

17.1 Introduction

It is well established that prosody conditions segmental and suprasegmental features. In English, for example, segments are lengthened at the end of a phrase (e.g. Oller, 1973; Beckman & Edwards, 1990), and the "gestural magnitude" of /h/ is weakened word medially or in deaccented words (Pierrehumbert & Talkin, 1992). Additionally, Keating, Linker & Huffman (1983) show that many languages have different allophones for voiced or voiceless stops depending on position within the word or the phrase. However, such effects are often not symmetrical with respect to the edges of a prosodic unit. 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 initial and word final position. In syllable initial position, there is a three-way contrast among aspirated, tense, and lenis voiceless obstruents, but this contrast is preserved only in the initial position of a word in isolation. In word medial onset position, the lenis stops are voiced between sonorants. In syllable final position, the distinction is neutralized completely to an unreleased lenis stop. The weakening processes in word medial and syllable final position have been described by phonologists (e.g. Cho, 1987; Kim-Renaud, 1974; Kang, 1992) as Lenis Stop Voicing and Coda Neutralization, respectively.

In Jun (1990a, 1990b, 1993), I show that Lenis Stop Voicing applies to a word initial lenis stop if the word and the preceding word are uttered in the same prosodic domain, higher than the Prosodic Word level, and equal to the

Lehiste, I. 1975. Experiments with synthetic speech concerning quantity in Estonian
Congressus Tertius Internationalis Fenno-Ugristrarum, Pars I Acta Linguistica
 Helsinki: Suomalais-Ugrialainen Seura, 254-269.

Lehtonen, J. K. 1992. Modeling assimilation in a non-segmental rule-free phonology. In G. J.
 Docherty & D. R. Ladd (eds.), *Papers in Laboratory Phonology II: Gesture,
 Segment, Prosody*. Cambridge: Cambridge University Press, 190-223.

Local, J. & A. Simpson. 1988. The domain of gemination in Malayalam. In D. Bradley,
 E. J. A. Henderson, & M. Mazaudon, (eds.), *Prosodic Analysis and Asian
 Linguistics: to Honour R. K. Sprigg, Pacific Linguistics, Series C no. 104*: 33-42.

McCarthy, J. J. 1989. Linear order in phonological representation. *Linguistic Inquiry* 20:
 71-99.

Ogden, R. A. 1992. Parametric interpretation in YorkTalk. *York Papers in Linguistics* 16:
 81-99.

Ogden, R. A. 1993. What Firthian Prosodic Analysis has to say to us. *Edinburgh
 Working Papers in Cognitive Science 8 (Computational Phonology)*: 107-127.

Palmer, F. R. (ed). 1970. *Prosodic Analysis*. London: Oxford University Press.

Sammallahti, P. 1977. *Norjansamen itä-Eonietkiön murteen äänneoppi* [The
 synchronic phonology of Eastern Eonietkiö dialect of Norwegian Lappish].
 Helsinki: Suomalais-Ugrialaisen Seuran Toimituksia 160.

Sprigg, R. K. 1961. Vowel harmony in Lhasa Tibetan: prosodic analysis applied to
 interrelated vocalic features of successive syllables. *Bulletin of the School of
 Oriental and African Studies* 24: 116-38. Also in F. R. Palmer (ed.), 1970, 230-252.

Wiik, K. 1981. *Fonetikkon Perusteet*. Juva WSOY.

Wiik, K. 1991. On a third type of speech rhythm: foot timing. *Proceedings of the XIIIth
 International Congress of Phonetic Sciences, Aix-en-Provence, 3*: 298-301.

In Phonology and Phonetics
Evidence. Papers in
Laboratory Phonology IV
 eds. by S. Connell and
 A. Arvaniti
 Cambridge Univ. Press.
 1995

Phonological Phrase proposed in the theory of Prosodic Phonology (Selkirk, 1986; Nespor & Vogel, 1986; Hayes, 1989). I call this higher level an *Accentual Phrase* because this level is defined on the basis of the intonational pattern of an utterance (see section 17.2). I propose that the domain of Lenis Stop Voicing is the *Accentual Phrase*.¹ Since Lenis Stop Voicing is a domain span rule in Selkirk's (1986) sense (applying anywhere within a certain domain), all intersonorant lenis stops both in onset and coda position are claimed to be voiced if the lenis stop is within the *Accentual Phrase*, α , as shown in (1) (Jun, 1993).

(1)

[-cont, -constricted glottis] → [+voice] / α [... [+voice]] [+voice] (...) α

However, to my knowledge, the voicing of word final lenis stop at the end of an *Accentual Phrase* or a *Phonological Phrase* has not been studied.

In this paper, I focus on the voicing of the coda lenis stop at the end of the *Accentual Phrase* as in [kimbaɸ] (arami) "Was the sushi frozen?" (/kimpap/ "sushi", /al-ass-ni/ "to freeze-past-Q"). (Throughout this paper, *Accentual Phrases* are given in phonetic transcription and enclosed in curly brackets.)

Acoustic data show that word final lenis stops very often become voiced across an *Accentual Phrase* boundary. Furthermore, the domain of //Flapping confirms that the *Accentual Phrase* final lenis stop is voiced when it is resyllabified as the onset of the initial syllable of the following *Accentual Phrase*. Moreover, the durational relationship between the lenis stop and the adjacent segments in different prosodic positions suggests that voicing of a lenis stop is not a categorical change, but a by-product of prosodic structure. In the last section, the phonetic nature of the rule is interpreted in terms of gestural overlap and reduction based on Browman and Goldstein's (1990) model. This experiment shows the importance of the underlying prosodic structure in the realization of phonetic features. That is, a resyllabified onset lenis stop is different from an underlying onset lenis stop in terms of the magnitude of glottal gesture.

Before introducing the experimental methods, I briefly introduce the definition of the *Accentual Phrase* and its relation to Lenis Stop Voicing based on Jun (1989, 1990a, 1990b, 1993).

17.2 The *Accentual Phrase*

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 an *Accentual Phrase* is a final rise, L(H)LH, with the first High optionally appearing when the phrase is longer than four or five syllables. In the Chonnam

dialect, the characteristic pattern is an initial rise-fall or fall, either LHL or HHL. The choice of pattern is determined by the laryngeal features of the first segment of the *Accentual Phrase*: when the segment has either [+spread glottis] (aspirated consonants and /s/) or [+constricted glottis] (tense consonants), the *Accentual Phrase* has the HHL pattern; otherwise it has the LHL pattern. I show in Jun (1993) that the *Accentual Phrase* is the domain of several postlexical phonological rules, and that Lenis Stop Voicing is one of them. Figure 17.1 illustrates the voicing of a lenis stop in different positions in the *Accentual Phrase* produced by a Seoul speaker for the sentence given in (2). The X-axis shows time and the Y-axis fundamental frequency in Hz. (This format is used for all pitch track figures in this paper.)

(2) jalme-ka jal-ass-ni

"the fruit - NOM" "sweet-past-Q marker" => "Was the fruit sweet?"

The *Accentual Phrases* in Figure 17.1(a) have a final rise with an initial High being undershot, but the *Accentual Phrase* in Figure 17.1(b) has both an initial

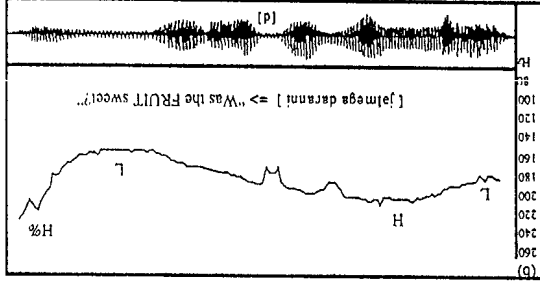
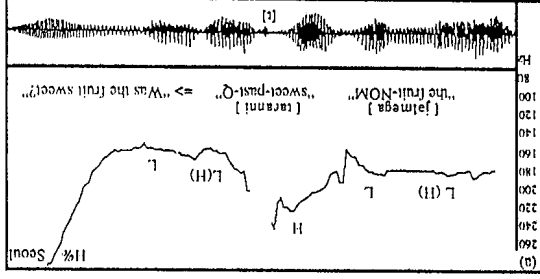


Figure 17.1. Pitch tracks and waveforms of *jalme-ka tal-ass-ni* in two *Accentual Phrases* by S2, forming (a) two *Accentual Phrases* as in [jalme-ka] [tal-ass-ni] and (b) one *Accentual Phrase* as in [jalme-ka darani].

Table 17.1. Corpus sentences for voicing, in phonemic transcription. Sentences in brackets show a morpheme breakdown indicated by “-”.

Asymmetrical effects on the laryngeal gesture

1. a. *fajmekā lās sni (namu) “Was the fruit sweet? (the tree)”*
/fajme-ka tal-ass-ni/ “the fruit-NOM” “sweet-past-Q”
/fajmekās ā lassni (namukas)³ “Did you know the fruit-hat? (the tree-hat)”
/fajme-kas al-ass-ni/ “the fruit-hat” “to know-past-Q”
2. a. *anīyū kā lassni (salku) “Did you grind the snacks to eat with drink? (the apricot)”*
/anīyū kal-ass-ni/ “the snacks to eat with drink” “to grind-past-Q”
b. panīlūk ā lassni (sokam) “Did you know the paste? (the salt)”
/panīlūk al-ass-ni/ “the paste” “to know-past-Q”
3. a. *fjampā pā jassni (opa) “Did you throw away the jacket? (the overcoat)”*
/fjampa pali-ass-ni/ “the jacket” “to throw away-past-Q”
b. kimpāp ā lassni (pokkimpap) “Was the sushi frozen? (the fried rice)”
/kimpap al-ass-ni/ “the sushi” “to frozen-past-Q”
4. a. *sal kū kā lassni (anīyū) “Did you grind the apricot? (the side food for liquor)”*
/sal kū kā lassni (anīyū) “the apricot” “to grind-past-Q”
b. sukūk ā lassni (nanī^ho) “Did you know the water mum? (the illy)”
/sukūk al-ass-ni/ “the water mum” “to know-past-Q”
5. a. *fjansin kū tā lassni (fjagnankam) “Did you wear the ornament? (the toy)”*
/fjansin kū tā lassni (nelimkus) “Did you know ‘fjansin-shamanism ceremony?’
 (“descending shamanism ceremony”)
/fjansin-kus al-ass-ni/ “fjansin-shamanism ceremony” “to know-past-Q”

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 were the same. The target segments and the relevant context segments are underlined.⁴ The word in parentheses after each sentence was used to trigger contrastive focus.

17.3.3 Methods

These sentences were placed in semi-random order, so that no sentence immediately followed the other sentence from the pair. This strategy was employed to avoid putting emphasis on the difference. Subjects were asked to read the list in two different Accentual Phrasings 10 times each at normal speech

rise and a final rise.² As shown by the absence of sinusoidal waveform and the broken line on the pitch track in Figure 17.1(a), the Accentual Phrase initial lenis stop is voiceless, [t]. However, the same lenis stop is voiced, [d], in the middle of the Accentual Phrase as shown in Figure 17.1(b). Figure 17.2 shows the same effect, but differs from Figure 17.1 in that this utterance is produced by a Chonnam speaker, thus having a different verbal ending and an initial rise contour, LHL.

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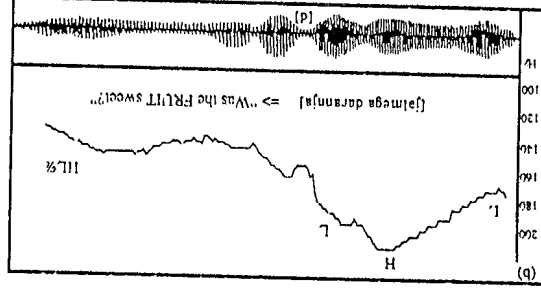
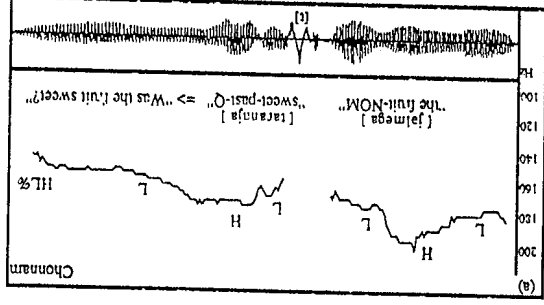


Figure 17.2. Same as Figure 17.1 produced by a Chonnam speaker, C1.

17.3 Experimental methods

17.3.1 Subjects

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

17.3.2 Material

Five pairs of two word sentences (listed in Table 17.1) were constructed so that one sentence of the pair has a lenis stop at the beginning of the second word.

rate. First, they read the list of sentences without contrastive focus, and 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. For the second reading, subjects were asked to read each sentence by contrasting the first word with the word in parentheses, thus facilitating the production of the whole sentence in one Accentual Phrase. An example is shown in (3). (The verbal endings given in this paper are for the Seoul speakers. For Chonnam speakers, [-nja] was substituted for [-ni].)

- (3) Given: jalme-ka talassni? (namu) "Was the fruit sweet? (the tree)"
 Read: {jalme-ga daranni} {namuga daranni} ?
 "Was the fruit sweet or was the tree sweet?"

For each utterance, the target lenis stop and context segments were analyzed for voicing using a Kay Sonagraph Model 5500 and the pitch track was checked for Accentual Phrasing. The audio waveform and amplitude were displayed simultaneously in the upper window, thus providing further cues to segmentation. The durations of the target lenis stop, underlyingly Accentual Phrase final or initial, as well as the duration of the following and preceding vowels, were measured using the spectrogram display. The durations of adjacent vowels were measured to see whether a segment shows any difference in duration depending on its position relative to the Accentual Phrase. In addition, I measured the word medial lenis stop (except for 3(b) in Table 17.1, where /p/ is produced as [pʰ]) to compare its duration with that of the word initial/final lenis stop. For the lenis stop, the duration was measured to include closure duration and any 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 had a clear amplitude (usually immediately after the stop release) to the point where the formant ceases (usually at the beginning of closure of the target lenis stop). The duration of the vowel following the target lenis stop was measured from the first formant onset to the onset of a flap.

17.4 Results and Discussion

17.4.1 Voicing of the Accentual Phrase final lenis stop and resyllabification

As in my earlier work, onset stops are mostly voiceless in Accentual Phrase initial position, and voiced in Accentual Phrase medial position. But, for all subjects, word final coda stops are voiced most of the time. Out of 300 tokens (5 sentences × 6 subjects × 10 repetitions) for each prosodic condition, 5 to 10% of

tokens show an exception to this voicing pattern: 10.67% were voiced at Onset/A-initial position, 4.78% were voiceless at Onset/A-medial position, 8.36% were voiceless at Coda/A-final position, and 4.76% were voiceless at Coda/A-medial position. Depending on the position of the target lenis stop relative to a Prosodic Word or an Accentual Phrase, I defined four prosodic positions as in Table 17.2. Figure 17.3 shows the percentage of voiced versus voiceless lenis stops in the four prosodic positions.

Contrary to my prediction, the lenis stop seems to differ in its voicing depending on which edge of an Accentual Phrase it occurs in. Only the lenis stop in the Accentual Phrase initial position remains voiceless, while that in the Accentual Phrase final position is not. Accordingly, the data do not support the claim that

Table 17.2. Four prosodic positions of the target lenis stop.

Prosodic Position	Word	Accentual Phrase
1	Onset/A-initial	beginning
2	Onset/A-medial	beginning
3	Coda/A-final	end
4	Coda/A-medial	end

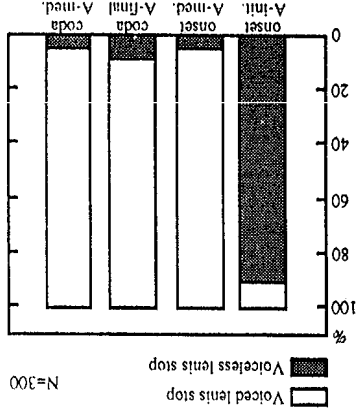


Figure 17.3. Percentage of voiced versus voiceless lenis stop in four prosodic positions combining data from six subjects (N=300).

Lenis Stop Voicing is a domain span rule. The Lenis Stop Voicing rule may apply anywhere except at the beginning of an Accentual Phrase.

However, there is a problem with this analysis. In Korean, a coda is resyllabified as an onset within a word and across word boundaries. Cho (1987) and Kang (1992) claim that the domain of resyllabification is the Intonational Phrase, a prosodic level higher than the Phonological Phrase. However, to my knowledge, there is no available phonetic data concerning the domain of resyllabification. To determine whether the coda lenis stop is resyllabified within the Intonational Phrase, i.e., across the Accentual Phrase boundary, the domain of another phonological rule, //Flapping, was examined in a pilot study.

In Korean, // only surfaces in a coda position, unless it is part of a geminate. By //Flapping, // becomes a flap, [ɾ] intervocalically and is realized as an onset to the following syllable. That is, the allophones of // are assumed to be syllabically determined. In the pilot study, I examined the domain of //Flapping, using five sentences. Each sentence had an object NP ending in // and a verb beginning with a vowel. The same six subjects read each sentence in two different Accentual Phrasings 10 times each; one in one Accentual Phrase and the other in two Accentual Phrases with each word forming one Accentual Phrase.

The results show that resyllabification *can* occur across any word boundaries within an Intonational Phrase. The frequency of flapping varied across speakers but all speakers produced a flap across an Accentual boundary ranging from 65% to 98% of the time.⁵ Thus, I assume that any coda can be resyllabified to be the onset of the initial syllable of the following Accentual Phrase, provided the Accentual Phrase is vowel-initial. Since an obstruct coda is neutralized to an unreleased lenis stop, and since the unreleased stop is shown to have a small but still open glottal configuration, i.e., is voiceless, (Sawashima *et al.*, 1980), I assume that a coda stop that is not resyllabified to an onset is unreleased and thus voiceless, while a resyllabified coda stop is released and becomes voiced. This means that the Accentual Phrase final lenis stop is resyllabified most of the time.⁶ To reflect the resyllabification, I hereafter use the term *Coda/A-initial* instead of *Coda/A-final*, when referring to this prosodic position.

The pitch contours and the corresponding segmental realization in Onset/A-initial position are shown in Figure 17.1(a) and those in Onset/A-medial position are shown in Figure 17.1(b). Accentual phrasings and the corresponding segmental realizations in Coda/A-initial and Coda/A-medial position are shown in Figure 17.4. The voicing of lenis stops in each prosodic position is outlined in (4). The arrows in (4c) and (4d) indicate resyllabification. Here, a dot indicates a syllable boundary.

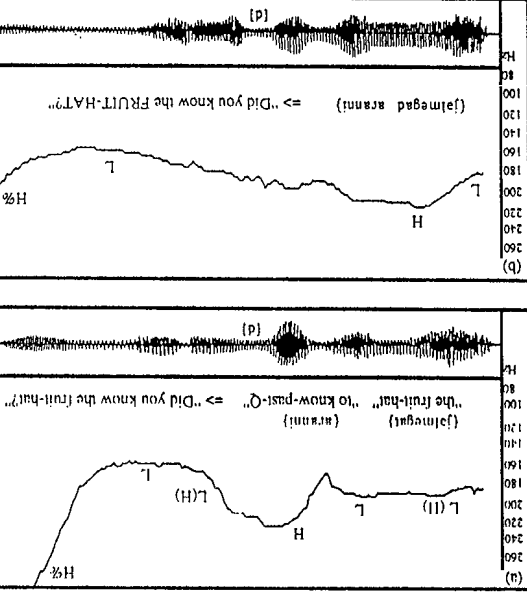


Figure 17.4. Pitch tracks and waveforms of lenis stop in two prosodic positions: (a) Coda/A-initial, (b) Coda/A-medial. The sentence is from Table 17.1(b) (speaker: S2).

- (4) jalmeŋka talassni? "Was the fruit sweet?"
- a. {jalmeŋga} {taraŋni} ⇒ [jal.me.ŋa.ta.ra.ni] : Onset/A-initial
- b. {jalmeŋga darani} ⇒ [jal.me.ŋa.da.ra.ni] : Onset/A-medial
- c. {jalmeŋga} {araŋni} ⇒ [jal.me.ŋa.da.ra.ni] : coda/A-initial
- d. {jalmeŋga araŋni} ⇒ [jal.me.ŋa.da.ra.ni] : coda/A-medial

As expected, the underlying onset or coda /l/ is voiced in Accentual Phrase medial position, (4b) and (4d), whereas the underlying onset /l/ is voiceless at the beginning of the Accentual Phrase, (4a). However, the resyllabified word initial /l/, as in (4c), is still *voiced*, as shown in Figure 17.4 (a). Thus, even though the tonal pattern of Figure 17.4 (a) is different from those of Figure 17.1 (b) and Figure 17.4 (b), all three are alike in terms of segmental realization. It was often difficult to distinguish between types (4b) and (4d) solely by listening, but type (4c) was easily distinguished due to the different tonal pattern.

In summary, we can predict most of the voicing data in terms of the underlying prosodic context of the lenis stop; a lenis stop is voiceless only when it is an underlying onset at the beginning of an Accentual Phrase, but voiced otherwise.

17.4.2 Duration of lenis stop and adjacent segments in different prosodic positions

Figure 17.5 shows the mean durations of the vowel preceding the target lenis stop (highly shaded bar), the target lenis stop (white bar), and the following vowel (highly shaded bar) plotted in the four different prosodic positions: Onset/A-initial, Onset/A-medial, Coda/A-initial, and Coda/A-medial position. The mean value of the word medial lenis stop is shown on the first row for each subject. (Here, this value is only based on the word medial lenis stop between vowels.)

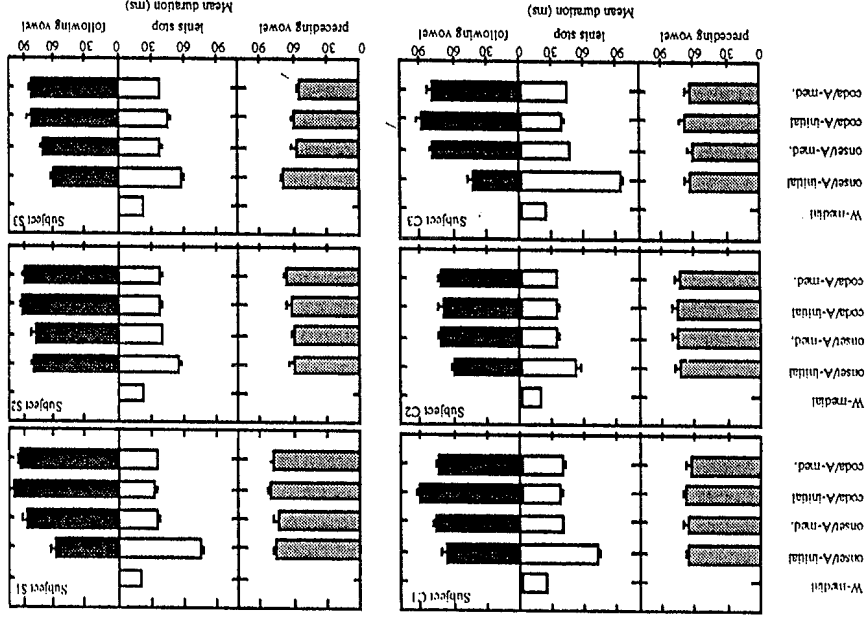


Figure 17.5. The mean duration of the word medial lenis stop, the vowel preceding the target lenis stop, the target lenis stop, and the following vowel in four different prosodic conditions (Onset/A-initial, Onset/A-medial, Coda/A-initial, and Coda/A-medial) for each subject. A standard deviation is shown on top of each bar.

For all subjects, there is a significant main effect of prosodic position on the target lenis stop duration (ANOVA for all: $p < 0.0001$, $df = 4$; $F_{C1} = 119.7$, $F_{C2} = 34.3$, $F_{C3} = 279.9$, $F_{S1} = 94.7$, $F_{S2} = 53.9$, $F_{S3} = 56.3$). The result of a *post hoc* test (Tukey, $\alpha = 0.01$) shows effects of Prosodic Word boundary and Accentual Phrase boundary: the word initial and final lenis stops are significantly longer than the word medial lenis stop, and the target onset lenis stop is significantly longer than the word medial lenis stop. This agrees with the results of Jun (1990a) regarding the duration of VOT of aspirated stops.

In addition, for all subjects, the target lenis stop is significantly longer in Onset/A-initial position than in Coda/A-initial position (Tukey, $\alpha = 0.01$). However, the target lenis stop is not significantly different among onset/A-med, Coda/A-initial, and coda/A-med. The vowel following a lenis stop also shows a significant main effect of prosodic position (ANOVA for all: $p < 0.0001$, $df = 3$; $F_{C1} = 27.3$, $F_{C2} = 18.0$, $F_{C3} = 123.8$, $F_{S1} = 103.2$, $F_{S2} = 11.2$, $F_{S3} = 33.5$). Except S2, vowels following Onset/A-initial lenis stops are significantly shorter than vowels following lenis stops in all other positions (Tukey, $\alpha = 0.01$). At the same time, vowels following Coda/A-initial lenis stops are in general longer than vowels following lenis stops in all other positions (significant at $\alpha = 0.01$ for C1, C3, S1). In fact, the vowel following Coda/A-initial lenis stop is the underlying initial segment of the Accentual Phrase. 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 shows the same effect, the duration of the vowel preceding the target lenis stop was examined. For all subjects, there is no significant difference among the four prosodic positions; there is no lengthening effect at the end of the Accentual Phrase. Thus, the boundary effect is not necessarily symmetrical at this level. But, at the same time, the prosodic boundary effect on the segment is not uniform: in Korean, Accentual Phrases show a left edge lengthening while the Intonational Phrase shows a right edge lengthening (Jun, 1992). Also the domains and patterns of these lengthening effects are not universally the same: for example, unlike Korean, English has a right boundary effect at both the Word level and the phrase level (Beckman & Edwards, 1990; Crystal & House, 1990).

17.4.3 The representation of lenis stop voicing

Since the word final lenis stop is shown to be mostly voiced at the boundary of the Accentual Phrase, we can no longer claim that the domain of the Lenis Stop Voicing in Korean is the Accentual Phrase. Rather, we can say that a lenis stop becomes voiced everywhere except in underlying Accentual Phrase initial position. But the question is whether Lenis Stop Voicing is indeed a categorical rule. To determine the categorality of this phenomenon, the durations of

For all subjects, there is no separation of data clouds between voiced and voiceless lenis stop duration. Rather, the duration of the lenis stop is negatively correlated to that of 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 the groups of the data for the different prosodic positions. Subject C3 seems to have a better separation between the tokens in Onset/A-initial position and the tokens of the other two groups. However, if we compare voiced tokens with voiceless tokens in the same prosodic position, we can clearly see 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.

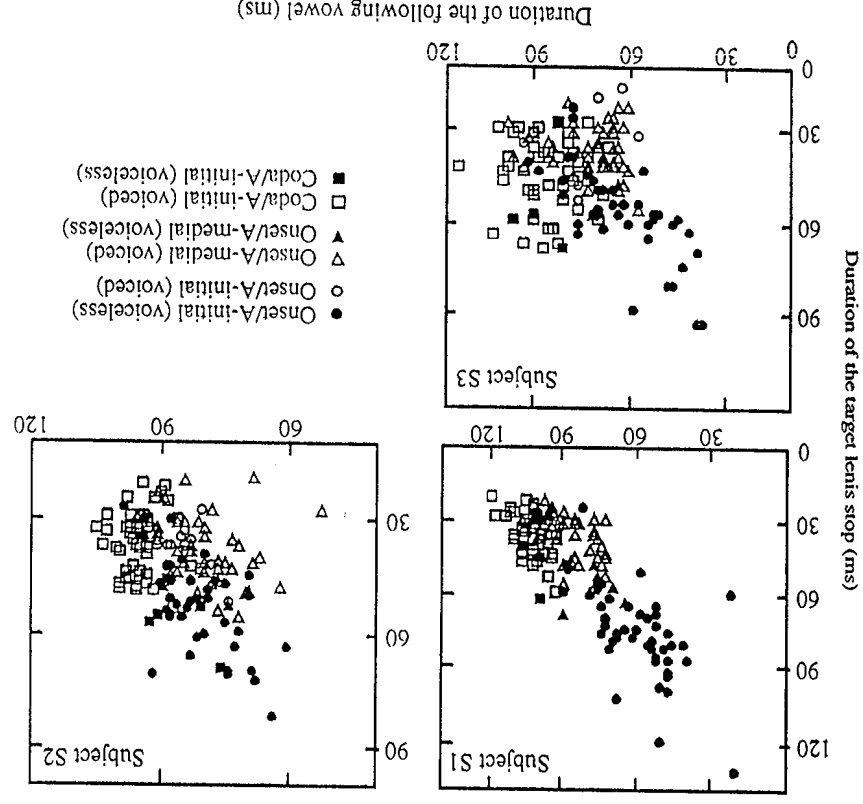


Figure 17.6. (continued)

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 17.6. If the rule is categorical, we would expect two separate groups of consonant durations: longer duration for the voiceless lenis stop and shorter duration for the voiced lenis stop. Here, a token was counted "voiced" if voicing continues through for the duration of the consonant, while "voiceless" if voicing continues through for the duration of the consonant, while all partially or fully voiceless ones were considered "voiceless". The lenis stops in Coda/A-medial position showed a similar pattern to that of Onset/A-medial position. For graphing convenience, only the lenis stops in Onset/A-medial position are plotted.

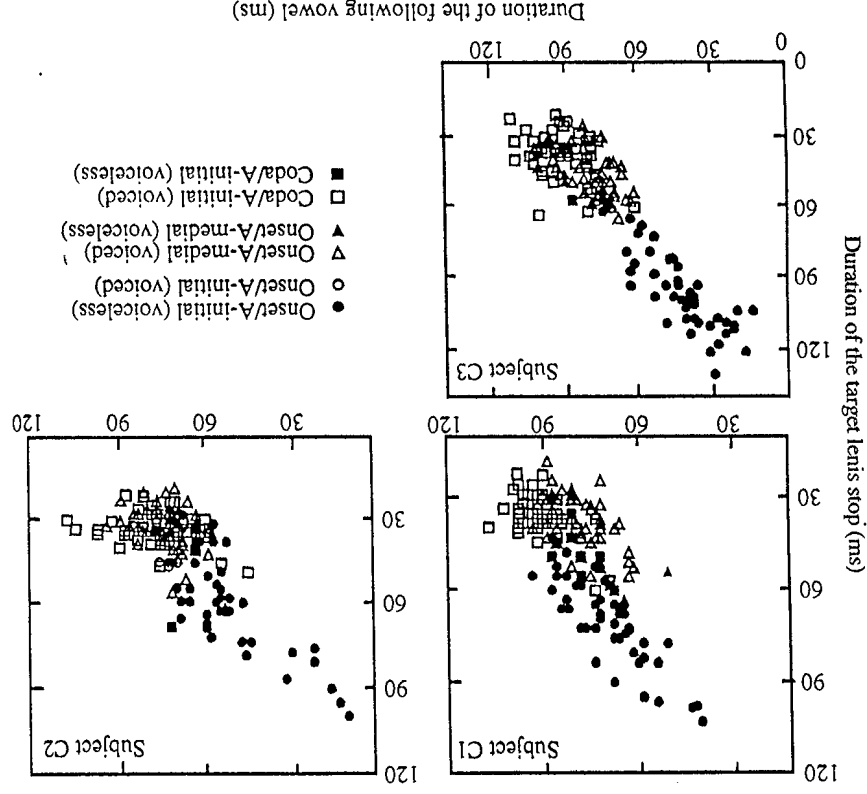
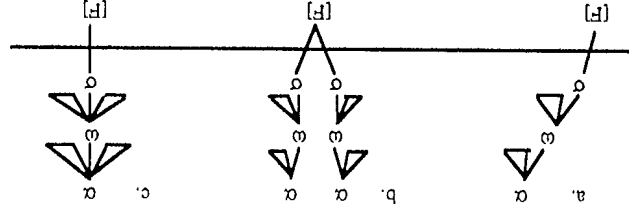


Figure 17.6. The duration of the target lenis stop against the following vowel, for each subject, in three different prosodic positions: Onset/A-initial, Onset/A-medial and Coda/A-initial position. Tokens of voiced lenis stop are indicated by a filled circle/triangle/square, and tokens of voiceless lenis stop are indicated by an empty circle/triangle/square.

representation for the coda stop resyllabified across the Accentual Phrase boundary. (5c) is the representation for the word medial lenis stop. To represent the different voicing patterns of the underlying onset vs. coda Accentual Phrase initial lenis stops, [F] is associated with one Accentual Phrase in (5a) but two Accentual Phrases in (5b).⁹ Brownman & Goldstein (1990) explain intervocalic voicing assimilation as a reduction in the magnitude of the glottal opening gesture responsible for 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, Nitsumi, Honda & Sawashima (1985) suggest that if the magnitude of the abduction gestures is slightly reduced, the critical value of vocal fold separation for devoicing might not be reached.

(5) Schematic representation of the prosodic structure conditioning the two extremes of the continuum and the Coda/A-initial type lenis stop.



However, in addition to the different amplitude of the glottal gesture, the negative gradient relationship between lenis stop and the following vowel, shown in Figure 17.6, suggests that there is gestural overlap 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 and closing gestures and the different degrees of amplitude of the glottal gesture would produce the gradient voicing output. The hypothetical gestural score for a lenis stop, here [t], in different prosodic positions is given in (6). 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 this gesture's duration. The white boxes represent the glottal opening gesture and the shaded boxes represent the glottal closing gesture. For the Accentual Phrase initial lenis stop, (6a), 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, (6b), the opening gesture would be smaller and shorter and overlapping less with the following vowel. This weaker opening glottal gesture would probably result in voicing and the following vowel will be longer than that in (6a) due to less overlap with the

This result suggests that voicing is a function of duration. This duration-

sensitive voicing is further supported by the fact that the lenis stop is more likely to be voiced in faster speech (Jun, 1990a, 1993). Thus, the voice/voiceless distinction is not a categorical change. This non-categoricity is also supported by Jun & Beckman (1993), who found that the voicing of a lenis stop in Accentual Phrase medial position is influenced by segmental context: a lenis stop is more often voiceless when it is preceded by an aspirated stop and a high vowel, or followed by a high vowel and a lenis stop. That is, a lenis stop is more likely to be voiced in faster rate, in shorter duration, and next to a segment with a stronger voicing gesture. This characteristic of gradient voicing supports the interpretation that Lenis Stop Voicing in Korean is not a phonological rule.⁷ Rather, lenis stop voicing itself is a gradient process, whose output is determined by the effects of prosodic position on the strength of glottal gestures and coproduction. This interpretation is also supported by Silva (1992) who claims that lenis stop voicing is due to the word internal weakening and that phrase edge strengthening is based on closure duration and percent of closure voicing data.⁸

To explain the different patterns of lenis stop voicing relative to the Accentual Phrase as well as the gradient nature 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, i.e., Onset/A-initial lenis stop. Here, all the gestures for the segment, including the glottal opening gesture and oral gesture, are "strong", having a larger amplitude and longer duration. 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 are "weak", having a smaller 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 resyllabification), the gestures for both segments possess 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 an onset associated with the left edge of the Accentual Phrase.

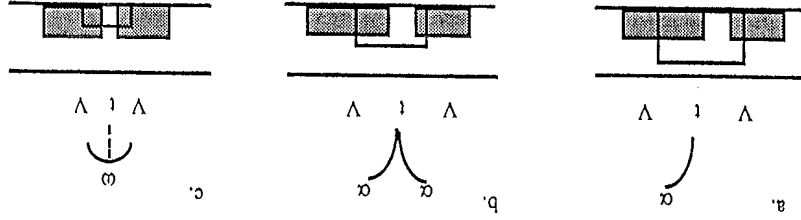
To distinguish these two cases, we need to know whether the Accentual Phrase initial lenis stop is underlyingly a coda (word final) or an onset (word initial). Schematic representations of the prosodic structures conditioning the two extremes of the continuum and the Coda/A-initial type lenis stop are shown

in (5).

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. (5a) is the representation for the Accentual Phrase initial onset lenis stop, and (5b) is the

glottal opening gesture. For the word medial lenis stop, (6c), the opening glottal gesture would be the smallest and shortest, thus voicing could easily occur as suggested by Brownman & Goldstein (1990).¹⁰

(6) Hypothetical score of overlapping glottal gestures



17.5 Conclusion

In contrast to word initial lenis stops in Korean, which are almost always voiceless at the beginning of the Accentual Phrase, word final lenis stops are voiced in resyllabified Accentual Phrase initial position. The data show that the voicing of lenis stops depends on their duration relative to the following vowel and that their duration is determined by their prosodic position. Therefore, I propose that the Lenis Stop Voicing rule in Korean is not a phonological rule, but a by-product of some other effect of prosodic position on the gestural amplitude and overlapping, thus producing a continuum of voicing. To distinguish the different duration patterns of lenis stops, and the resulting difference in the voicing patterns of these stops, I suggest different prosodic representations utilizing the coda/onset information. The lenis stop voicing pattern in Korean illustrates that the information of prosodic structure is reflected in the phonetic realization of the segment.

Notes

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1 Cho (1987, 1990), Kang (1992) and Silva (1989, 1992) propose the Phonological Phrase as the domain of Lenis Stop Voicing based on either Selkirk's (1986, 1990) end-based theory, or Nespor and Vogel's (1986) relation-based theory.
 2 The final rise in Figure 17.1(b) and that of the second Accentual Phrase in Figure 17.1(a) are due to the intonational phrase boundary tone (H%) for an interrogative sentence.
 3 The word final coda /s/ is realized as [t] due to Coda Neutralization, thus becoming a minimal pair with the sentence in (1a). The same is true for the word final /s/ in (5b).
 4 The words *jalmekat* in (1b) and *ɕagsinkut* in (5b) in Table 17.1 are not real but possible words. Subjects had no trouble understanding the possible meanings.
 5 The percentage was a little higher (70–100%) within an Accentual Phrase for every speaker. It seems that // -flapping depends on the force of articulation: more emphasis given to a coda results in less // -flapping. Thus, flapping happens more often in fast and casual speech.
 6 Comparing the voicing data with the // -flapping data, it seems that a lenis stop is more likely to be resyllabified than // . I think this is because there are two strategies for // resyllabification: by flapping // or by geminating // . I found from acoustic data that some speakers lengthen the coda //, thereby making it also function as an onset. This // -gemination seems to be the result of emphasizing the coda // . To clarify this phenomenon, articulatory data, as well as more acoustic data, are needed.
 7 There were also different degrees of voicing within a stop closure, as claimed by Silva (1992); the shorter the stop, the higher the percentage of voicing. But this kind of gradience is not incorporated in my analysis here.
 8 His phrase edge was mainly phrase initial. Moreover, since his PE (phrase initial) category is based on the syntactic structure of a sentence, his results are not comparable with mine in terms of voicing with respect to duration.
 9 The weak gesture of the underlying coda can also be shown in English Flapping data. In English, // can be a flap across a word boundary if the // is a coda and also becomes an onset (ambisyllabic). On the other hand, a word initial onset // can never be a flap (Kahn, 1976); e.g. *ear* [tʰ] *again* vs. *my* [tʰ] *on* *again*.
 10 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).

References

- Beckman, M. E. & J. Edwards. 1990. Lengthenings and shortenings and the nature of prosodic constituency. In J. Kingston & M. E. Beckman (eds.), *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*. Cambridge: Cambridge University Press, 152–178.
 Brownman, C. P. & L. Goldstein. 1990. Tiers in articulatory phonology, with some implications for casual speech. In J. Kingston & M. E. Beckman (eds.), *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*. Cambridge: 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 & D. Zec (eds.), *The Phonology-Syntax Connection*. Chicago: University of Chicago Press, 47-62.
- Crystal, T. & A. House. 1990. Articulation rate and the duration of syllables and stress groups in connected speech. *Journal of the Acoustical Society of America* 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 P. Kiparsky & G. Youmans (eds.), *Perspectives on Meter*. New York: Academic Press, 203-260.
- Hirose, H., S. Nijimi, K. Honda & M. Sawashima. 1985. The relationship between glottal opening and transglottal pressure difference during consonant production. *Annual Bulletin of the Research Institute of Logopedics and Phoniatrics* 19: 55-64.
- Jun, S-A. 1990a. *The domains of laryngeal feature lenition effects in Chonnamm Korean*. Paper presented at the 19th ASA meeting.
- Jun, S-A. 1990b. The prosodic structure of Korean - in terms of voicing. In E.-J. BaeK (ed.), *Proceedings of the 7th International Conference on Korean Linguistics*. Toronto: University of Toronto Press, 87-104.
- 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. & M. E. Beckman. 1993. A gestural-overlap analysis of vowel devoicing in Japanese and Korean. Paper presented at the 67th LSA meeting.
- Kahn, D. 1976. Syllable-based generalizations in English phonology. Ph.D. dissertation, MIT.
- Kang, O. 1992. Korean prosodic phonology. Ph.D. dissertation, University of Washington.
- Keating, P., W. Linker & M. Hurfman. 1983. Patterns in allophone distribution for voiced and voiceless stops. *Journal of Phonetics* 11: 277-290.
- Kim-Renaud, Y.-K. 1974. Korean consonantal phonology. Ph.D. dissertation, University of Hawaii.
- Nespor, M. & I. Vogel. 1986. *Prosodic Phonology*. Dordrecht: Foris.
- Ohman, S. 1966. Coarticulation in VCV utterances: spectrographic measurements. *Journal of the Acoustical Society of America* 41: 310-320.
- Oller, D. K. 1973. The effect of position in utterance on speech segment duration in English. *Journal of the Acoustical Society of America* 54: 1235-1247.
- Pierrehumbert, J. & D. Talkin. 1992. Lenition of /h/ and glottal stop. In G. T. Docherty & D. R. Ladd (eds.), *Papers in Laboratory Phonology II: Gestures Segment, Prosody*. Cambridge: Cambridge University Press, 90-116.
- Sawashima, M., H.-S. Park, K. Honda & H. Hirose. 1980. Fiberscopic study on laryngeal adjustments for syllable-final aplosives in Korean. *Annual Bulletin of the Research Institute of Logopedics and Phoniatrics* 14: 125-138.
- Selkirk, E. O. 1984. *Phonology and Syntax: the Relation between Sound and Structure*. Cambridge, MA: MIT Press.

Selkirk, E. O. 1986. On derived domains in sentence phonology. *Phonology Yearbook* 3: 371-405.

Silva, D. J. 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 University Press, 177-188.

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