Initial Consonant, F0, and Tone Pattern in Korean Multi-Syllable Words*

Mi-Ryoung Kim
(Korea Cyber University)

Kim, Mi-Ryoung. 2003. Initial Consonant, F0, and Tone Pattern in Korean Multi-Syllable Words. *The Linguistic Association of Korea Journal, 11*(1), 191-215. This paper examines the effects of initial consonant on the F0 contour of multi-syllable words in Korean. Specifically, it focuses on seeing how far the effect observed for the monosyllable data (M.-R. Kim 2001) does extend in the multi-syllable data. F0 measurements and visual inspection of F0 contours were obtained for a total of 9,600 words (from two- to five-syllables) recorded by eight Korean speakers. The results show that, in long words, there is a strong correlation between the initial consonant and the H and LH patterns across dialects. This study suggests that the so-called lax stop is underlyingly a plain voiced stop and the consonant-tone correlation is a standard case of voiceless-high and voiced-low, a tonogenesis effect found in many languages.

Key words: consonant, tone, correlation, F0, voice, Korean words

1. Introduction

Traditionally, it is known that Korean has three kinds of voiceless stops, typically described as aspirated /p^h t^h k^h/, tense or fortis /p* t* k*/, and lax or lenis /p t k/. Phonetic studies have shown that there is a consonant-tone correlation in Korean. Specifically, in neutral speech, if the word initial consonant is voiceless aspirated or tense, the word has a H pattern; otherwise the word has a LH pattern (Gim, 1969; Jun, 1993; M.-R. Kim, 2000a)[1]. The domain of such correlation has been

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called an "accentual phrase" (henceafter AP; Jun, 1993), which is usually made of a word or a compound plus its suffixes. Thus, in a Korean accentual phrase, tones are predictable from consonant types. Perception studies provide additional evidence for the consonant-tone correlation. In word pairs like [t*al] 'daughter' and [tal] 'moon' in Korean, if the contrast is mainly in the initial stops, we expect the stop portion to carry more perceptual information. On the other hand, if the contrast also occurs in tone, or perhaps mainly in tone, we expect the vowel or rime portion to carry just as much perceptual information. According to M.-R. Kim (2000a, Chapter 5), and M.-R. Kim et als. (2002), in word pairs like [t*al] and [tal], the vocalic portion carries more contrast than the consonantal portion[2]. Jun (1996, p. 104-105) cites some evidence that in Korean a low tone helps the perception of the lax stop in initial position. Perceptual findings suggest that the main phonetic differences in word pairs such as [t*al] and [tal] does not lie in the stops themselves, as previously thought, but in the tone of the vowel, in agreement with more recent studies on Korean tone (Jun, 1993; M.-R. Kim, 2000a; M.-R. Kim et als., 2002).

Although researchers have agreed that there is a consonant-tone correlation in Korean, they have somewhat different observations on the tone patterns of Korean words and different phonological accounts on the correlation. Jun (1993) reports that the tonal patterns of Korean AP differ according to dialect: the tonal pattern of Seoul AP is either HHLH or LHLH, whereas that of Jeonnam AP is either HHL or LHL depending on the initial consonant type of an AP (initial H for either

1) Following Peirrehumbert (1980), I use tone to refer to the phonological features H and L that are needed to characterize pitch contour, whether the pitch contour is used to distinguish word meaning (as in Chinese and Japanese) or not (in English). In other words, I do not imply that tone in Korean is contrastive or lexical.

2) M.-R. Kim et als. (2002) examine to see which portion, either consonantal or vocalic portion, plays more important role to distinguish the three syllable types in Korean using a cross-splicing methodology. They found that vocalic portion (probably low tone) rather than consonantal portion plays a greater role in the perception of three syllables.

aspirated or tense and initial L elsewhere). Jun's observation slightly differs from Gim's (1969, 1975, 1998). Gim observed that the tonal patterns of Seoul and Jeonnam dialects are similar: HHM for non-lax consonant and MHM for lax consonants except that Jeonnam Korean has H:M patterns for long syllable words (where M=Mid tone and H:=long H). Gim suggests a mid tone instead of a low tone for the lax syllable. M.-R. Kim (2001) examines the effects of segmental factors on F0 in Korean monosyllables and shows a substantial effect of initial consonants on F0 contour. As observed in previous studies (Gim, 1969; Jun, 1993), she found that there is phonetically a strong correlation between initial consonant and tone. Unlike other studies, however, she assumes that the lax stop is underlyingly a plain voiced stop and suggests that the consonant-tone correlation in Korean is another case of voiceless-high and voiced-low, as suggested by Kingston and Diehl (1994). In this study, I basically assume that the lax stops are underlyingly voiced[3] (M.-R. Kim, 2000b, 2001).

Despite the importance of consonant-tone interaction, there have been few systematically designed quantitative and experimental studies on tone in Korean long words. Since the results presented in M.-R. Kim (2001) are based on the acoustic analysis of monosyllables only, the question of whether Korean multi-syllables have the same effect of

3) A reviewer asks for reasons why I assume that lax stops are underlyingly voiced. As the reviewer points out, it is a radically different point of view from previous studies and needs a detailed phonological explanation. Since this paper focuses on the phonetic observations of the tone patterns in Korean words and the phonological accounts for the reasons are already given in M.-R. Kim (2000b), here I will give a very brief explanation for the reviewer. Since the so-called 'lax' stop has two forms (voiceless and voiced), there are two possible analyses. One is to choose the voiceless form as underlying (and propose a voicing rule for the medial environment). The other is to choose the voiced form as underlying (and propose a devoicing rule for the initial environment). My analysis follows the second approach and represents the lax stop as a plain voiced stop. There are three main reasons. First, there are no genuine minimal triplets to justify the three-way voiceless contrast. Second, there is no independent evidence from other languages for the traditional analyses, and Korean remains an exception. Third, the traditional analysis cannot explain the consonant-tone correlation (see also section 4)

initial consonant on F0 is left unanswered. In addition, it is questionable what types of tone pattern are correlated with initial consonants. Thus, the present study examines the nature and magnitude of the effect of initial consonant on F0 contour in multi-syllables, investigating the additional factors such as syllable weight and medial consonant types. Therefore, the following questions will be mainly addressed:

(1) What is the effect of the initial consonant on the F0 contour of two-, three-, four-, and five-syllable words? Specifically, how far does the effect observed for monosyllables extend?
(2) What kinds of tonal patterns do initial consonants trigger in Korean multi-syllables?
(3) Are there any dialectal differences related to the tonal patterns of Korean multi-syllables?

For two-syllable words only:
(4) Is there a relationship between syllable weight and F0 contour?
(5) Is there any relationship between the onset consonant of the second syllable and F0 contour?

These questions will be addressed through acoustic measurements of F0 values as well as through visual inspection of F0 contours.

2. Methods

2.1. Corpus

Recall that four factors, $C_{INITIAL}$ (=initial consonant), V_{OWEL}, L_{ENGTH} and C_{FINAL} (=final consonant), were investigated for monosyllabic words in M.-R. Kim (2001). Of these factors, only $C_{INITIAL}$ is strongly correlated with tone. For two-syllable words, additional factors including $C_{INITIAL}$ were added to investigate whether there is a correlation between medial consonants and F0, and rime types (for syllable weight) and F0. Consequently, the factors consist of $C_{INITIAL}$ (=the first syllable onset), R_{IME1} (=the first syllable rime), C_{SECOND} (=the second syllable onset), and

R_{IME2} (=the second syllable rime). Table 1 summarizes segmental factors and their individual categories.

Table 1. Factors and segments for two-syllable words

Syllable	Factors	Total	Segment types
First syllable	$C_{INITIAL}$	4	aspirated/tense C lax C sonorant glottal ieung (ɦ)[4]
	R_{IME1}	4	heavy V:/VN light V superheavy V:N heavy VP
Second syllable	C_{SECOND}	3	aspirated/tense C lax C sonorant
	R_{IME2}	3	light V heavy V:/VN heavy VP

(C=consonant, V(:)=vowel (long), N=sonorant, P=stop)

The factors $C_{INITIAL}$ and C_{SECOND} consist of four and three types respectively. Rime types are varied in terms of "weight" to see whether syllable weight correlates with F0: similar weight types are used for R_{IME1} and R_{IME2}, except that superheavy V:N (long vowel and sonorant coda) is omitted for R_{IME2} because it does not occur in the second syllable. Thus, the factor R_{IME1} consists of four types while R_{IME2} three. Since the occurrence of the glottal 'ieung' onset ('ㅇ') is rarely found

4) Korean has a consonant that is traditionally called 'ieung'. Its transcription varies in the literature. When it occurs in the onset position of a vowel initial syllable, some phonologists treat it as a pure orthographic placeholder, with no sound value, whereas others consider there to be still some glottal gesture. When 'ieung' occurs in the coda position, it is a velar nasal [ŋ]. In this study, I assume that the initial 'ieung' is a voiced glottal sound [ɦ] (or it may be represented as a 'voiced' glottal stop or sort) because this explains why it triggers a low tone. Since the phonetic reality and the phonological status of 'ieung' remain somewhat controversial, I leave the final analysis open.

in the second syllable, it is also omitted. The resulting word list, given in Appendix A, consists of 144 two-syllable words (4 types of initial consonants x 4 types of first syllable rimes x 3 types of second consonants x 3 types of second syllable rimes). All are real words.

Since it was impossible to design three-syllable words in a balanced way because of the restriction of syllable structure, 108 three-syllable words were arbitrarily chosen from a literary novel (three to four words per page according to different initial consonant types). As a result, 86 out of 108 words ended in /i/ in the third syllable (see Appendix B). Four- to five-syllable words are rarely found in native Korean words; hence, not only native Korean but also loan words were arbitrarily chosen and the same method was used as done for three-syllable words. This approach resulted in 37 four-syllable words and 11 five-syllable words (see Appendix C). Five-syllable words were necessarily loan words of place name (e.g., California, Las Vegas, Detroit etc.)

2.2. Speakers and Procedures

Five Seoul and three Jeonnam speakers served as speakers in this experiment (the same speakers as ones in M.-R. Kim, 2001). The mean age was about 27 years and individuals ranged from 23 to 35 years. No speakers had any history of speech pathology or phonetic training.

The recordings of the word list were done using a Panasonic Digital Audio Tape Deck SV-3500 in a sound-attenuated room. The randomized list of target words was recorded twice in a carrier sentence and twice in isolation. The carrier sentence was [igə _____t*araheba] "repeat after (me) this _____". Each speaker was asked to read the target words in a natural intonation as if talking to someone at a normal rate. The target words were naturally located in the beginning of accentual phrase. All recorded utterances were digitized at a sampling rate of 22.2 kHz and low-pass filtered at 11.1 kHz. A total of 4,608 two-syllable words, 3,456 three-syllable words, 1,184 four-syllable words, and 352 five-syllable words were analyzed using GWI's Soundscope. For two-

and three-syllable words, F0 was measured at rime onset, midpoint, and offset of each syllable. For the four- and five-syllable words, F0 contours of each word were visually inspected in order to determine the common tonal patterns of Korean long words. Statistical analyses were done for two-syllable words only because of balanced word list of four factors. The six F0 measurements (onset, midpoint, and offset of each syllable) were each submitted to a repeated measures ANOVA (Analysis of Variance) to see whether there is any main and interaction effect of factors (SAS Institute Inc., 1996). For the outcomes of these tests, I present the midpoint results for each syllable. Therefore, F0 measured at the first and second midpoint is the dependent variable. Factors such as DIALECT, $C_{INITIAL}$, R_{IME1}, C_{SECOND}, and R_{IME2} are independent variables. For independent variables, main effects as well as two-way interactions were tested at a *0.05* probability significance level.

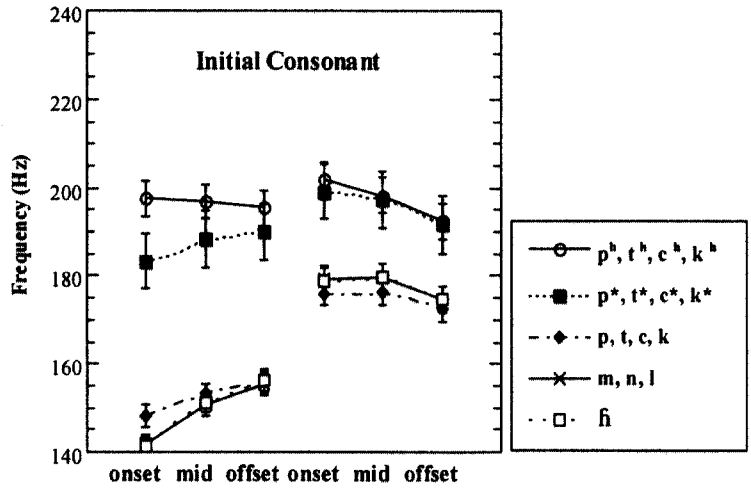
3. Results

The effects of the factor $C_{INITIAL}$ on F0 contour will be described in section 3.1 from two- to five-syllable words in turn in terms of its spectral (Hz) and temporal (ms) magnitude. The effects of the factors C_{SECOND}, R_{IME1}, and R_{IME2} on F0 contour for two-syllable words will be provided in section 3.2 and 3.3.

3.1. Effects of INITIAL CONSONANT on F0 contour

Figure 1 illustrates the mean F0 contour according to the five initial consonant types-aspirated, tense, lax, sonorant, and glottal 'ieung'-for two-syllable words. The plot was generated by averaging across the eight speakers (five male and three female) the F0 values at rime onset, midpoint, and offset of the first and second syllable.

Figure 1. Overall mean F0 contours according to initial consonants for two-syllable words.



The effect of initial consonant types on F0 for two-syllable words is robust as observed in the monosyllable results in terms of the nature and magnitude of the effect (see Fig. 1 in M.-R. Kim, 2001). A repeated measures of ANOVA for the pooled data showed significant main effects of $C_{INITIAL}$ on F0 at both the first and second midpoints ([F(3, 15) = 130.51, p <0.0001], [F(3, 15) = 32.6 p <0.0001]) due to the raising effect of voiceless aspirated and tense consonants, compared to lax, sonorant, and glottal 'ieung' consonants.

Consider the nature of the effect first; i.e., how consonant types are grouped. F0 contours following initial consonants dynamically fall into the two tonal groups: H and LH. Aspirated and tense consonants form the H tone pattern, whereas lax, sonorant, and glottal 'ieung' (ɦ) form the LH tone pattern. In the H pattern, F0 is slightly lower after tense consonants than after aspirated consonants in the first syllable but the contours following aspirated and tense consonants are overlapped in the second syllable. Although the effect of tense consonants is to lower F0

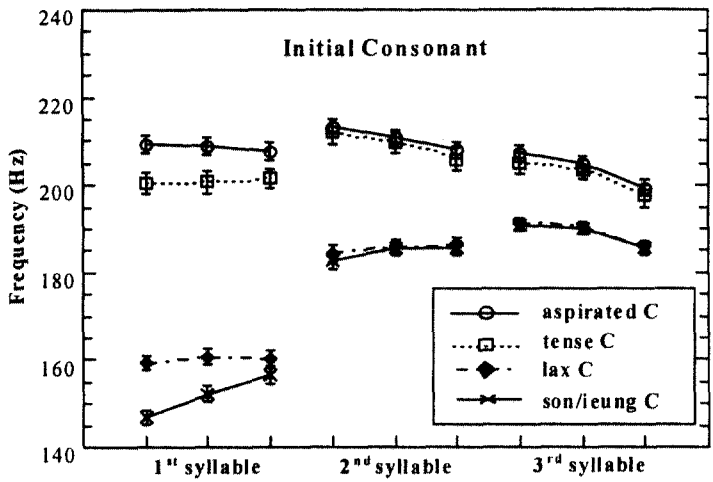
compared to aspirated consonants in the first syllable, the overlapped F0 contours of aspirated and tense consonants in the second syllable suggest that aspirated and tense syllables belong to the same H pattern. In the LH pattern, the contours following sonorant and glottal 'ieung' are completely overlapped, indicating that there is little F0 difference between the two. Post hoc pairwise tests showed that, at the first and second midpoints, the difference between any member of the H group and any member of the LH group was significant, whereas the difference between any two members within the same tonal group was not significant. Turning to the spectral (Hz) and temporal (ms) magnitude of the effect of the initial consonants, the mean F0 difference between the two groups is about 40 Hz in the first syllable and 20 Hz in the second syllable. Although the F0 separation between the two groups decreases across the three temporal locations in the second syllable, the effect of the initial consonant on F0 is still robust until the second syllable offset. As seen in Figure 1, the spectral (Hz) and temporal (ms) magnitude of the effect of the initial consonant on F0 contour holds across the two syllables, indicating that Korean two-syllables also carry a tonal differentiation, H and LH, due to initial consonant types.

Figure 2 gives the overall mean F0 contours according to the four initial consonant types--aspirated, tense, lax, and sonorant/glottal 'ieung' (where the F0 contours for sonorant and glottal 'ieung' are not separated because of their complete overlapping). The plot was generated by averaging across the eight speakers the F0 values at each of the nine temporal locations (rime onset, midpoint, and offset of each syllable), as done for the two-syllable data.

The effect of the initial consonant on F0 contour observed for the three-syllable data is robust and similar to that found for the one- and two-syllable data in terms of its nature and spectral/temporal magnitude. As seen in Figure 2, voiceless aspirated and tense consonants form the H tone pattern, while lax and sonorant/glottal 'ieung' consonants form the LH tone pattern. The initial peak for the LH pattern occurs in the second syllable. The initial consonants affected

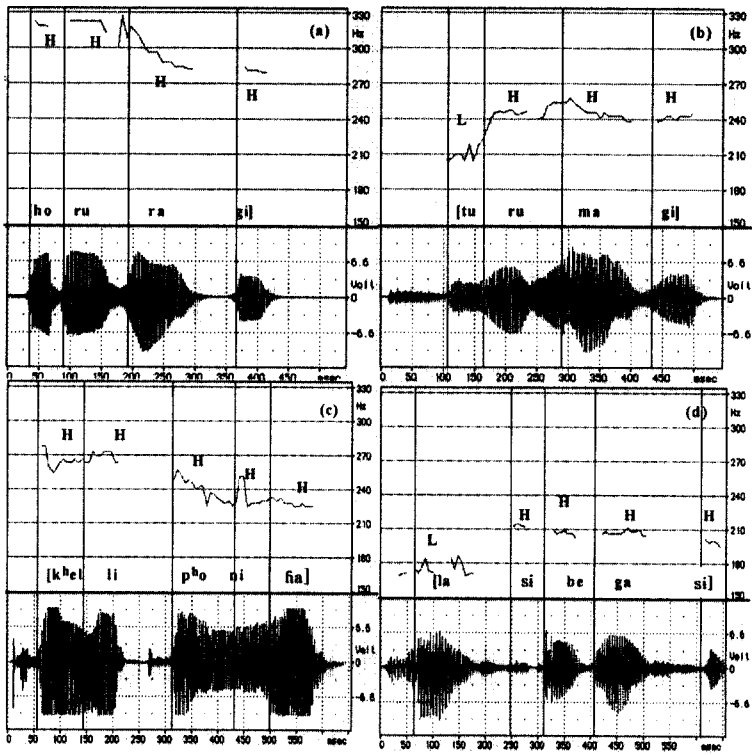
F0 across the entire three syllables in that voiceless aspirated and tense consonants have a mean raising effect of 50 Hz in the first syllable, 25 Hz in the second syllable, and 15 Hz in the third syllable, compared to lax and sonorant/glottal 'ieung' consonants. Although the magnitude of the effect of the initial consonant on F0 is smaller in the third syllable than that in the first and second syllables, its effect is still robust even at the third syllable offset.

Figure 2. Overall mean F0 contours according to initial consonants for three-syllable words.



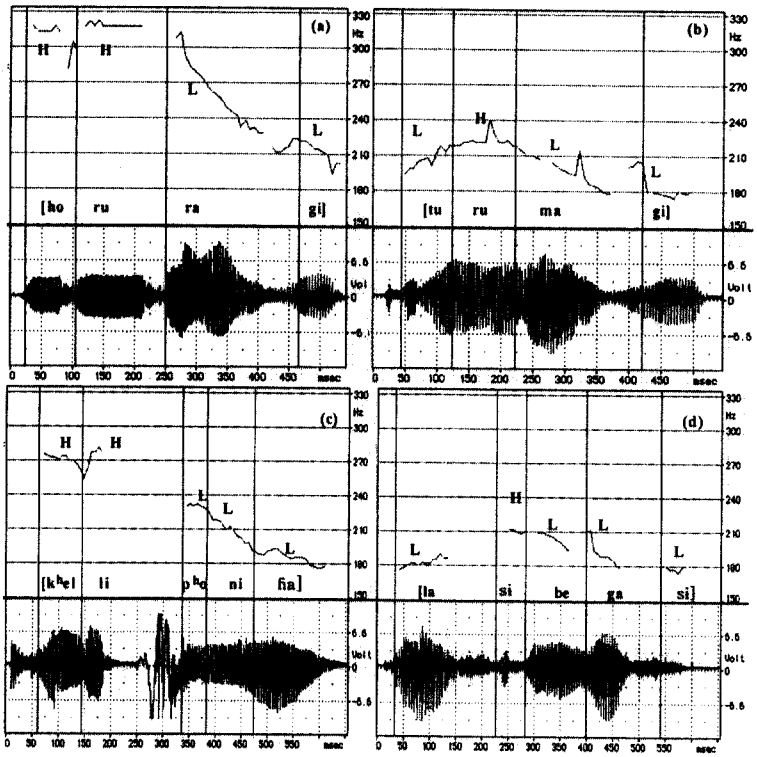
The great effect of the initial consonant on F0 contour was observed for four- and five-syllable words. Similarly, the two types of tone patterns were observed: (i) H_0 vs. HL_0 after voiceless aspirated/tense consonants and (ii) LH_0 vs. LHL_0 after voiced lax/sonorant/ieung consonants (where H_0 means H, H-H, H-H-H...). For the two patterns, there was a rough tendency for Seoul speakers to prefer final H tones whereas Jeonnam speakers preferred final L tones in natural utterances. Figure 3 illustrates representative F0 contours for the H and LH pattern of four- and five-syllable words uttered by a female Seoul speaker.

Figure 3. Representative H (a, c) and LH (b, d) pattern according to initial consonants for four- and five-syllable words (S8)



In Figure 3, the spectral (about 30Hz on the fourth and fifth syllable) and temporal magnitude (about 450ms for four-syllable and 600 ms for five-syllable word) of the effect are robust until the end of the word (compare panel (a) to (b), and (c) to (d)). Representative examples of HL_0 and LHL_0 patterns for four- and five-syllable words are illustrated in Figure 4 uttered by a male Jeonnam speaker (S1).

Figure 4. Representative HL (a, c) and LHL (b, d) pattern according to initial consonants for four- and five-syllable words (S1)

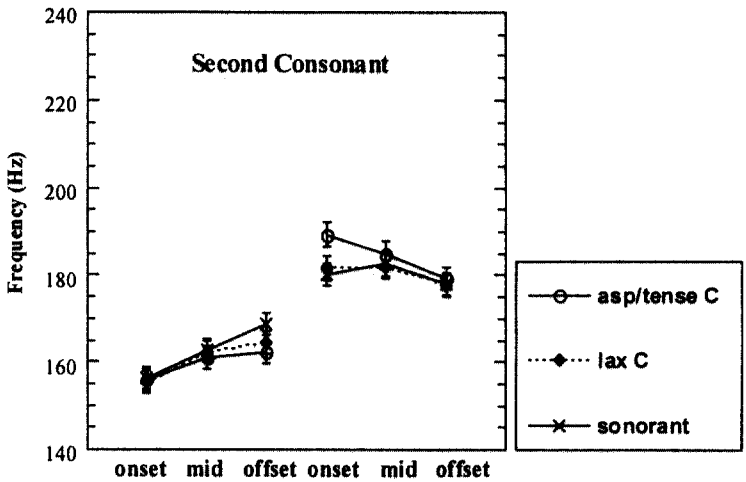


Compared to speaker S8's pattern in Figure 3, speaker S1 in Figure 4 showed temporally less extensive effects of initial consonantal voicing. F0 values between the two F0 contours are overlapped by the end of target words in Figure 4, with all tones after the second being L, compared to H in Figure 3. However, in the first two syllables, consonant-tone interactions were consistently observed, with a voiceless consonant yielding a HL_0 tone pattern and a voiced consonant a LHL_0 pattern.

3.2. Effects of Second Consonant on F0 contour

Figure 5 plots the overall mean F0 contours according to second (or AP-medial) consonant types for two-syllable words.

Figure 5. Overall mean F0 contours according to second consonants



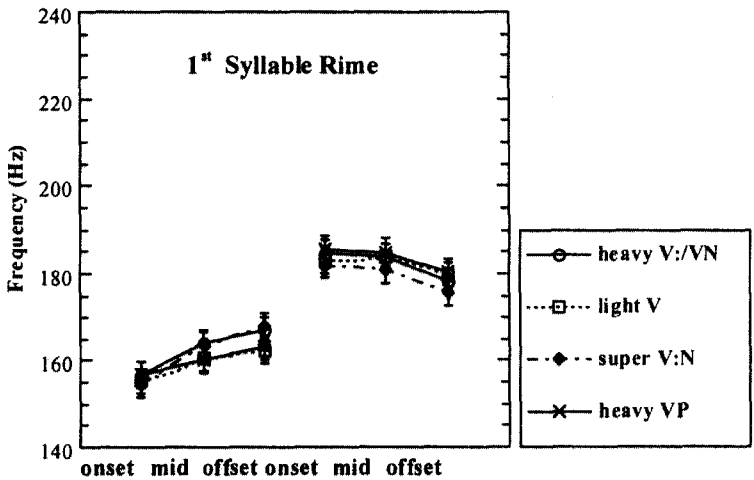
A repeated measures of ANOVA for the pooled data showed that the factor C_{SECOND} had a significant effect on F0 at the second midpoint ([$F(2, 10) = 11.26$, $p < 0.005$]) but not at the first midpoint. Post hoc results showed that this effect was due to the raising effect (about 10Hz) of aspirated/tense consonants, compared to other consonants. Relative to the effects of $C_{INITIAL}$, those of second consonant were relatively smaller and more localized. As seen in Figure 5, a small effect of the second consonant is seen at rime onset of the second syllable in that aspirated and tense consonants have a slightly higher F0 than lax and sonorant consonants. However, the effect does not extend to a neighboring temporal location, indicating that the effect of non-initial consonant on F0 is localized. This localized effect suggests that the substantial effects of onset consonants on F0 contour are

restricted to word- or possibly phrase-initial position. The results support Jun's (1993) assumption that the domain of consonant-tonal interaction is AP and the interaction does not occur AP-medially.

3.3. Effects of RIME on F0 contour

In order to see whether there is a relation between syllable weight and F0, the effects of rime types on F0 for two-syllable words were investigated. Figure 6 illustrates the F0 contour according to the four types of rimes--heavy V:/VN, light V, superheavy V:N, and heavy VP--in the first syllable.

Figure 6. Overall mean F0 contours according to the 1st syllable rime

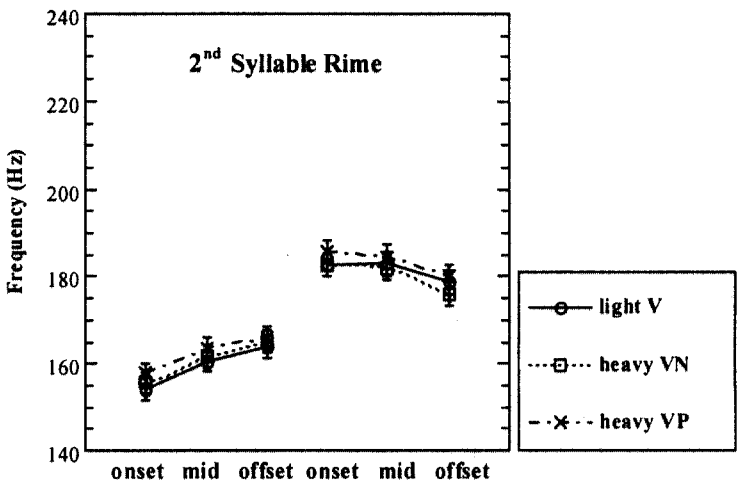


The nearly overlapping mean F0 values and the overlapping error bars among the first syllable rime types indicate that there is little if any systematic effect of the first syllable rime on F0. In the first syllable, F0 of the light V and heavy VP rimes has a mean lowering of 4-5 Hz at midpoint and offset, as compared to others. In the second

syllable, superheavy V:N rime has a mean lowering of 3-4 Hz across the three temporal locations, as compared to others. Although the effect of R_{IME1} on F0 was significant at both midpoints ([F(3, 15) = 4.82, p <0.05], [F(3, 15) = 8.88 p <0.005]) due to the raising effect of heavy V:/VN and superheavy V:N at the first midpoint and the lowering effect of superheavy V:N at the second point, the size of this effect was much smaller than that of initial consonant; also the same nature of the effect was not consistently found throughout the two entire syllables. As a result, since this raising or lowering effect is very small, neither consistent nor systematic for both syllables, it is hard to tell that there is a relation between syllable weight and F0.

Similar effects are observed for the effect of the second syllable rime on F0. Figure 7 gives F0 contours according to the three rime types--light V, heavy VN, and heavy VP.

Figure 7. Overall mean F0 contours according to the 2nd syllable rime



The factor R_{IME2} had a main effect at the first midpoint due to the small raising effect (about 2 Hz) of the second syllable heavy VP rime, compared to the other rime types. However, it had no main effect at

the second midpoint. One would expect that, if the effect were localized, it should occur only for the second midpoint. A significant effect at the first but not at the second midpoint suggests that this statistical outcome is due to a sporadic effect. As seen in Figure 7, although mean F0 values are slightly higher when the second syllable rime is heavy, the error bars for the different rime types substantially overlap. This suggests that there is little relation between second rime types and F0.

3.4. Summary: tonal patterns of Korean multi-syllables

In sum, the dynamic F0 contours according to the consonant and rime types of the first and second syllables showed that, among the four factors, only consonant types for the first syllable had a robust effect on F0 across the two syllables. The robust effect of the initial consonant on F0 contour was also observed for three-, four-, and five-syllable words. As a result, including the monosyllable data presented in M.-R. Kim (2001), this experiment showed that there are two different types of tone patterns in Korean words where AP-initial tones are consistently correlated with the initial consonantal voicing but final boundary tones are different across speakers. The tonal patterns of one- to five-syllable words are summarized in Table 2.

Table 2. Tonal patterns of 1- to 5-syllable words

Initial voice	1σ	2σ	3σ	4σ	5σ	Tonal pattern
Voiceless	H	H-H	H-H-H	H-H-H-H	H-H-H-H-H	H_0
	HL	H-HL	H-H-L	H-H-L-L	H-H-L-L-L	HL_0
Voiced	LH	L-H	L-H-H	L-H-H-H	L-H-H-H-H	LH_0
	LHL	L-HL	L-H-L	L-H-L-L	L-H-L-L-L	LHL_0

(Tones on different syllable are separated by a hypen)

In Table 2, the H and LH patterns were largely observed for the embedded words and the HL and LHL for the isolated words across dialects. If the dialectal difference is responsible for the different tone patterns of embedded words, the tendency is for Seoul speakers to have

final H tones (i.e., H or LH) and Jeonnam speakers final L tones (i.e., HL or LHL). However, the present data showed speaker variation within each dialect, leaving this issue unresolved.

4. Discussion

The findings of the present study are similar to Jun's (1993, 1996, 1998) in that there is a correlation between the initial consonant and the H and LH patterns: aspirated and tense consonants are correlated with H and other consonants are correlated with L. However, they are different from Jun's in three aspects. First, the tone patterns of longer words in the two studies are slightly different. Jun (1993, p. 42; 1996, p. 97, 1998, p. 193) suggests that in long words the H pattern is HHL in Jeonnam Korean but HHLH in Seoul Korean and the LH pattern is LHL in Jeonnam Korean and but LHLH in Seoul Korean. In the model of Pierrehumbert (1980), the final H in Seoul Korean can be attributed to a boundary tone. On the other hand, the present study did not find a consistent difference between the two dialects, and Seoul Korean does not always end in H (see M.-R. Kim, 2000a). I have noted that, to the extent that the current data may reflect a dialect difference, Seoul AP-final tones are H and Jeonnam AP-final tones are L. I leave the dialectal issue open to further research because of inconsistency across speakers within each dialect in the present study. Second, the location of the initial peak for the LH_0 pattern slightly differs from Jun's findings. According to Jun (1993), the initial H is associated with the second syllable of an AP in Seoul Korean (see Koo, 1986 for a similar observation) and with the second mora of an AP in Jeonnam Korean. Similar to Jun's observation, the present study also showed that the initial peak is generally realized on the second syllable of a target word for almost all words for both dialects (see Fig. 2). However, unlike Jun's observation for Jeonnam Korean, the initial peak is realized on the second syllable even when initial syllables have two moras (e.g., [a] and [:] in [ka:ʤaŋ] 'the head of the house'). In addition, when the first syllables are superheavy (i.e., [ʧa:ŋsa] 'funeral', [ka:ŋdo] 'burglar' etc.),

the location of the initial peak is frequently realized near the offset of the first syllable of a target word, rather than the second mora.

Finally, as pointed out by Jun, consonant-tone interactions are fully predictable only when words occur AP-initially. AP-medial consonants do not show the same magnitude of effects as AP-initial consonants on F0 contour. With regard to the phenomena that the consonant-tone interaction does occur AP-initially but not AP-medially, however, the present study differs from Jun's in the interpretation of the source of the F0 effects. Since there is no satisfactory phonetic and phonological explanation for the consonant-tone correlation, Jun concludes that the Korean tones are either underlyingly specified or assigned by rules that are either just partially related to consonant properties or not at all. In various versions of Jun's analysis (1993, 1996, 1998), three voiceless stops are assumed as done in the traditional analysis. There are at least three fundamental problems. First, the assumption is unsupported because of the fact that there is no genuine minimal pairs to justify the three-way contrast. The words [t*al] 'daughter' has H tone and [tal] 'moon' has LH tone. Since the words differ in tone, the contrast between 'daughter' and 'moon' is no longer in [t*] and [t] alone. Second, there is a lack of independent evidence from other languages. In other words, it over-predicts possible stop consonants. For example, the feature [voice] and [aspirated] give four stops; [p^h p b^fi b] (e.g., Hindi). With the new feature [tense] (or its equivalent), the number is doubled [p^h p b^fi b p^h* p* b^fi* b*]. There is no language that uses all the stops, or anywhere near so. If Korean has three sets of voiceless stops, it is unique among the world's languages and calls for a revision in feature theory. Third, there is no possible explanation for the consonant-tone correlation; instead, the correlation is seen to be essentially arbitrary. In Korean, all voiceless consonants trigger the H pattern, except lax stops, which trigger the L pattern, just as voiced consonants do. If lax stops are voiceless, the problem is why they pattern with voiced consonants and not with voiceless ones.

In the present approach, the lax stop is underlyingly a regular voiced stop and the tense stop is underlyingly a regular voiceless unaspirated

stop. The difference shows as it is in medial position. At the beginning of an accentual phrase, the lax stop is devoiced, and its [voice] feature is shifted to the following vowel to create a low tone (see also Halle and Stevens, 1971; cf. C.-W. Kim, 1965). Tonal differentiation does not occur in AP-medial position, since there is no devoicing. In other words, the main phonetic difference in word pairs such as [t*al] and [tal] does not lie in the stops themselves, as previously thought, but in the tone of the vowel, in agreement with more recent studies on Korean tone (Jun, 1993; M.-R. Kim, 2000b; M.-R. Kim et als., 2002). If lax stops are underlyingly voiced, the consonant-tone interaction in Korean is straightforward: it is another case of voiceless-H and voiced-L, as a tonogenesis effect found in many languages (see Kingston and Diehl, 1994; M.-R. Kim, 2000b, 2001). According to a theory of tonogenesis (Haudricourt, 1954; Matisoff, 1973; Hyman, 1973; Hombert et als,. 1979; Baxter, 1992; Duanmu, 1992, 1996), tonal differences are enhanced when loss of voicing occurs. In most languages which have undergone tonogenesis, the loss of voicing has occurred domain-initially.

For tonal variation beyond the second syllable, at least three accounts are possible. One possibility, discussed above, is that AP-final tones are either H or L depending on the speaker's dialect, with Seoul speakers showing final H and Jeonnam speakers final L tones. The final H tones can be obtained by an optional spreading of a H tone (from left to right) and the final L tones by an insertion of default L tone. A second possibility is that the tonal variation is due to speaking rate. There is a tendency in the data for final tones to be L for speakers with faster speaking rate. For instance, speakers S1 and S7 had faster speech than others, and their final tones were L. Another possible interpretation is that syllables beyond the second are toneless. All toneless syllables acquire higher or lower tones by various conditioning factors, as suggested by Keating (1988, 1990). Keating proposed that not every linguistic element is fully specified and the phonetic values for underspecified segments may be independently derived by principles of phonetic implementation which depend on neighboring target values. Pierrehumbert (1980) also demonstrated that in English not every

syllable is fully specified with regard to tone. Beckman and Pierrehumbert (1986) argued for Japanese that the syllable previously described as low tones are in fact toneless where their F0 values are determined by phonetic interpolation between two targets. Since tones beyond the second syllables were not consistent across speakers employed in this experiment, it is possible to consider them "toneless" and phonetic implementation can make a toneless syllable have a H or L tone. I leave it open how the tonal variation beyond the second syllable is specified.

5. Conclusion

The present study shows that the effects of initial consonants on F0 contour in Korean multi-syllable words (from two- to five-syllable) are as robust as those of monosyllable words presented in M.-R. Kim (2001). Other factors related to medial consonant and syllable weight are further taken into consideration but none of the factors is shown to be linguistically important. The results indicate that there is a strong consonant-tone correlation in Korean words: voiceless aspirated and tense consonants correlate with H and voiced consonants correlate with L. In the present analysis, the "lax" stop is underlyingly a plain voiced stop. At the beginning of an accentual phrase, the lax stop is devoiced, and its [voice] feature is shifted to the following vowel to create a low tone. Tonal differentiation does not occur in AP-medial position, since there is no devoicing. By this account, the phonological source of L tone and the relationship between lax consonants and L tone, as well as the lack of tonal differentiation in AP-medial position, are coherently accounted for. In addition, the consonant-tone correlation is also natural-it is a standard case of voiceless-high and voiced low (Kingston and Diehl, 1994), a tonogenesis effect found in many languages.

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Mi-Ryoung Kim
Department of Practical English, Korea Cyber University
Yonsei Engineering Research Center
Shinchon-dong, Seodaemun-Ku, Seoul, Korea, 120-749
Phone: 82-2-3143-2588
E-mail: kmrg@mail.kcu.ac

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Appendix A. Two-syllable word list

까치	끽반	반:란	문:책	이민
티끌	착각	반:납	난:자	우락
친구	탁마	박차	난:중	암:투
빨강	탁남	박탈	만:국	안:찰
파국	탁립	각축	만:리	운:책
파:리	김치	각기	난:립	암:기
탐문	반찬	직감	낙타	암:굴
타:락	단짝	직각	낙찰	운:각
추파	감자	궁리	낙착	안:마
까탈	간장	국민	낙지	운:문
차축	구:직	각막	낙담	암:묵
투기	빌미	날짜	묵독	악기
파당	가:망	남침	낙망	악단
까닭	단락	밀착	막막	압축
끼니	구타	나:부	이:차	악가
따님	기쁨	무:당	인칭	악감
추락	가축	난국	안착	입각
탄:피	가구	난:리	안부	악마
찬:탈	가:장	미:남	인간	임문
찬:탁	가닥	난립	아집	임묵
딸:기	다리	미끼	임무	필답
창:간	바람	무참	인물	낙마
탄:박	발악	나비	안락	미착
찬:미	반:파	나방	이끼	만:물
찬:문	감:탄	미국	이빨	
창:립	반:칙	나무	이축	
딱지	감:기	나물	아가	
축출	반:감	무릎	아담	
탁발	반:박	난:투	우각	
탁구	반:미	만:찬	우리	

Appendix B. Three-syllable word list

소나기	할머니	고:구마	우거지
청량리	소쿠리	골짜기	아리랑
터미널	뻐다귀	도깨비	율타리
코끼리	돋보기	진달래	아가씨
사다리	독수리	고양이	아버지
살쾡이	바가지	병아리	올가미
뻐꾸기	달팽이	배짱이	인절미
시누이	도시락	도토리	우:렁이
캘린더	달리기	며누리	올빼미
호:랑이	복숭아	모퉁이	여드름
사:마귀	구:렁이	나머지	올챙이
산더미	보퉁이	마누라	원:숭이
파고다	두꺼비	라디오	어머니
항아리	보따리	누룽지	옥수수
카메라	고드름	메뚜기	꼭대기
토마토	비둘기	리어카	꾀꼬리
컴퓨터	잠자리	너구리	싸라기
사:투리	지렁이	무지개	꼬투리
설거지	주머니	메추리	깔때기
사마귀	개구리	막대기	깍두기
송:충이	도라지	이태리	꾸러미
송아지	강아지	엉:덩이	찌꺼기
스커트	그림자	아저씨	껍데기
피라미	거머리	이바지	싸구려
키다리	장:도리	이파리	까마귀
피아노	바구니	이야기	쓰레기
파라핀	귀퉁이	오징어	까투리

Appendix C. Four- and five-syllable word list

four-syllable word		five-syllable word
코스모스	두루마기	디트로이트
호루라기	불가사리	캘리포니아
시나리오	고슴도치	네브라스카
크레파스	가까스로	펜실베니아
할아버지	비비꼬기	필라델피아
파노라마	두드러기	스코트랜드
하모니카	미꾸라지	루이지애나
파인애플	노고지리	세크라멘토
허수아비	아주머니	라스베가스
텔레비젼	멍텅구리	오클라호마
페르시아	아지랭이	캐롤라이나
포루투갈	아주까리	
콜럼버스	르네상스	
플로리다	네덜란드	
뿌시래기	이탈리아	
딱다구리	아톨란타	
꼬들빼기	일리노이	
꺼끄러기	뿌시래기	
스파게티		