at  $\alpha = 0.05$  level. Each speaker shows somewhat different relationships among groups but both speakers show a significant difference between word initial and word medial groups. At the same time, each speaker also showed a significant ( $p < .01$ ) difference between accentual phrase initial and medial.

This suggests that the smallest domain of VOT duration is not an accentual phrase but a prosodic word. Figure 6 shows the mean duration (in ms) of each group for each subject. There was no significant difference between word medial groups, group 5 to 8, and between word-initial and accentual phrase initial groups, group 1 to 3. Therefore, there were three groupings depending on position within a word or a phrase: 1. word-initial and phrase-initial, 2. word-initial but phrase-medial, 3. word-medial and phrase-medial.

For both subjects, the duration of VOT is significantly longer word initially, (in group 4), than word medially (groups 5 to 8). Also the duration of VOT is

significantly longer accentual phrase initially (groups 1 to 3), than accentual phrase medially (group 4).

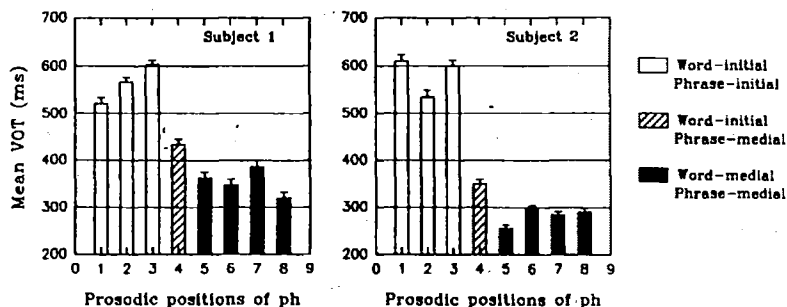


Figure 6. Mean duration of VOT in different prosodic positions.

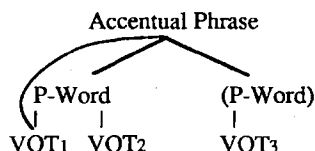
## Conclusion

This investigation of two phonetic aspects of laryngeal features of Chonnam Korean suggests that there are a voicing lenition effect intervocalically in a phrase medial position and a reduced aspiration duration word medially as compared to word initially. The domain of voicing of the voiceless lenis obstruents is shown to be an accentual phrase, which was defined by Jun(1989) based on the intonational pattern of a sentence. That is, word initial lenis stops become voiced intervocalically if the word is within an accentual phrase and all accentual phrase initial lenis obstruents are voiceless.

In Jun(1989), an accentual phrase was the lowest level of the prosodic hierarchy and there was no basis for positing a level of prosodic word, which has been proposed in the literature on prosodic phonology by such researchers as Selkirk(1980, 1986) and Nespor & Vogel(1986).

In the second experiment, however, the duration of VOT of aspirated consonants in Chonnam showed that the domain of VOT is smaller than an accentual phrase suggesting that there is a level of prosodic word. That is, the duration of VOT in Chonnam was longer word-initially than word-medially even within an accentual phrase.

On the other hand, the duration of VOT was also longer accentual phrase initially than phrase medially. This suggests that there is a hierarchy of prosodic levels: an accentual phrase is higher than a prosodic word (P-word) level. Since there is an edge effect (longer VOT at left edge) of each prosodic level, we can represent the realization of different VOT durations using a metrical tree as follows.



VOT in P-word initial boundary (VOT<sub>1</sub> or VOT<sub>3</sub>) is longer than that within the P-word (VOT<sub>2</sub>) and this word-initial VOT is further longer if it occurs at an accentual phrase initial boundary (VOT<sub>1</sub>) than at the accentual phrase medial position (VOT<sub>3</sub>). And this may suggest that the word-initial laryngeal feature is also linked to the higher prosodic level, an accentual phrase.

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### Appendix

Thirty four sentences or phrases used in the first experiment.  
Word-initial lenis obstruents examined for voicing are underlined.  
Word medial lenis stops, /s/ and /h/ are also examined for voicing.

1. abədʒi-ga pəŋ-e t̪rəgasi-ŋə pwanŋja?  
'Father-subj. a room-loc. to enter-honor.-rel. to see-question'  
=> 'Did you see Father entering the room?'
2. abədʒi kabaŋ-e t̪rəgasi-ŋə pwanŋja?  
'Father-subj. a bag-loc. to enter-honor.-rel. to see-question'
3. K̪jəŋman-iga t̪fal kat'a.  
'Kyəŋman-subj. well to go-past' => 'Kyəŋman went safely.'
4. K̪jəŋman-iga t̪fal kat'a. => 'It is good for us that Kyəŋman left.'
5. kəmin kojaŋi-e palmok  
'black a cat-poss. an ankle' => 'a black cat's ankle'
6. kəmin kojaŋi-e palmok => 'a cat's ankle which is black'
7. ki'te Seoul-esə pon ki kirim-i katʃ'a-radira.  
'then Seoul-loc. to see-rel. that a picture-subj. fake-they said-decl.'  
=> 'They said the picture (we) saw at Seoul then was fake.'
8. ne kirim-i t̪feil nat'adira.  
'my a picture-subj. very best-they said-decl.'  
=> 'They said my picture was the very best.'
9. t̪fatotʃ<sup>h</sup>a-hago kirim  
'a car-and a picture' => 'a car and a picture'
10. kiŋən adʒu t̪foin kirim-igiman.  
'that-subj. very good a picture-decl.'  
=> 'That is a very good picture.'
11. ki t̪foin kirim  
'the good a picture' => 'the good picture'
12. Kisu-ga pon kirim  
'Kisu-subj. to see-rel. a picture' => 'a picture Kisu saw'
13. Kisu-ga kirin kirim-il pwanŋinde, t̪ŋmal t̪fal --  
'Kisu-subj. to draw-rel. a picture-obj. to see-past-and, really well  
kirjət'əra.  
to draw-past-decl.'  
=> '(I) saw a picture Kisu drew and it was really well drawn.'
14. na abədʒi-ga t̪fusi-n kirim pogois'əs'a.  
'I Father-subj. to give-honor.-rel. a picture to look at-past prog.'

- ==> 'I was looking at the picture Father gave to me.'
15. na abədʒi-ga tɔŋseŋ-hantʰe tʃun kɪrim pogois'əs'ə.  
'I Father-subj. brother-dat. to give-rel. a picture to look at-past prog.'  
==> 'I was looking at the picture Father gave to my brother.'
16. ke-ga tʃa-ŋa?  
'a dog-subj. to sleep-question' ==> 'Does the dog sleep?'
17. ke-ga kɪn-ga?  
'a dog-subj. to crawl-question' ==> 'Does the dog crawl?'
18. ki kɪrim tʃemog-i adʒu tʃoɪn tʃandi-radira.  
'the a picture a title-subj. very good lawn-they say-decl.'  
==> 'They said the title of the picture was 'very good lawn.''
19. Kjəŋsu-ga tɔn pədin-gə pɔŋjəginnja?  
'Kyəŋsu-subj. money to receive-rel. to see-experience-question.'  
==> 'Have you seen Kyəŋsu received money?'
20. Kjəŋsu-hantʰe tɔn tʃu-ŋgə pɔndʒəginnja?  
'Kyəŋsu-dative money to give to see-experience-question.'  
==> 'Have you seen someone gave Kyəŋsu money?'
21. uri sənseŋin Suni-hantʰe tʃəmsu-lil tʃal tʃu-ningə gat'ira.  
'our teacher-subj. Suni-dat. a score-obj. good to give is likely-decl.'  
==> 'It seems to be that our teacher gives a good score to Suni.'
22. pəbil tʃaju məgəra.  
'rice-obj. often to eat-imperative.'  
==> 'Eat (your) rice often!'
23. isəŋhəge kɔjəni-ga ul-go ke-ga tʃisəs'ath'ira.  
'strangely a cat-subj. to cry-and a dog-subj. to bark-habitual-decl.'  
==> 'Strangely, a cat has been crying and a dog has been barking.'
24. nə kɔjəni tʃ'onnin kəŋədʒi t'eri-n pəbo pwanja?  
'you a cat o follow-rel. a puppy to bit-rel. a fool to see-experience'  
==> 'Have you seen a fool who is biting a puppy which follows a cat?'
25. Kjəŋsu-nin pimat-k'oinnin kɔjəni-lil pɔat'a.  
'Kyəŋsu-subj. to be in the rain-rel. a cat-obj. to see-past.'  
==> 'Kyəŋsu saw a cat in the rain.'
26. na indʒesa tʃʰegil tu-gwən pwat'a.  
'I now a book-obj. two to read-past.'  
==> 'I now just read two books.'
27. na indʒesa tʃʰek tu-gwənɪl pwat'a.  
'I now a book two-classifier to read-past.'  
==> 'I now just read two books.'
28. jədʒa-ga tu-mjəŋ tʃinaga-nda.  
'women-subj. two-people to pass by-prog.'  
==> 'There are two women passing by.'
29. jədʒa tu-mjəŋ-i tʃinaga-nda.  
'women two-people-subj. to pass by-prog.'  
==> 'There are two women passing by.'
30. pəb is'ə.  
'rice to have' ==> '(We) have rice.'
31. abənim kjesjə  
'Father-honor. to be-honor.-decl.'  
==> 'Father is inside (or at home).'
32. Kɔsəŋseŋnim-i kjesjə.  
'Ko teacher-honor-subj. to be-honor.-decl.'  
==> 'Teacher Ko is inside.'
33. abənim kjesimmik'a?  
'Father-honor. to be-honor.-question.'

- ==> 'Is Father inside (or at home)?'  
 34. Kosənsəŋnim-i kjesimnik'a?  
 'Ko teacher-honor-subj. to be-honor-question.'  
 ==> 'Is Teacher Ko inside?'

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