

Asymmetry of prosodic effects on the glottal gesture in Korean*

Sun-Ah Jun
sjun@ling.ohio-state.edu

Abstract : Many languages have different allophones for voiced or voiceless stops depending on position within the word or the phrase (Keating et al. 1983). However, such effects are not always symmetrical. In this paper, I examined the voicing of the word final lenis stop when it comes at the end of the Accentual Phrase. By contrast to the word initial lenis stop, which is almost always voiceless at the beginning of the Accentual Phrase (Jun 1990a,b, 1993), the word final lenis stop was voiced at the resyllabified Accentual Phrase initial position. The data showed that the voicing of lenis stop depends on its duration relative to the following vowel and this duration was determined by its position relative to the prosodic contexts. Therefore, I proposed that the Lenis Stop Voicing rule in Korean is not a phonological rule, but is a byproduct of some other effect of prosodic position on the gestural amplitude and overlapping, thus producing a continuum of voicing. To distinguish the different duration pattern of the lenis stop, thus the different voicing pattern of the lenis stop, I suggested different prosodic representations utilizing the coda/onset information.

1. Introduction

It is well established that prosody conditions segmental and suprasegmental features. For example, in English, the 'gestural magnitude' of /h/ is weakened in word medial position or in deaccented words so that overall amplitude is smaller and energy is more concentrated in the first harmonic (Pierrehumbert and Talkin 1992). Also, segments are found to be lengthened at the edge of a phrase (e.g. Oller 1973; Beckman and Edwards 1990). As shown in Keating et al.'s (1983) survey of phonetic studies, many languages have different allophones for voiced or voiceless stops depending on position within the word or the phrase. However, such effects are not always symmetrical. For example, in German, voiced stops often become voiceless word initially as well as word finally, but this causes neutralization only word finally, where the contrasting voiceless stop is not aspirated.

Korean also has such prosodically conditioned strengthenings and weakenings of laryngeal features, and asymmetries between word final and non-final position. In the initial position of a word in isolation, there is a three way contrast among aspirated, tense, and lenis voiceless obstruents. In word medial position, the stops are weakened so that the aspirated stops are less aspirated (Jun 1990a, 1993) and the lenis stops are voiced intervocally. In final position, the

* The revised version of this paper will appear in *Papers in Laboratory Phonology IV*. B. Connell and A. Arvaniti, eds., Cambridge University Press, England. I would like to thank Mary Beckman, Michel Jackson, and Janet Pierrehumbert for their comments and suggestions. The work reported in this paper was supported by the NSF under Grant No. IRI-8858109 to Mary E. Beckman.

distinction is neutralized completely to an unreleased lenis stop. Kagaya (1974) shows the laryngeal configuration of the three types of obstruents; the aspirated stop has a large glottal opening gesture which peaks around the oral release, while the tense or fortis stop has a much smaller opening and is closed even before the oral release. This is true both in initial and medial position. However, the glottal pattern of the lenis stop is more variable: in initial position a lenis stop has a large glottal opening, like that of the aspirated stop, but timed differently so that voicing starts soon after oral release. In word medial intervocalic position, it shows no glottal opening and the closure duration is very short enhancing the percept of voicing.

The laryngeal adjustment of coda obstruents, utterance finally and before other obstruents was examined in Sawashima et al. (1980). They show that the laryngeal gesture of a word final obstruent at the end of a sentence has a small glottal opening, which begins at or slightly after the oral closure and remains open for about 80-100 ms. (The laryngeal feature of the syllable final obstruent followed by other obstruent appears to be assimilated to that of the following obstruent. No fiberoptic data is available for the laryngeal gesture of the word final obstruents followed by a vowel initiated word.) That is, a coda obstruent is neutralized to an unreleased voiceless lenis stop.

Then, what is the domain of coda neutralization? The examples in (1) show that the domain is a stem plus a case marker, the Prosodic Word (Kang 1992). (Here, a dot refers to a syllable boundary.)

- (1) a. /tʃip/ => [tʃip^o] 'a house'
 /tʃip^h/ => [tʃip^o] 'straw'
 /taptʃi/ => [tap^o.tʃi] 'an answer sheet'
- b. /tʃip-in/ => [tʃi.bi.n]¹ 'a house-TOP'
 /tʃip^h-i/ => [tʃi.p^hi] 'straw-NOM'
- c. /tʃip/+/ilim/ 'name' => [tʃip^o.i.rim] or [tʃi.bi.rim] 'the name of a house'
 /tʃip^h+/ədiinni/ => [tʃip^o.ə.di.in.ni] or [tʃi.bə.di.in.ni]
 'Where is the straw?'

(1a) shows coda neutralization before pause and before another obstruent within a Prosodic Word. (1b) shows that the different types of underlying coda obstruents are realized as an onset when they come before a vowel within the Prosodic Word. (1c) shows that the underlying coda is not realized as an onset across the Prosodic Word boundary. Instead, the coda is neutralized within the Prosodic Word and is realized either as an unreleased coda or as a voiced onset. Korean phonologists have assumed that the neutralized coda is resyllabified as an onset of the following Prosodic Word at the postlexical level. Cho (1987) claims the domain of resyllabification is the Intonational Phrase and Kang (1992) claims it as the Phonological Phrase, larger than the Prosodic Word. However, no phonetic data concerning the domain of resyllabification has been published as far as I know. To determine whether the voiced lenis stop had been resyllabified across the word or across even larger boundaries, the domain of another phonological rule, /l/-flapping was examined as a pilot study.

In Korean, [l] only surfaces in the coda of a syllable, and never as an onset unless the lateral is a geminate. When followed by a vowel, /l/ is resyllabified to an

1 /p/ becomes [b] intervocalically by the Lenis Stop Voicing rule. The underlying coda /p/ is resyllabified as an onset of the following syllable.

onset of the vowel and appears as a flap [r]. The results show that the resyllabification *can* occur across any word boundaries within an Intonational Phrase (i.e. across the boundary of an Accentual Phrase, the definition of which will be introduced later this section.). Thus, I will assume that any coda lenis stop can be resyllabified to be the onset of the following Accentual Phrase and therefore the following word. I will call this a 'resyllabified' Accentual Phrase initial lenis stop, to distinguish it from the underlying onset lenis stop in Accentual Phrase initial position.

In addition to this asymmetry between syllable onset and coda, however, Korean seems to show an asymmetry at a higher level of prosodic unit. That is, there seems to be a difference between word initial and word final lenis stop in terms of voicing. The word initial voiceless lenis stop in Korean becomes voiced in the middle of the Accentual Phrase but remains voiceless at the Accentual Phrase initial position (Jun 1990a, b). However, in casual speech, informal observation shows that the word final lenis stop becomes voiced most of the time across Accentual Phrase boundaries as well as within the Accentual Phrase. Since lenis stop voicing has been claimed to be a domain span rule in Selkirk's (1986) sense, applying anywhere 'within' the Accentual Phrase, the lenis stop at the end of the Accentual Phrase should be voiceless.²

In this paper, I will focus on the voicing of the coda lenis stop at the end of the Accentual Phrase (= at the beginning of the Accentual Phrase after resyllabification), as in {kimpap} {əɭəssni} 'Was the sushi frozen?' (/kimpap/ 'sushi', /əɭ-əss-ni/ 'to freeze-past-Q'). Second, based on the durational relationship between the lenis stop and the adjacent segments in different prosodic positions, I will discuss whether or not Lenis Stop Voicing is a categorical rule. Finally, I will interpret the results in terms of gestural overlapping and reduction based on Browman and Goldstein's (1990) model.

Before introducing the experimental methods, I will briefly introduce the definition of the Accentual Phrase and its relation to the Lenis Stop Voicing rule. The Accentual Phrase is a grouping of Prosodic Words defined on the basis of the tonal pattern of an utterance. In the Seoul dialect, the tonal pattern of the Accentual Phrase is L(H)LH, with the first high optionally appearing when the phrase is longer than four or five syllables. Thus, the salient characteristic of the Accentual Phrase in Seoul Korean is a final rise in pitch. (But, when a phrase is produced with contrastive focus, an initial rise pattern can be found in Seoul, even in a short Accentual Phrase.) In the Chonnam dialect, the characteristic pattern is an initial rise-fall or simple fall, i.e. either LHL or HHL. The choice of pattern is predictable from the laryngeal features of the first segment of the Accentual Phrase: when the segment has either [+spread glottis] (i.e. aspirated consonants and /s/) or [+constricted glottis] (i.e. tensed consonants), the Accentual Phrase has the HHL pattern and otherwise the LHL pattern.

The Accentual Phrase is the comparable level to the Phonological Phrase assumed in Prosodic Phonology (Selkirk 1984, 1986; Nespor and Vogel 1986; Hayes 1989). However, I call it the Accentual Phrase to highlight that its basis is different from what defines the Phonological Phrase. In addition to the syntactic factors emphasized by the prosodic phonologists, the Accentual Phrase is influenced by nonsyntactic and nonlinguistic factors such as focus, speech rate and weight of a phrase (for more detail, see Jun 1993).

Jun (1990a, b) found that this Accentual Phrase is the domain of Lenis Stop Voicing. That is, the underlyingly voiceless lenis stop is voiced intervocally in

² Cho (1987, 1990), Kang (1992) and Silva (1989, 1992) have proposed the Phonological Phrase as the domain of Lenis Stop Voicing rule based on either Selkirk's (1986, 1990) end based theory or Nespor and Vogel's (1986) relation based theory.

the middle of the Accentual Phrase but remains voiceless at the beginning of the Accentual Phrase. Figure 1 illustrates the application of Lenis Stop Voicing in different positions in the Accentual Phrase produced by a Seoul speaker. The X-axis is time dimension and Y-axis is the fundamental frequency, f_0 , value in Hz. (This format will be used for other pitch track figures in this paper.) Figure 1(a) shows the pitch track and waveform of the sentence (2) produced (a) in two Accentual Phrases and (b) in one Accentual Phrase.

(2) *jəlme-ka* *tal-ass-ni*
 'the fruit - NOM' 'sweet-past-interrogative marker' -> 'Was the fruit sweet?'

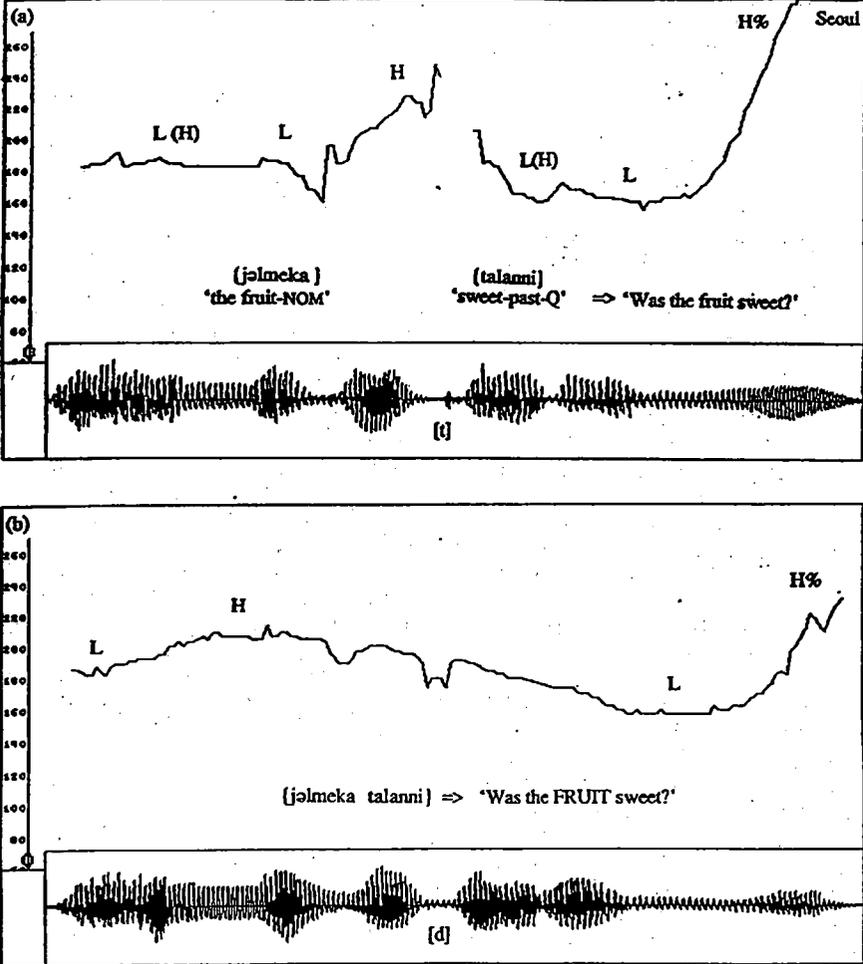


Figure 1 Pitch tracks and waveforms of *jəlmeka talanni* 'Was the fruit sweet?' in two Accentual Phrasings by Seoul speaker, S2, forming (a) two Accentual Phrases as in *{jəlmeka} {talanni}* and (b) one Accentual Phrase as in *{jəlmeka talanni}*.

The Accentual Phrases in Figure 1(a) have a final rise with an initial high being undershot, but the Accentual Phrase in Figure 1(b) has both an initial rise and a final rise. As shown by the absence of the sinusoidal waveform and the broken line on the pitch tracks in Figure 1(a), the Accentual Phrase initial lenis stop is voiceless, [t]. On the other hand, the same lenis stop is voiced, [d], in the middle of the Accentual Phrase as in Figure 1(b). Figure 2 shows the same fact but only differs from Figure 1 in that Figure 2 is produced by a Chonnam speaker, thus having a different verbal ending and an initial rise contour, LHL.

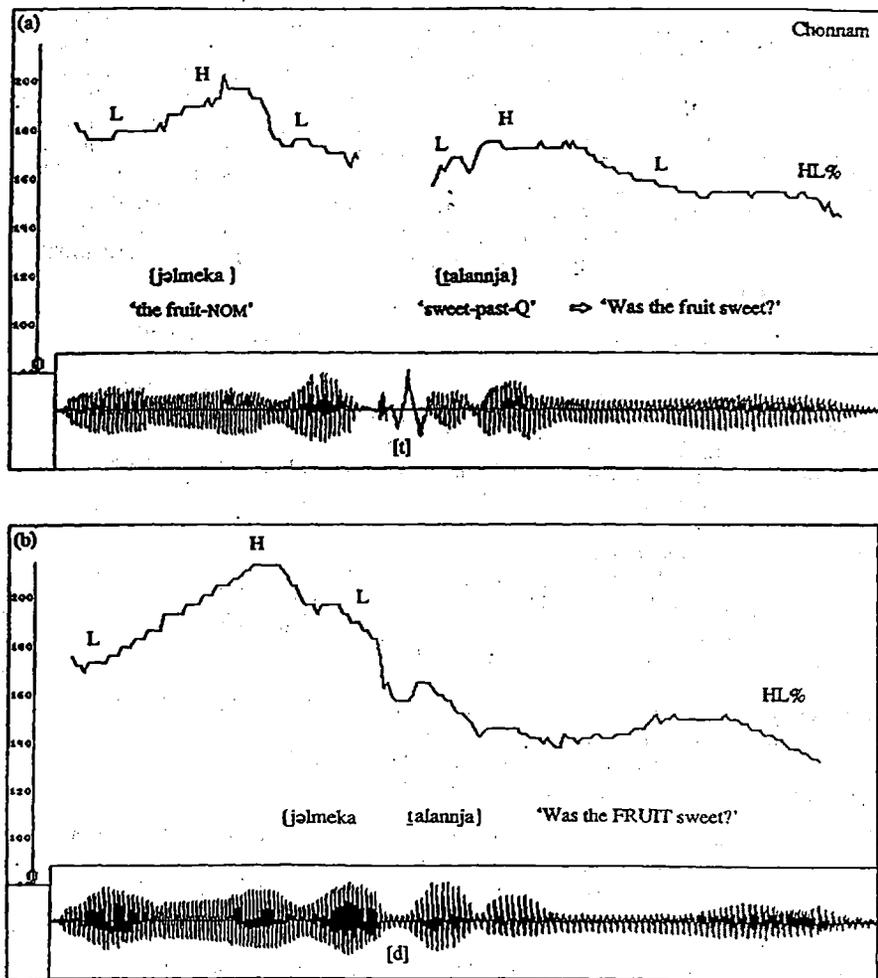


Figure 2. Same as Figure 1, but produced by a Chonnam speaker, C1.

As shown in the figures above, the domain of Lenis Stop Voicing is determined by the tonal pattern of an utterance. That is, a lenis stop at the beginning of an Accentual Phrase remains voiceless, while a lenis stop in the middle of an Accentual

Phrase becomes voiced. To find out the voicing status of the Accentual Phrase final lenis stop, the following experiment was conducted.

2. Experimental Methods

Subjects : Three Seoul speakers (S1: female, S2: male, and S3: male) and three Chonnam speakers (C1: female, C2: male, and C3: male) were participated in the experiment. All subjects were in their late twenties or early thirties.

Material : Five pairs of two word sentences (listed in Table 1) were constructed so that one sentence of the pair has a lenis stop at the beginning of the second word while the other sentence of the pair has the same lenis stop at the end of the first word. Except for this prosodic difference, the contexts surrounding the lenis stops are the same. In the table, the target segments and the relevant context segments are underlined. The word *jəlmekat* in (1b) and *tʃaŋsinkut* in (5b) in Table 1 are not real words but are possible words referring to a kind of a hat or a kind of shamanism ceremony, respectively. Subjects had no trouble understanding the possible meanings. The word in parenthesis after sentence was used to trigger contrastive focus, to help subjects to produce the whole sentence in one Accentual Phrase, as described in (3).

Table 1 Corpus sentences for the Accentual Phrase final lenis stop voicing

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1. a. *jəlmeka taranni* (namu) 'Was the fruit sweet? (the tree)'
 /jəlmɛ-ka tal-ass-ni/ 'the fruit-NOM' 'sweet-past-Q'
 b. *jəlmekat aranni* (namukat) 'Did you know the fruit-hat? (the tree-hat)'
 /jəlmɛ-kat al-ass-ni/ 'the fruit-hat' 'to know-past-Q'
2. a. *antʃu karanni* (salku)
 'Did you grind the snacks to eat with drink? (the apricot)'
 /antʃu kal-ass-ni/ 'the snacks to eat with drink' 'to grind-past-Q'
 b. *pantfuk aranni* (sokim) 'Did you know the paste? (the salt)'
 /pantʃuk al-ass-ni/ 'the paste' 'to know-past-Q'
3. a. *tʃampa pəɾjənni* (opa) 'Did you throw away the jacket? (the overcoat)'
 /tʃampə pəli-əss-ni/ 'the jacket' 'to throw away-past-Q'
 b. *kimpap aranni* (pokimpap) 'Was the sushi frozen? (the fried rice)'
 ?kimpap əl-əss-ni/ 'the sushi' 'to frozen-past-Q'
4. a. *salku karanni* (antʃu) 'Did you grind the apricot? (the side food for liquor)'
 /salku kal-ass-ni/ 'the apricot' 'to grind-past-Q'
 b. *suku aranni* (nantʃ^ho) 'Did you know the water mum? (the lily)'
 /sukuk al-ass-ni/ 'the water mum' 'to know-past-Q'
5. a. *tʃaŋsinku taranni* (tʃaŋnankam) 'Did you wear the ornament? (the toy)'
 /tʃaŋsinku tal-ass-ni/ 'the ornament' 'to wear-past-Q'
 b. *tʃaŋsinkut aranni* (nerimkut) 'Did you know "tʃaŋsin-shamanism ceremony"? ("descending shamanism ceremony")'
 /tʃaŋsin-kut al-ass-ni/ 'tʃaŋsin-shamanism ceremony' 'to know-past-Q'
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Methods : These sentences were placed in pseudo-random order so that no sentence came after the other sentence from the pair to avoid putting emphasis on

the difference. Seoul and Chonnam dialect speakers were asked to read the whole list in two different Accentual Phrasings 10 times each in normal speech rate. First, they read the whole list of sentences in neutral focus without considering the word in parentheses. In this reading, they nearly always produced the sentence as two Accentual Phrases, one for each word within the sentence. Then they read each sentence a second time putting focus on the first word to contrast it with the word in parentheses by making the whole sentence one Accentual Phrase. To help produce the contrast focus naturally, I asked the subjects to make a new sentence by substituting the contrasting word for the original word. An example is shown in (3). The verbal endings given in Table 1 and other example sentences in this paper were for the Seoul speakers. For speakers of the Chonnam dialect, the dialect form [-nja] was substituted for [-ni].

- (3) Given: /jəlmekataranni/? (namu)
 'Was the fruit sweet? (the tree)'
 Read: {jəlmekataranni} {namukataranni}?
 'Was the fruit sweet or was the tree sweet?'

For each utterance, the target lenis stop and context segments were analyzed for voicing using Kay Sonagraph Model 5500 and the pitch track was checked for the Accentual Phrasing. The durations of the target lenis stop and the following vowel were measured using the spectrogram display. To help measurement, the audio waveform and amplitude were displayed simultaneously in the upper window. In addition, I measured the word medial lenis stop (except for 3(b) in Table 1, where /p/ is produced as [pʰ]) to compare with the duration of the word initial lenis stop. I also measured the word final vowel (underlyingly word final or derived word final after resyllabification), which was the vowel preceding the target lenis stop to see whether the segment shows any difference in duration depending on its position relative to the Accentual Phrase, i.e. Accentual Phrase final or medial. For the target lenis stop and the word medial lenis stop, the duration was measured to include closure duration and any voiceless portion after the release (i.e. VOT). The duration of the vowel preceding the target lenis stop was measured from the point where the first formant of the vowel has a clear amplitude (this mostly matches right after the stop release) to the point where the formant stops (this mostly matches the implosion of the target lenis stop). The duration of the vowel following the target lenis stop was measured from the first formant onset after the stop release to the onset of the flapping.

Next, to examine the domain of flapping for each subject, five sentences containing a word final lateral before a vowel-initial word were given after the list in Table 1. Subjects read each sentence in two Accentual Phrasings ten times each as before and the spectrogram was examined to see whether the word final lateral is produced as a flap. The five sentences are given in Table 2. As in (3) above, the contrasting word is given in the parenthesis.

Table 2 Corpus sentences for flapping

- a. əlluŋma₁ aranni (tʃoraŋma₁) 'Did you know the zebra? (a pony)
 /əllukma₁al-ass-ni/ 'the zebra' 'to know-past-Q'
- b. ɔriba₁ aranni (kəwi-pa₁) 'Did you know the duck's foot? (the goose's foot)
 /oli-pa₁al-ass-ni/ 'the duck-foot' 'to know-past-Q'
- c. jaŋmu₁ aranni (kukmu₁) 'Did you know the medicine water? (the soup)
 /jakmu₁alassni/ 'the medicine water' 'to know-Q'

d. *kojaŋibaɪ aranni* (*kajaŋʃipaɪ*) 'Did you know the cat's foot? (the puppy's foot)'
 /*kojaŋi-paɪ aɪ-ass-ni*/ 'the cat-foot' 'to know-past-Q'

e. *ʃəɪmeriɪ aranni* (*namu*) 'Did you know the fruit? (the tree)'
 /*ʃəɪme-lɪɪ aɪ-ass-ni*/ 'the fruit-ACC' 'to know-past-Q'

3. Results and Discussion

3.1. Resyllabification of Lateral

Figure 3 shows spectrograms of example sentence (a) in Table 2 above produced in two Accentual Phrasings: (a){*əɪluŋmaɪ arannja*} and (b){*əɪluŋmaɪ*}{*arannja*} uttered by C2, and (c){*əɪluŋmaɪ*}{*aranni*} by S1. The resyllabified flap is shown in (a) and (b) and a lateral is shown in (c) and these are marked by an arrow underneath the spectrogram.

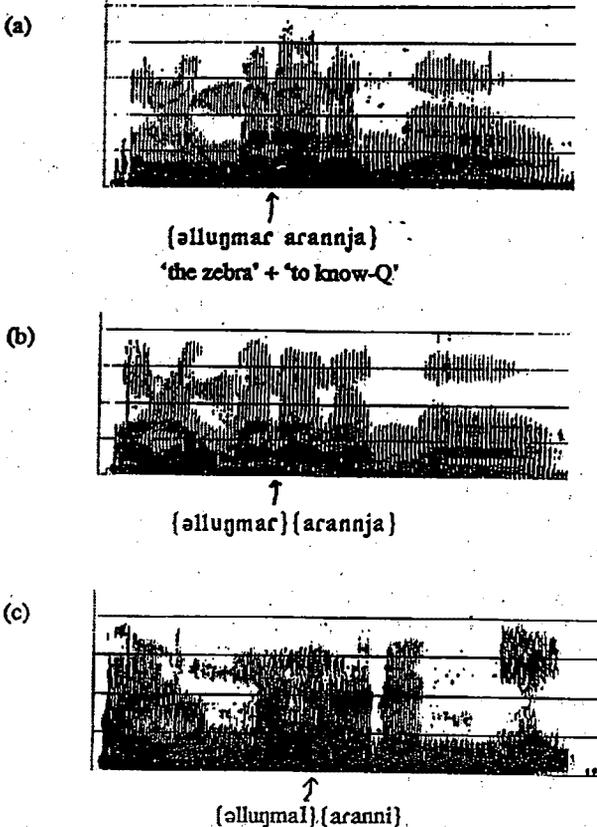


Figure 3. Example spectrograms showing (a) when an Accentual Phrase medial /l/ becomes a flap, (b) when an Accentual Phrase final /l/ becomes a flap, and (c) when an Accentual Phrase final /l/ doesn't become a flap.

As seen in Figure (3a) and (3b), the word final lateral can be resyllabified to be an onset for the following word, showing a flap in both Accentual Phrasings. Thus, we can assume that the word final and phrase final lateral can be resyllabified as the onset of the following word across the Accentual Phrase boundary. The resyllabification across Accentual Phrases occurs in casual speech. In careful and deliberate speech, it does not occur even within an Accentual Phrase. Table 3 shows the percentage of flapping within an Accentual Phrase and across Accentual Phrases for each subject. The percentage is based on 50 tokens.

Table 3. Percentage of flapping within and across Accentual Phrases for each subject

Subject	Accentual Phrase medial	Accentual Phrase initial
C1	89.0 %	70.9 %
C2	100 %	98.0 %
C3	81.4 %	80.0 %
S1	66.0 %	63.6 %
S2	82.0 %	68.0 %
S3	83.6 %	73.5 %

For subjects C1, S2, and S3, the word final lateral is flapped more often within the Accentual Phrase than across Accentual Phrases and, for subjects C2, C3, and S1, there seems to be no difference in this regard. Each subject seems to be consistent in their casualness or carefulness in producing a lateral; Subject C2 has flapping most often and S1 least often and this order is consistent within each prosodic position. However, the lateral is not always resyllabified even within the Accentual Phrase. These data suggest that resyllabification is not related very closely to the Accentual Phrase position. But it is clear that the resyllabification *can* occur across Accentual Phrase boundaries.

Generalizing from these utterances, I will assume that any coda consonant type, and specifically the lenis stop, can be resyllabified to be the onset of the following word and therefore the following Accentual Phrase. I will call this a 'resyllabified' Accentual Phrase initial lenis stop, to distinguish it from the underlying onset lenis stop in Accentual Phrase initial position.

3.2. Voicing of the Word initial and final lenis stop

Depending on the position of the target lenis stop relative to a Word or an Accentual Phrase, I defined four prosodic positions: onset/A-initial position when the lenis stop is at the beginning of a Word and at the beginning of an Accentual Phrase, onset/A-medial when the lenis stop is at the beginning of a Word but in the middle of an Accentual Phrase, coda/A-initial position when the lenis stop is at the end of a Word but at the beginning of an Accentual Phrase after resyllabification, and coda/A-medial position when the lenis stop is at the end of a Word and in the middle of an Accentual Phrase. The pitch contours and the corresponding segmental realization in onset/A-initial position are what is shown in Figure 1(a) and those in onset/A-medial position are shown in Figure 1(b). Different phrasings and the corresponding segmental realizations in coda/A-initial and coda/A-medial position are shown in Figure 4. The Accentual Phrasing and the voicing of lenis stop in each prosodic position are outlined in (4). The arrow in (4c) indicates a resyllabification. (4c) and (4d) correspond to Figure 4(a) and (b), respectively.

- (4) i. *jəlmeka talanni?* 'Was the fruit sweet?'
 a. {*jəlmeka*} {*talanni*} => [*jəlmega taranni*] : onset/A-initial
 b. {*jəlmeka talanni*} => [*jəlmegadaranni*] : onset/A-medial
- ii. *jəlmekat alanni?* 'Did you know the 'fruit hat'?'
 c. {*jəlmekat*} {*alanni*} => [*jəlmegadaranni*] : coda/A-initial
 d. {*jəlmekat alanni*} => [*jəlmegadaranni*] : coda/A-medial

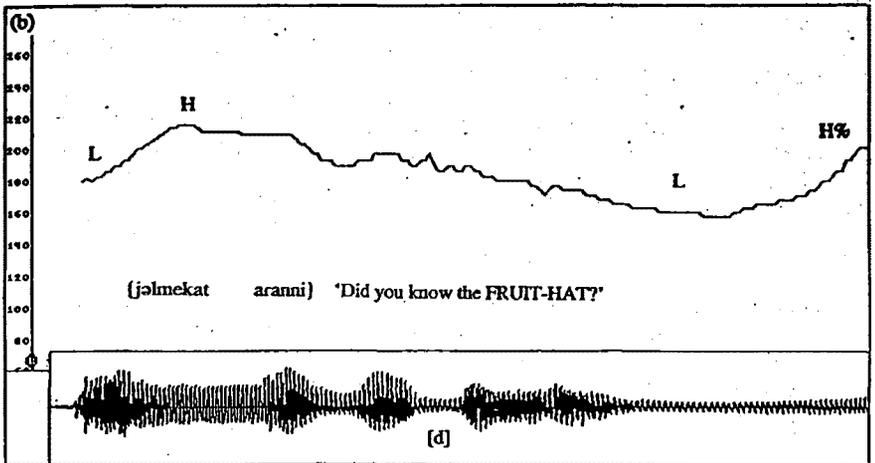
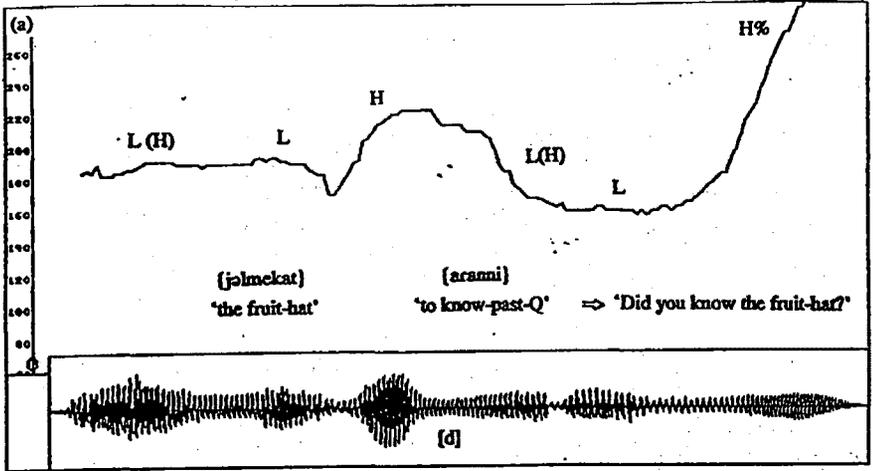


Figure 4. Pitch tracks and waveforms of lenis stop in two prosodic positions: (a) coda/A-initial, (b) coda/A-medial. The sentence is (1b) in Table 1. (speaker: S2)

As expected, the underlying onset or coda /t/ is voiced in Accentual Phrase medial position, (4b) and (4d), whereas the underlying onset /t/ is voiceless at the beginning of the Accentual Phrase, (4a). However, the resyllabified word initial /t/ is still *voiced* as shown in Figure 4(a), i.e. (4c). Thus, even though the tonal pattern of Figure 4(a) is different from those of Figure 1(b) and Figure 4(b), all three are alike in terms of segmental realization. Most of the time, it was hard to distinguish between the type (4b) and (4d) when I was listening without looking at the text. But the type (4c) was easily distinguished from (4b) and (4d) due to the different tonal pattern.

The result of the experiment shows that, as found before, for six subjects, onset stops are mostly voiceless at the Accentual Phrase initial position and voiced in the Accentual Phrase medial position. But word final coda stops are mostly voiced all the time. Out of 300 tokens (5 sentences * 6 subjects * 10 repetitions) for each prosodic condition, in general, 5 to 10 % of tokens show an exception to this voicing pattern. (10.67 % voiced at Onset/A-initial position, 4.78% voiceless at Onset/A-medial position, 8.36% voiceless at Coda/A-initial position, and, 4.76% voiceless at Coda/A-medial position.) Figure 5 shows the percentage of voiced versus voiceless lenis stop in four prosodic positions.

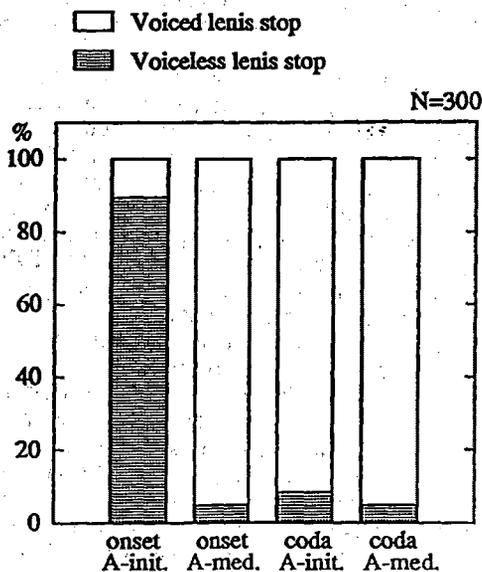


Figure 5. Percentage of voiced versus voiceless lenis stop in four prosodic positions combining data from 6 subjects (N=300).

In summary, though it is not perfect, we can predict most of the voicing data (90 to 95% of occurrences) in terms of the underlying and surface prosodic context of the lenis stop. That is, underlying onset stops are voiceless at the beginning of the Accentual Phrase and voiced in the middle of the Accentual Phrase, whereas underlying coda stops are nearly always voiced.

3.3. Duration of lenis stop and adjacent segments in different prosodic positions

The mean durations of the vowel preceding the target lenis stop, the target lenis stop itself, and the following vowel are plotted in Figure 6 in the four different prosodic positions: onset/A-initial, onset/A-medial, coda/A-initial, and coda/A-medial position. The mean duration of the word medial lenis stop, the lenis stop preceding the target lenis stop, is shown in the first row in the target lenis stop column in Figure 6. Here, the mean value of the word medial lenis stop is only based on the word medial lenis stop between vowels. The error bars indicate the standard error.

For all subjects, there is an effect of Prosodic Word boundary on the duration of lenis stops; the target onset and coda consonants, all of which are at the edges of the word, are substantially longer than the word medial stop. There was also an effect of prosodic phrase boundary; the target onset consonant is substantially longer in Accentual Phrase initial position than in Accentual Phrase medial position. This conforms to the previous results found in Jun (1990a) about the duration of VOT; that is, VOT of word initial aspirated stop was significantly longer in the Accentual Phrase initial position than in the Accentual Phrase medial position which was again significantly longer than VOT in the word medial position.

In addition, for all subjects, the target lenis stop at the Accentual Phrase boundary is substantially longer when it is an underlying onset consonant than when it is an underlying coda consonant. In fact, here its duration is longer than that in any other position, and conversely the following vowel of this position is substantially shorter than that in any other position. The target lenis stop is not significantly different among the other three positions, but the following vowel is in general longer after coda consonants in the phrase edge position. That is, the lenis stop is substantially longer as an underlying onset in Accentual Phrase initial position than as a resyllabified onset in Accentual Phrase initial position, and the vowel following the resyllabified lenis stop which we can understand as the underlying initial segment of the Accentual Phrase is longer in general than the vowel following the target lenis stop in any other position.

Thus, it seems that the left edge of the Accentual Phrase is strong in Korean; it shows a lengthening effect. To see if the right edge of the Accentual Phrase also shows the same effect, we can compare the durations of the vowel preceding the target lenis stop for the four different prosodic positions. For all subjects, there was no significant difference among four different prosodic positions. The duration of the underlying word final vowel was not significantly longer when it is at the end (the right edge) of the Accentual Phrase. Thus, the duration data of word final vowels indicate that it is not necessarily both edges of the prosodic unit which show a segmental lengthening. That is, the boundary effect is not necessarily symmetrical.

Moreover, there are differences among different levels: A segment is very much lengthened at the right boundary of Intonational Phrase (Jun 1992). Therefore, the prosodic boundary effect on the segment is not uniform: Words and Accentual Phrases show a left edge lengthening while Intonational Phrase shows a right edge lengthening. Also the domains and patterns of these lengthening effects are not universally the same: unlike Korean, English has a right boundary effect at both the Word level and Intonational Phrase level (Beckman and Edwards 1990, Crystal and House 1990).

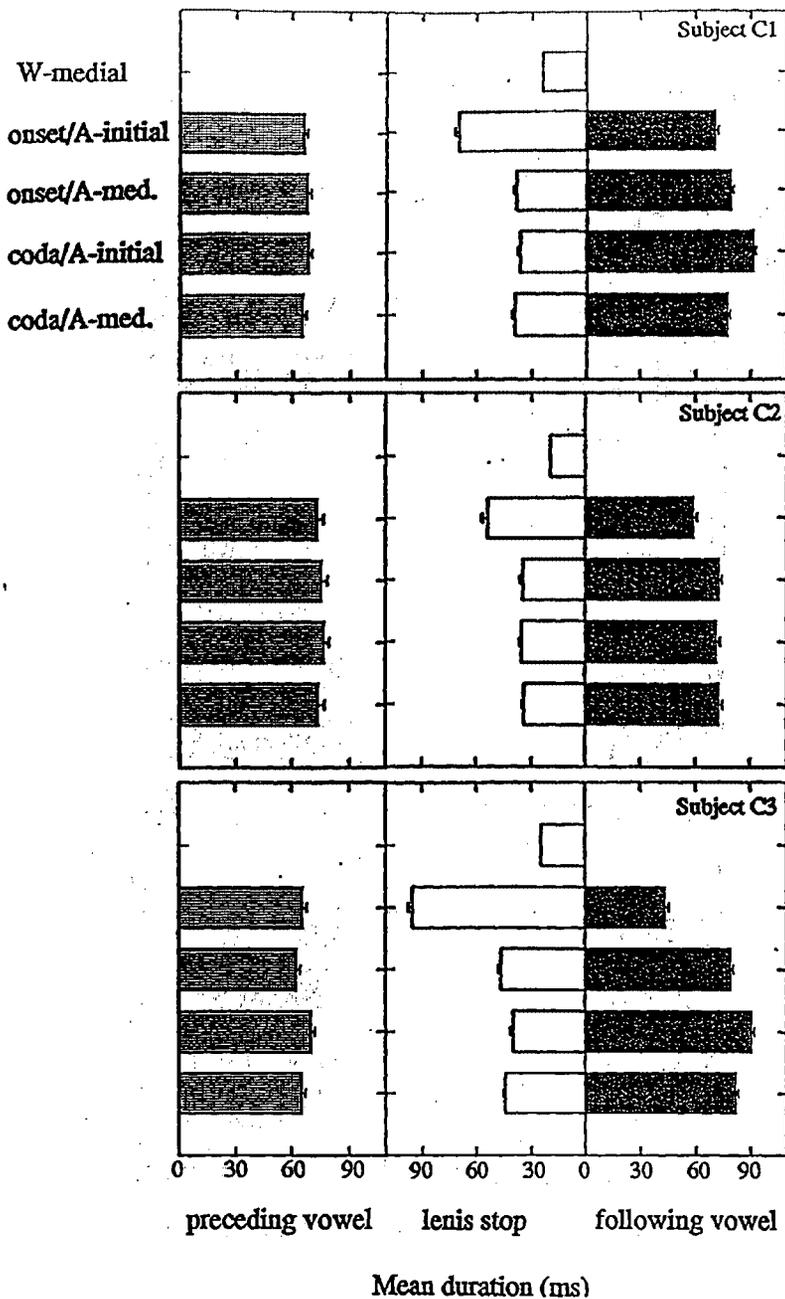


Figure 6. The mean duration of the word medial lenis stop, the vowel preceding the target lenis stop, the target lenis stop, and the following vowel in four different prosodic conditions (onset/A-initial, onset/A-medial, coda/A-initial, and coda/A-medial) for each subject.

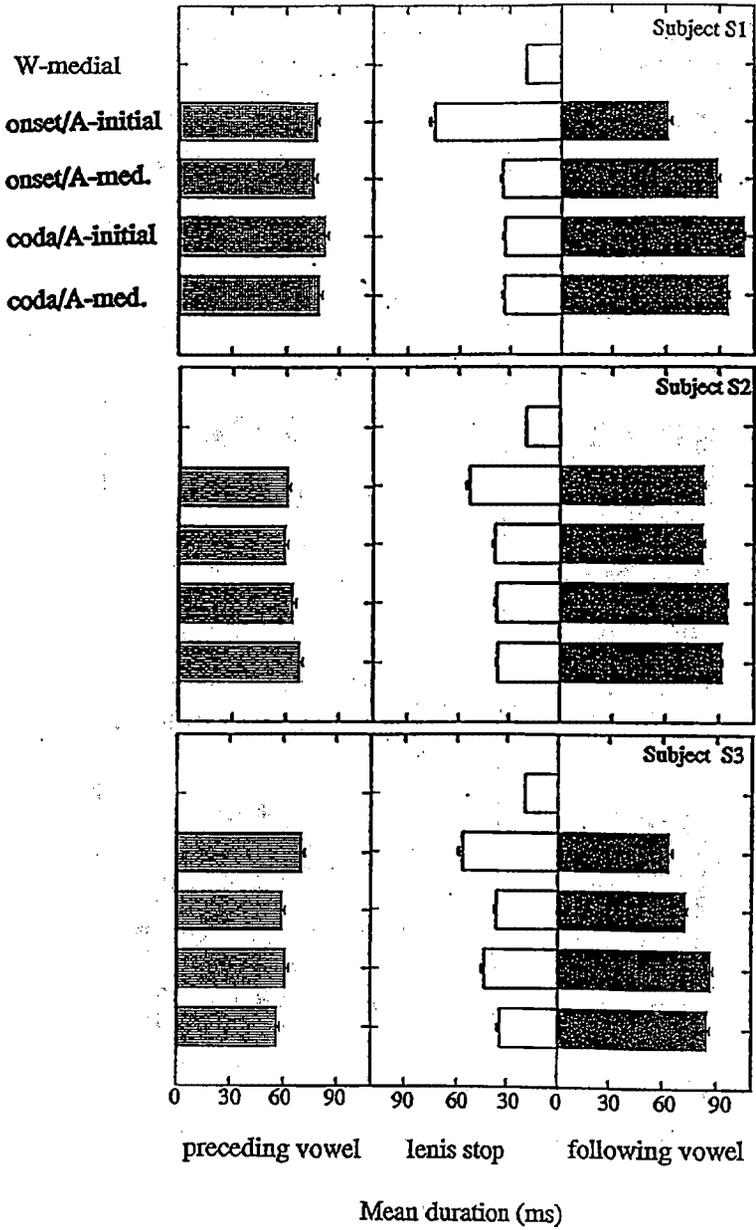


Figure 6. (Continued)

3.4. The representation of lenis stop voicing

I have shown in earlier studies that the lenis stop is almost always voiceless at the beginning of the Accentual Phrase and voiced in the middle of the Accentual Phrase. Thus, the Lenis Stop Voicing rule was represented as a domain span rule, which is limited to the Accentual Phrase, α , as shown in (5).

- (5)
- $$\left[\begin{array}{l} \text{-cont, -constricted glottis} \\ \text{-spread glottis} \end{array} \right] \rightarrow [+voice] / \alpha \dots [+voice] _ _ [+voice] \dots) \alpha$$

However, as shown in previous sections, the word final lenis stop, which would be expected to be voiceless based on the glottal aperture data from Sawashima et al. (1980), is shown to be mostly voiced at the boundary of the Accentual Phrase (the beginning of the Accentual Phrase after resyllabification). Therefore, we can not claim any more that the domain of the Lenis Stop Voicing in Korean is the Accentual Phrase. One possible solution would be that there are two different lenis stop voicing rules in Korean: one is the voicing of onset lenis stops which applies within the Accentual Phrase and the other is the voicing of coda lenis stops which applies across the Accentual Phrase boundaries. Or, alternatively, we can say that a lenis stop becomes voiced in all positions but the underlying Accentual Phrase initial position. These solutions imply that the Lenis Stop Voicing rule is a categorical rule. The first solution is not favorable because two rules are needed to explain basically the same phenomena. However, if the voicing vs. voicelessness of the lenis stop is a categorical phenomena, the Lenis Stop Voicing rule should be treated as a phonological rule of some kind. Then, the next question arises: Is the Lenis Stop Voicing rule a phonological rule at all? Rather, the rule can be a byproduct of some other effect of prosodic position, still allowing us to preserve the generalization. That is, the voicing of the lenis stop can be determined by its association with a prosodic unit with a different strength.

To find out if the voicing of the lenis stop is a categorical change or not, the durations of individual tokens of the target lenis stop are plotted against the following vowel in three prosodic positions: Onset/A-initial, Onset/A-medial and Coda/A-initial. This is shown in Figure 7. If the rule is a categorical rule, we should expect separate groups of consonant durations: longer durations for the voiceless lenis stops and shorter durations for the voiced lenis stops. For the same prosodic position, tokens of voiceless lenis stop are indicated by a filled circle/triangle/square and tokens of voiced lenis stop are shown by an empty circle/triangle/square. Since all sentence pairs showed very similar patterns, the duration data in the figure combines that for all five pairs of sentences. The lenis stops in Coda/A-medial positions are not plotted because they show a similar pattern to that of Onset/A-medial position.

For all subjects, there is no clear separation between voiced and voiceless lenis stop duration. Rather, the duration of the lenis stop is negatively related to that of the following vowel: the longer the stop, the shorter the following vowel. That is, it seems that the duration of the lenis stop is trading off with that of the following vowel. Furthermore, no subject shows a clear separation between groups of the data for the different prosodic positions. Although Subject C3 seems to have a better separation between tokens in Onset/A-initial position and the tokens of the other two groups, if we compare voiced tokens with voiceless tokens in the same prosodic position, we can see clearly that the voicing of the lenis stop is predicted by the relative duration of the lenis stop and the following vowel: i.e.

longer stops followed by shorter vowels tend to be voiceless and shorter stops followed by longer vowels tend to be voiced.

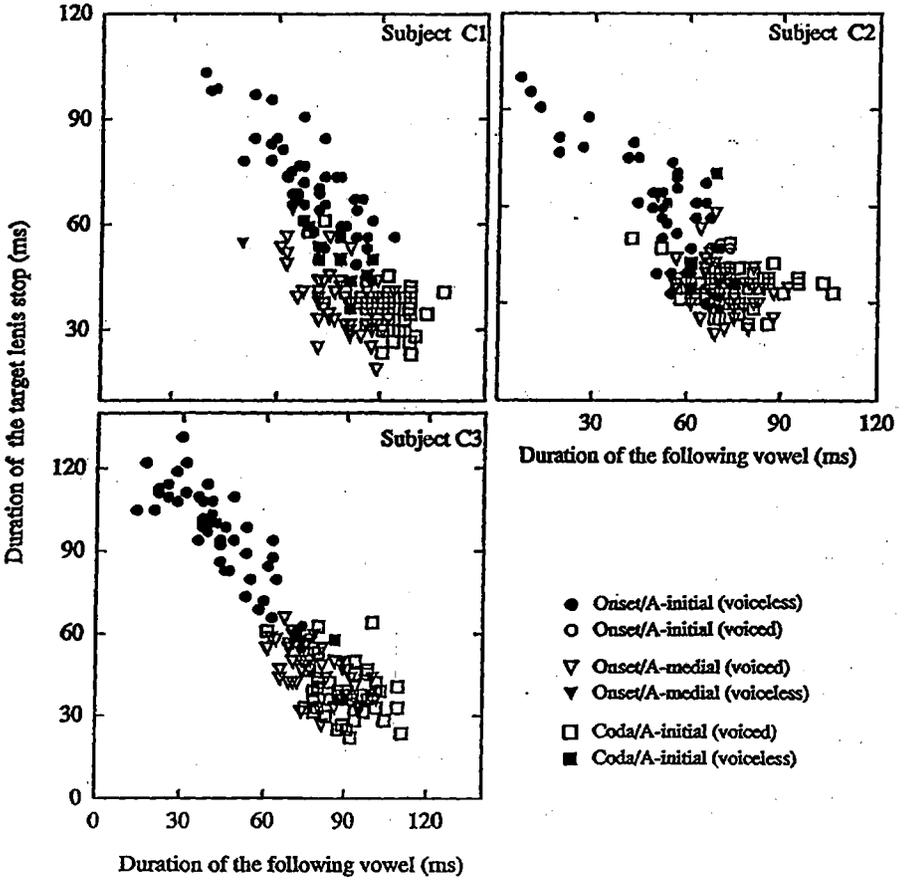


Figure 7. The duration of the target lenis stop plotted against the following vowel in three different prosodic positions for each subject: onset/A-initial, onset/A-medial and coda/A-initial position. Tokens of voiced lenis stop are indicated by a filled circle/triangle/square, and tokens of voiceless lenis stop are indicated by an empty circle/triangle/square.

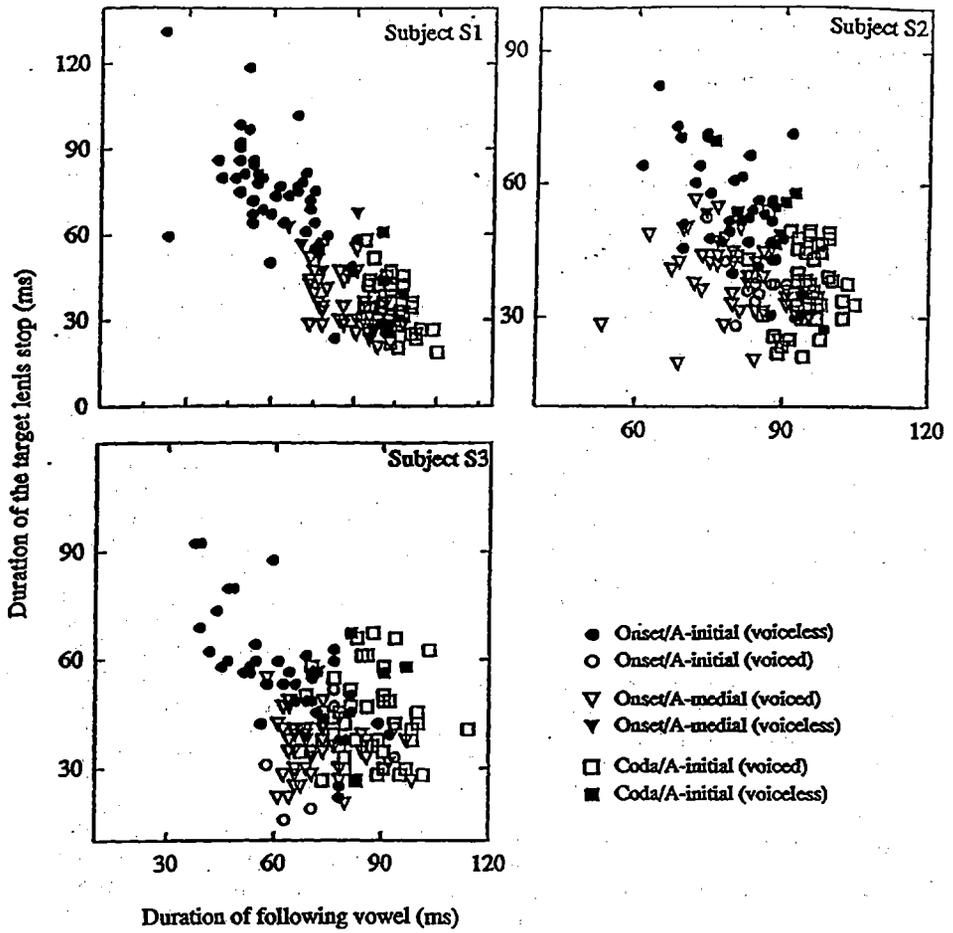


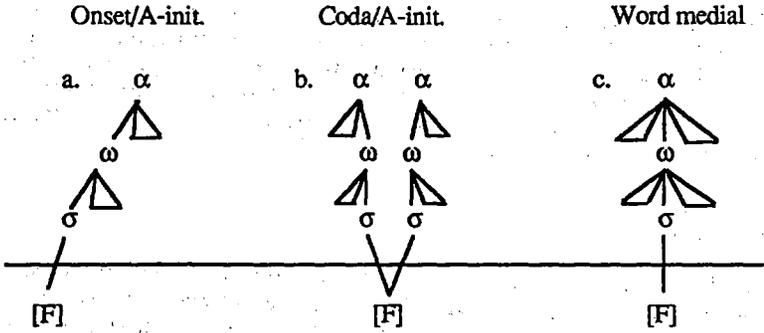
Figure 7. (Continued)

This result indicates that the lenis stop voicing is gradual. The gradual characteristic of voicing is further supported by the fact that the lenis stop is more likely to be voiced in faster speech (Jun 1990a, 1993), and also by the vowel devoicing experiment (Jun and Beckman 1993), where we found that a lenis stop in Accentual Phrase medial position is more often voiceless when it is preceded by an aspirated stop and a high vowel, or followed by a high vowel and an aspirated stop than when it is surrounded by a high vowel and a lenis stop. This gradual characteristic of voicing supports the interpretation that the lenis stop voicing rule in Korean is not a phonological rule. Rather, the lenis stop voicing seems to be the result of the prosodic position effect on segmental duration and coproduction. This interpretation is also supported by Silva (1992) who claims that the lenis stop voicing is due to the word internal weakening and phrase edge strengthening based on the closure duration and percent of closure voicing duration data. (But, here what he meant by phrase edge was mainly phrase initial. He did not test phrase final lenis stops.)³

To explain the different patterns of lenis stop voicing relative to the Accentual Phrase as well as the graduality of voicing, I posit a gradation of strengths for the realization of the glottal gesture of the lenis stop. At one end of the continuum is the lenis stop associated with a syllable at the left edge of the Accentual Phrase solely, i.e. word initial and Accentual Phrase initial lenis stop. Here, all the gestures for the segment, including the glottal opening gesture or the lip or other closure gesture, would be 'strong', having a larger amplitude and longer duration for the gesture. At the other end of the continuum is the lenis stop associated with a syllable anywhere inside the word. Here, the gestures for the segment would be 'weak', having a weaker amplitude and shorter duration. When a lenis stop is associated with the left edge of the word but within the Accentual Phrase and when a lenis stop is an underlying coda but is associated with the left edge of the following Accentual Phrase (due to the resyllabification), the gestures for both segments would show values intermediate between these two extremes. Thus, even though the coda lenis stop is associated with the left edge of the Accentual Phrase, the glottal opening gesture is not as strong as that of onset associated with the left edge of the Accentual Phrase. That is, association with the left edge of the Accentual Phrase does not have the same effect on the glottal opening gesture. To distinguish these two cases, we need information about whether the Accentual Phrase initial lenis stop is underlyingly a coda (word final) or an onset (word initial). Schematic representations of the prosodic structures conditioning the two extremes of the continuum and the coda/A-initial type lenis stop are shown in (6). Here, α is an Accentual Phrase, ω a Prosodic Word, and [F] is the bundle of features specifying the lenis stop. The horizontal line separates the prosodic specification plane from the associated segmental features. (6a) is the representation for the Accentual Phrase initial onset lenis stop. (6b) is the representation for the coda stop resyllabified across the Accentual Phrase boundary. (6c) is the representation for the word medial lenis stop. To represent the different voicing pattern of the underlying onset Accentual Phrase initial and the underlying coda Accentual Phrase initial lenis stop, [F] is associated with one α in (6a) but two α s in (6b).

³ His PE (phrase initial) category is determined based on syntactic structure of a sentence. Thus his PE is not necessarily the same as my Accentual Phrase initial. Therefore, since some of his WE (word initial) or PE could be my Accentual Phrase initial or Accentual Phrase medial, I can't compare his results with mine in terms of voicing related duration data.

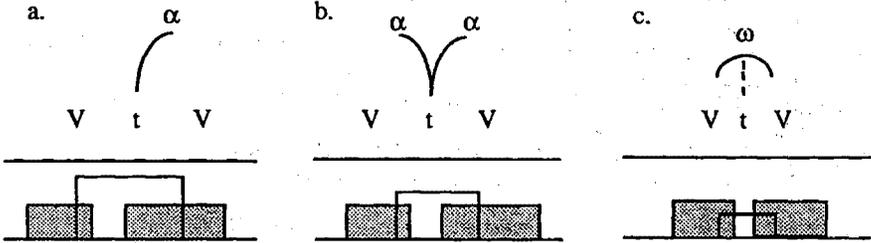
(6) Schematic representations of the prosodic structure conditioning the two extremes of the continuum and the coda/A-initial type lenis stop



Browman and Goldstein (1990) explain the intervocalic voicing assimilation as a reduction in the magnitude of the glottal opening-and-closing gesture responsible for the voicelessness. That is, if the magnitude of the opening is reduced sufficiently, devoicing might not take place at all. Based on data from Japanese (Hirose et al. 1985), where the separation between the vocal folds at the point where voicing ceases at the beginning of an intervocalic voiceless stop is much larger than at the point where voicing begins again at the end of the stop, they suggest that if the magnitude of the abduction gestures were slightly reduced, the critical value of vocal fold separation for devoicing might never be reached.

However, in addition to the different amplitude of the glottal gesture, the negative gradual relationship between lenis stop and the following vowel shown in Figure 7 suggests that there is a gestural overlapping between the lenis stop's glottal opening gesture and the following vowel's glottal closing gesture. That is, the different degrees of overlapping between the glottal opening or closing gestures and the different degrees of amplitude of the glottal gesture would produce the gradual voicing output. The hypothetical gestural score for a lenis stop, here /t/, in different prosodic positions is given in (7). Only the glottal tier is shown. The height of the box indicates degree of opening (aperture) or closing (closure) of the glottal gesture and the width of the box indicates the gesture's duration. The white box is for the glottal opening gesture and the shaded boxes are for the glottal closing gestures.

(7) Hypothetical score of overlapping glottal gestures



For the Accentual Phrase initial lenis stop, (7a), the opening gesture would be larger and longer, overlapping and hiding the vowel's glottal closing gesture,

while for the resyllabified phrase initial lenis stop, (7b), the opening gesture would be smaller and shorter and overlapping less with the following vowel. This weaker opening glottal gesture will be likely to result in the voicing and the following vowel will be longer than that in (7a) due to less overlapping with the glottal opening gesture. For the word medial lenis stop, (7c), the opening glottal gesture would be smallest and shortest, thus the voicing would easily happen as suggested by Browman and Goldstein. This kind of overlapping of consonant and vowel gestures was also used to explain vowel-to-vowel coarticulation across consonants in Ohman (1966 and later literature) and Fowler (1980).

4. Conclusion

In this paper, I examined the voicing of the word final lenis stop when it comes at the end of the Accentual Phrase. By contrast to the word initial lenis stop, which is almost always voiceless at the beginning of the Accentual Phrase, the word final lenis stop was voiced at the resyllabified Accentual Phrase initial position. The data show that the voicing of lenis stop depends on its duration relative to the following vowel and this duration is determined by their position relative to the prosodic contexts. Therefore, I proposed that the Lenis Stop Voicing rule in Korean is not a phonological rule, but is a byproduct of some other effect of prosodic position on the gestural amplitude and overlapping, thus producing a continuum of voicing. To distinguish the different duration pattern of the lenis stop, thus the different voicing pattern of the lenis stop, I suggested different prosodic representations utilizing the coda/onset information.

References

- Beckman, M. and J. Edwards. 1990. Lengthenings and shortenings and the nature of prosodic constituency. In J. Kingston and M. Beckman (eds.) *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*. Cambridge, England: Cambridge University Press, 152-178.
- Browman, C. and L. Goldstein. 1990. Tiers in articulatory phonology, with some implications for casual speech. In J. Kingston and M. Beckman (eds.) *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*. Cambridge, England: Cambridge University Press, 341-376.
- Cho, Y. Y. 1987. The Domain of Korean Sandhi Rules. Paper presented at the 62nd LSA meeting.
- Cho, Y. Y. 1990. Syntax and Phrasing in Korean. In S. Inkelas and D. Zec (eds.) *The Phonology-Syntax Connection*. Chicago: University of Chicago Press, 47-62.
- Crystal, T. and A. House. 1990. Articulation rate and the duration of syllables and stress groups in connected speech. *JASA* 88: 101-112.
- Fowler, C. 1980. Coarticulation and theories of extrinsic timing. *Journal of Phonetics* 8: 113-133.
- Hayes, B. 1989. The Prosodic Hierarchy in Meter. In Kiparsky, P. and G. Youmans (eds.) *Perspectives on Meter*, 203-260, New York: Academic Press.
- Hirose, H., S. Niimi, K. Honda, and M. Sawashima. 1985. The relationship between glottal opening and transglottal pressure difference during consonant production. *Annual Bulletin of RILP* 19: 55-64.
- Jun, S.-A. 1990a. The Domains of Laryngeal Feature Lenition Effects in Chonnám Korean. Presented at the 119th meeting of the ASA, Baltimore.

- Jun, S.-A. 1990b. The Prosodic Structure of Korean - in terms of voicing. In E-J. Baek (ed.) *Proceedings of the Seventh International Conference on Korean Linguistics*, Vol. 7. Univ. of Toronto Press.
- Jun, S.-A. 1992. The Domain of Nasalization and the Prosodic Structure in Korean. In H. Sohn (ed.) *Korean Linguistics* 7: 11-29.
- Jun, S.-A. 1993. *The Phonetics and Phonology of Korean Prosody*. Ph.D. dissertation. The Ohio State University.
- Jun, S.-A. and M. Beckman. 1993. A gestural-overlap analysis of vowel devoicing in Japanese and Korean. Paper presented at the 67th LSA Meeting, Los Angeles, CA.
- Kagaya, R. 1974. A Fiberscopic and Acoustic Study of the Korean Stops, Affricatives and Fricatives. *Journal of Phonetics* 2: 161-180.
- Kang, O. 1992. *Korean Prosodic Phonology*. Ph.D. dissertation. University of Washington.
- Keating, P., W. Linker, and M. Huffman. 1983. Patterns in allophone distribution for voiced and voiceless stops. *Journal of Phonetics* 11: 277-290.
- Nespor, M. and I. Vogel. 1986. *Prosodic Phonology*. Dordrecht: Foris.
- Ohman, S. 1966. Coarticulation in VCV utterances: spectrographic measurements. *JASA* 41: 310-320.
- Oller, D. K. 1973. The effect of position in utterance on speech segment duration in English. *JASA* 54: 1235-1247.
- Pierrehumbert, J. and D. Talkin. 1992. Lenition of /h/ and Glottal Stop. In G. Docherty & D. R. Ladd (eds.) *Papers in Laboratory Phonology II: Gestures, Segment, Prosody*, Cambridge, England: Cambridge University Press, 90-116.
- Sawashima, M., H-S. Park, K. Honda, and H. Hirose. 1980. Fiberscopic study on laryngeal adjustments for syllable-final applosives in Korean. *Ann. Bull. RILP*, No. 14: 125-138.
- Selkirk, E. 1984. *Phonology and Syntax: The Relation between Sound and Structure*, Cambridge, MA: MIT Press.
- Selkirk, E. 1986. On Derived Domains in Sentence Phonology. *Phonology Yearbook* 3: 371-405.
- Silva, J. D. 1989. Determining the Domain for Intervocalic Stop Voicing in Korean. In S. Kuno et al. (eds.) *Harvard Studies in Korean Linguistics III.*, Cambridge, MA: Harvard Univ. Press.
- Silva, J. D. 1992. *The Phonetics and Phonology of Stop Lenition in Korean*. Ph.D. dissertation. Cornell University.