Interaction between Pitch Accent and Segment in North Kyeongsang Korean

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Lee, Hye-Sook. (2010). Interaction between Pitch Accent and Segment in North Kyeongsang Korean. ***Language Research*** **46. 2, 103-121.**

This paper examines the interaction between pitch accent and segment in North Kyeongsang Korean with respect to F0 peak scaling and alignment. In this study, F0 and time were measured at each segment of four-syllable phrases as well as the F0 peak of the phrase, and then the relative placement of the F0 peak was examined against the segmental environment. This study reveals that F0 peak is consistently delayed in this language such that the peak comes after the accented syllable offset. It also shows that the F0 peak is realized in a constant distance from the accented syllable offset so that as the syllable duration gets longer, the peak moves farther away from the syllable onset. Intrinsic F0 scaling is observed as well such that high vowels have a higher F0 than low vowels.

Keywords: North Kyeongsang Korean, pitch accent, F0 alignment, F0 scaling, peak delay

1. Introduction

Across languages, it has been reported that pitch and temporal realization of tone may vary depending on the segmental structure. One of the most widely known cases is the Fundamental Frequency (F0) difference among vowels with different heights. For instance, Taylor (1933) reported that there is about a 10 Hz difference on average between high and mid vowels and about a 5 Hz difference on average between mid and low vowels in English.[1] Besides such a "vertical" dimension of F0, variability of phonetic tone realization is also described with respect to their "horizontal" dimension (Arvaniti, Ladd & Mennen 1998). Silverman and Pierrehumbert (1990) reported that the peak delay co-varied with the duration of the vowel of the accented syllable. In several languages, the temporal alignment of an F0 target (usually F0 peak) relative to the segmental string was shown to be quite constant across various intrinsic segmental durations, unless it is constrained by different prosodic conditions

[1] See Taylor (1933), Ohala (1973) and Hombert (1977) for the discussion on why the intrinsic F0 is different for different vowel heights.

such as adjacent stress or relative placement within a sentence (sentence-medial or sentence-final) (Xu 1991).

Segment-tone interactions in North Kyeongsang Korean (NK Korean hereafter) have not been addressed systematically. Compared to Seoul Korean, NK Korean has rarely been studied phonetically, although its tone system, tonal correspondence with Middle Korean, and phonological tone changes in syntactic phrases are described quite comprehensively (S-O Lee 1980, W Huh 1985, Y-H Chung 1991, C-K Kim 1985, N-J Kim 1997). Recently, there have been a few phonetic studies on NK Korean lexical tones. S-E Chang (2003) compared the F0 and timing of four different North Kyeongsang Korean tones. J Jun et al. (2006) proposed phonological representations of NK Korean lexical tones based on their phonetic data. J Kim and de Jong (2007) found that minimal pairs, distinguishable only by lexical tones, were successfully identified by NK Korean native listeners, whereas they were not correctly identified by South Cholla Korean listeners. Kenstowicz and C Park (2005) examined the F0 perturbation due to the phrase-initial laryngeal features in Kyeongsang Korean, and confirmed that aspirated or tense stops raise F0 in the following vowel as found in many other languages. Still, the phonetic variability of lexical tones, especially the temporal variability according to different segmental environments, warrants more comprehensive studies in NK Korean.

Identifying segment-tone interactions is important in NK Korean because there seems to be a mismatch in temporal dimension between phonological tone and its phonetic correlate. Figure 1 shows an example F0 contour of a NK Korean Accentual Phrase, /nuna-lako/ 'older sister-Quotative.' By the intuition, the pitch accent H* is associated with the initial syllable /nu/, but the F0 peak is placed within the following syllable /na/. Here arises an important question: the retrieval of phonological contrast through potentially variable phonetic signals. How do the native speakers know that the pitch accent is linked to the second syllable, not the first, when the F0 peak, one of the most salient acoustic cues for pitch accents, does not come within the first syllable? What if the F0 peak is realized with great variability depending on the segmental environment? These questions lead us to an expectation that there is some kind of regularity in the phonetic realization of a pitch accent, and the regularity should include information regarding the interaction between the pitch accent and segmental environments.

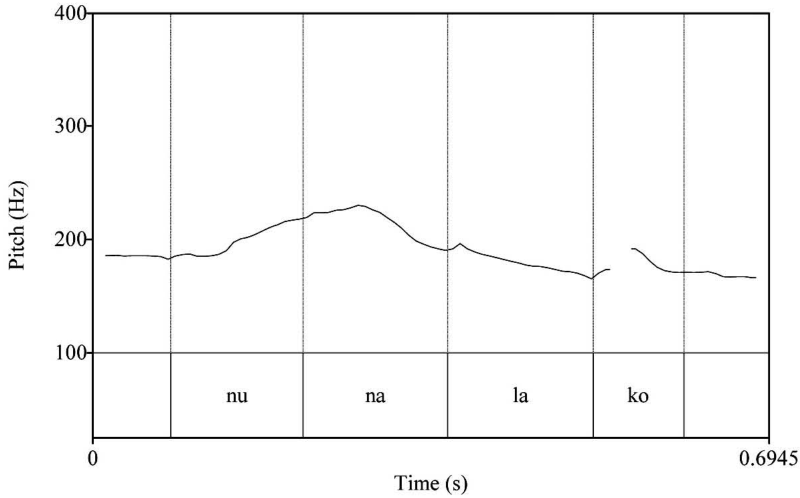

Figure 1. A pitch contour of a phrase /nunalako/ 'sister-be-Quotative' with the lexical pitch accent H associated with the initial syllable /nu-/.

In order to capture the regularity in terms of phonetic realization of pitch accents, this paper examines the temporal placement as well as the scaling of F0 peak of NK Korean pitch accent. In this paper, basic phonetic realization patterns of three lexical pitch accents are identified first, and then phonological length and intrinsic duration are examined as factors that affect the F0 scaling or alignment of lexical pitch accents in NK Korean. For the phonological length contrast, phonologically short and long vowels are compared, whereas high, mid and low vowels are compared for the intrinsic phonetic duration differences.

2. Data Collection

2.1. Materials

A set of words were carefully selected to examine the effect of phonological length, and phonetic duration on the accentual F0 realization. The materials are divided into three groups: underlying tone, phonological length, and phonetic/intrinsic duration. First, three tone types are compared: following J Jun et al. (2006)'s terminology, two "singly-linked" H tones, linked either with the initial syllable (informally HL) or with the second syllable (LH), and the doubly-linked H tone (HH). The materials for this condition do not constitute minimal triplets as shown in Table 1. The second condition is the vowel length contrast, i.e., short vowel and long vowel. Tone HH was used for this pair because the phonological vowel length contrast of NK Korean is found only in words with tone HH. Finally, the third condition is vowel height, which is assumed to have variable intrinsic vowel durations. For this condition, three back vowels /u/, /o/ and /a/ were selected. The materials in the last two conditions are minimal pairs or triplets. The minimal pairs or triplets are listed in Table 1. Those minimal pairs or triplets are different only for the relevant factor, while all the other tonal or segmental conditions are identical. That is, for the vowel height factor, /nuli/ 'world,' /noli/ 'game' and /nali/ 'lily' are different only in terms of the quality of the initial vowels, while all the other segmental, tonal and syllable structures are identical. For all the conditions, the syllable structure of the first two syllables was CV(:)CV- followed by a carrier –CVCV (see example (1)). For the vowel height condition, tone H was linked to the initial syllable followed by L, whereas for the vowel length contrast, HH was used such that the first two syllables were linked to H.

Each word was embedded in the carrier sentence in (1). Depending on the structure of the final syllable of a bi-syllabic test word, a different quotation suffix was attached. If a target word ends with a consonant, *–ila* was used, whereas *–lako* was used otherwise, for the purpose of keeping the number of syllables in the phrase identical. There were 18 test words,[2] so 18 sentences were created. Due to the structure of the carrier sentence, the target word in each sentence was assumed to be focused by the context.

Table 1. The List of Words Used in the Recording

Factors			
Lexical tone CVCV HL vs. HH vs. LH	/nala/ 'country' /nuna/'older sister' /na-ko/ 'born-Connect'	/manun/ 'Manwun'[3] /nun-i/ 'eye-Nom' /mal-i/ 'end-Nom'	/namu/ 'tree' /napaŋ/ 'moth' /nalɨm/ 'its own'
Vowel length (HH) CVCV vs. CV:CV	/manun/ 'Manwun' /nun-i/ 'eye-Nom' /mal-i/ 'end-Nom'	/ma:hn-in/[4] 'many-Adnom' /nu:n-i/ 'snow-Nom' /ma:l-i/ 'word-Nom'	
Vowel height (HL) /u/ vs. /o/ vs. /a/	/nuli/ 'world' /muli/ 'stock'	/noli/ 'game' /moli/ 'chasing'	/nali/ 'lily' /mali/ 'head (count)'

[2] Table 1 lists 21 words, but three of them, Manwun, nwuni, and mali, are repeated in the list.

[3] Manwun is the name of a village where the author was born. All the native speakers who participated in the recording had no problem producing the right tone.

[4] Apparently, /manwun/ and /ma:hn-un/ are not minimal pairs by the phonological representations, but they become minimally distinctive as /h/ in the latter is phonologically deleted.

(1) andong mal-lo ______-ila/-lako ha-n-ta.
Andong word-Instr ______-Quot say-Present-Declarative
'We say ______ in the Andong dialect.'

Those eighteen sentences with the test words embedded were randomly shuffled and printed in the Korean orthography on a paper script. For those words that are potentially ambiguous in the script, such as /nun-i/, extra information was provided in the parenthesis at the end of the sentence, such as *eye, nose, mouth*.

2.2. Subjects and Procedures

Five female native speakers of North Kyeongsang Korean participated in the recordings. Four of them were in their early twenties and the other was in her early thirties. They were recruited in Andong, Kyeongsang-Buk-do (Northern Kyeongsang Province) by the author's personal network. They were all born and lived for their entire life in Andong. The recordings were conducted in various quiet locations, such as the subject's campus or home. A Marantz Digital Recorder (PMD 670) and a SHURE head-mount microphone were used in the recordings.

Each subject read the script including 18 sentences six times. First, they were asked to read through the whole script as a training session. They were instructed to read each sentence as naturally as possible. Because it was reading instead of actual conversations, it might have slowed the speech rate of some speakers or made the speakers produce their speech more clearly. However, the reading style did not affect the basic patterns of tones and intonation. The speakers were instructed to read the script six times. Each speaker read the whole list of the target sentences for one repetition and they read again the whole list for another repetition. The order of the target sentences was identical across repetitions and speakers. None of the subjects had any problem reading the script naturally. When the subjects got confused about the lexical tone, producing a wrong tone, such as HL for LH, they were asked to repeat the whole sentence over again. It was assumed that the experimenter's intervention only involved the subjects' phonological realization, and their phonetic realizations were not affected. When they paused between words or stuttered, they were also instructed to repeat the whole sentence. Their overall performance was quite good.

2.3. Measurements and Analyses

A total of 540 utterances (=18 sentences × 5 subjects × 6 repetitions) of the recordings were analyzed. In order to capture general pitch contours and F0 targets such as F0 peak and valley, F0 and time of the onset of each segment in each word as well as F0 maxima and minima were measured, as shown in (2).

(2) Measurements
 a. F0 and time of the onset of the following:
  i. C1 and V1: first prevocalic consonant and first vowel of a four-syllable phrase
  ii. C2 and V2: second consonant of a four-syllable phrase, which immediately follows V1, and second vowel of a phrase
  iii. C3 and V3: third prevocalic consonant and vowel of a four-syllable phrase
  iv. C4 and V4: fourth prevocalic consonant and vowel of a four-syllable phrase
 b. F0 and time of F0 targets
  i. Local F0 maxima: P (Peak)
  ii. Local F0 minima: M (Min)

The segments and F0 targets were manually annotated in Praat as illustrated in Figure 2. The first tier contains phonetic transcriptions. On the second tier, intervals of consonants and vowels are marked for the target phrase.[5] In this example, the target phrase is /nala-lako/ 'country-Quotative.' For the segments, F0 and time of the onset of each segment, i.e., the left edge of the corresponding interval tier, were measured. On the third and fourth point tier, pitch targets such as H peak "P" and the pre-accentual F0 minimum "M" are marked. The values corresponding to each target were automatically extracted by a script written by the author.

(3) Time standardization based on mean duration
 a. Normalized time: the time of a target segment onset, relative to the C1 onset (= phrase onset)
 b. Mean duration: mean duration of a target phrase across all speakers
 c. Standardized time

$$= \text{Normalized time} \times \frac{\text{mean duration of a relevant population (= b)}}{\text{duration of an individual phrase}}$$

[5] In this paper, the term "target" refers to something under investigation. So target segments refer to C1 through V4 in this study; target words refer to the words listed in Table 1; target phrases refer to target word plus *-ila/lako* (see (1)).

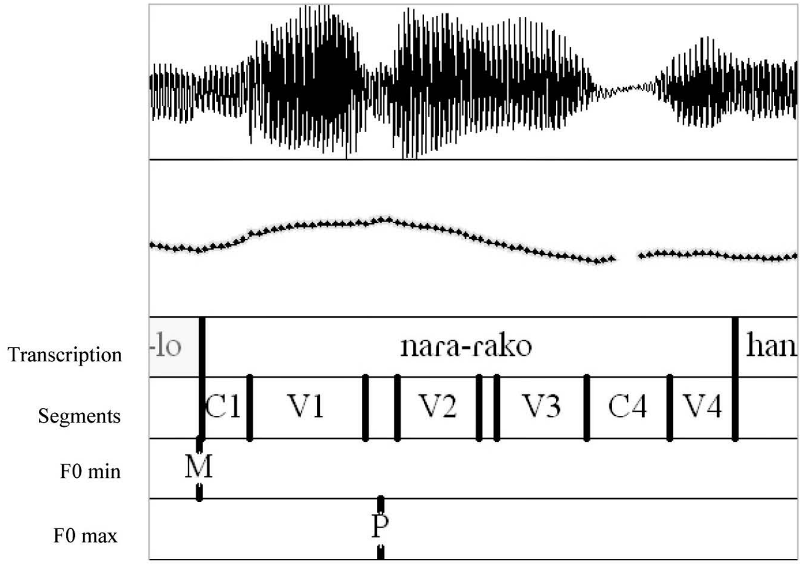

Figure 2. An example annotation window in Praat: a target phrase /nala-lako/ 'country-Quotative.' zoomed in from the entire sentence /andongmal-lo nala-lako hanta/ '(We) say "nala" in the Andong dialect.'

F0 values were initially measured in Hertz, and then converted into semitones, which was believed to minimize the variation of speakers' pitch ranges (see Nolan 2003). The timing of each target was standardized to account for speakers' intrinsic speech rates. The way the time was normalized and standardized is shown in (3).

Examples of normalized time are illustrated in Figure 3. The normalized V2 time is the distance of the segment onset from the C1 onset, and the normalized P time is the distance of the target P from the C1 onset. The normalized C1 time is always 0. The mean duration was calculated for groups of data under comparison, while all the other factors were pooled. For instance, when long vowel and short vowel were compared, the mean durations were calculated across all speakers and repetitions for the two vowel length groups separately.

The measured time was standardized to accommodate speaker variability in timing. The rate of speech varied among the subjects, and one speaker produced sentences faster than another. Such variance in the timing of the segments would make it difficult to capture temporal regularity and draw a generalization across the speakers. By the equation in (3c), a slow speaker's standardized time would get smaller, whereas a fast speaker's got greater, by the ratio of the mean duration of the phrase of all speakers over his actual duration of the individual phrase. For example, if one speaker's duration of a single

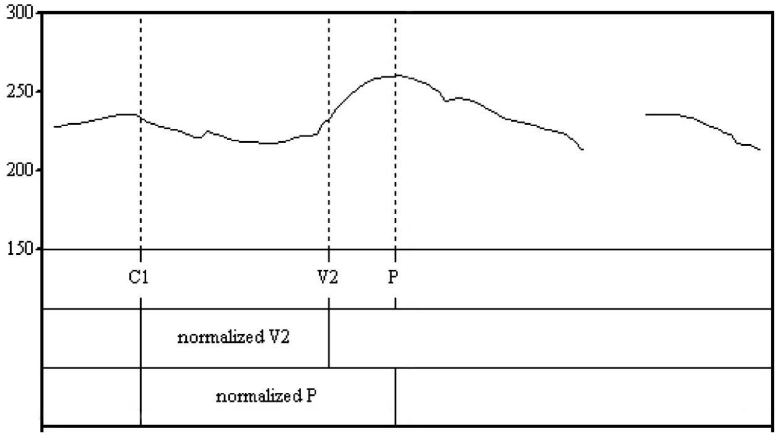

Figure 3. Normalized C1 onset, V2 onset and P(eak) time on the phrase /nala-lako/ ('country-Quotative').

phrase is 1500 ms, but the mean duration of the phrase of all speakers and all repetitions is 2000 ms, then this speaker's standardized time of segments, e.g., V2, C3, and so on, will get longer than the normalized time by the product of 2000/1500. The standardized time was used only for drawing pitch contours averaged over all subjects, but not for the statistical analysis.

To examine statistical significance of observed differences between pairs, t-tests or Wilcoxon Signed Rank tests were run. Those tests were run on the population of differences between members of a pair. For example, when V and V: were compared, the significance test was run on the values like $PeakF0_{V:}$-$PeakF0_{V}$ or $LowF0_{V:}$-$LowF0_{V}$, which were calculated within the speaker and repetition. In other words, the difference values of speaker1-repetition1, speaker1-repetition2, and so on, made up one sample population for the factor in question, e.g., vowel length. The t-tests adopted here were a one-sample t-test, testing whether the difference is equal to zero or not, but since the population was a set of differences between pairs, the result was assumed to be the same as that of Paired two-sample t-tests, testing whether two samples are different or not. The Wilcoxon Signed Rank tests are non-parametric tests, used for the sample populations that are *not* Normal. For the Normal populations, t-tests were used. Analysis of variance was also used for the comparison of three samples with one factor, such as F0 scaling for three lexical tones or three vowel heights. This test was only used when all three populations had equal variances, whereas t-tests or non-parametric two-sample tests were conducted when the populations did not have equal variances. Note that all the statistical tests were run on the normalized time, not the standardized time, for the time values. The statistics package JMP 7 was used for all the statistical significance tests in this study.

3. Variability in F0 Alignment and Scaling of Lexical Pitch Accents

In this section, the discussion of acoustic results is focused on the accentual F0 peak in describing the timing of pitch contours. Overall, phonetic realizations of accentual peaks and pre-accentual low targets are significantly affected by the factors listed in Table 1. F0 peak moves closer to or farther away from the phrase onset significantly in accordance to the tone type and the segmental duration. However, the relative positioning of the F0 peak against the segmental string remains constant. F0 scaling is also affected by vowel height such that high vowels have highest peak F0.

3.1. Underlying Contrast: Tone Type

This section concerns distinct peak alignment patterns of three distinct tones linked to the word-initial two syllables: HL, LH and HH. As S-E Chang (2003) showed, it was expected that the F0 peak is earliest for HL, latest for LH, and in between for HH. The current study goes further than this, showing how each tone is phonetically realized against the syllable structure. Simply saying the F0 peak of one tone is earlier than that of another may not suffice to define the characteristics of the lexical tones phonetically. In the current data, three sets of target phrases in a similar segmental context were compared. Segments were all sonorant, and the first vowel of the target phrase was /a/ in most cases (see Table 1).

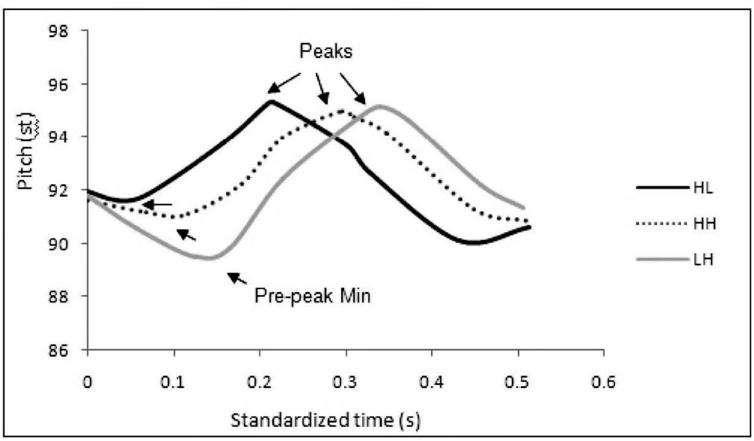

Figure 4. Pitch contours connecting mean values of measurements for three lexical tones: HL (solid dark line), HH (dotted line) and LH (solid lighter line).

Figure 4 shows mean pitch contours of target phrases, tests words plus *-ila/lako*, for the three lexical tones. The contours were drawn by connecting mean F0 and time values of each segment onset from C1 through V4. In this figure, it is obvious that the Peak alignment is distinct between the lexical tones. First, the F0 Peak of HL comes earliest and that of LH latest. To test the statistical significance of the apparent differences, non-parametric two-sample t-tests were run on the pairs of HL versus HH and HH versus LH. It turned out that the differences in Peak time of in both pairs were statistically significant ($\chi^2 = 10.1628$, $p < 0.005$). The difference between HL and LH was not tested, because its significance was assumed based on the fact that the mean difference was much greater than those of the other two pairs, as shown in Figure 4.

Peak F0, in contrast, was not significantly different between the three underlying tones, which contradicts the previous observations in the literature that tone HH is slightly lower in pitch either acoustically or perceptually than HL (C-K Kim 1985, S-E Chang 2007). An analysis of variance supports that the difference in Peak F0 is not significant between those tones [$F(2, 126) = 0.0098$, $p = 0.9902$].

Another noticeable difference among the three pitch contours in Figure 4 is the pre-Peak minimum (Min). In Figure 4, we see that the F0 scaling of Min of the tone LH is much lower than those of the other two tones, whereas the HH and HL tones have similar values. However, a non-parametric independent two-sample test on the Min F0 height reveals that the similar-looking Min F0s of the tones HH and HL are significantly different ($p < .05$).

Along with the F0 scaling, the pre-Peak Min time was significantly different between the three tones. We can see in Figure 4 that the Min of the tone LH is farther away from the phrase onset than those of the other two tones are, whereas the Mins of HL and HH are quite close to each other in the temporal dimension. A non-parametric two-sample test was run to examine whether HH and HL are undistinguishable in terms of the Min time. The test results show that the Min time was significantly different between HH and HL ($\chi^2 = 15.6629$, $p < .0001$).

Now let us look at exactly where in the segmental context the F0 Peak is realized. Figure 5 shows that the mean Peak aligns near the onset of the second vowel for HL, slightly before the offset of the second vowel for HH, and inside the third consonant (=C3) for LH. The Peak is about 10 ms on average after the onset of V2 for the tone HL, about 10 ms before the offset of V2 for HH, and about 30 ms before the onset of V3 for LH. Moreover, the mean Min, the pre-Peak F0 minimum, is realized slightly before the onset of the first vowel for HL, at the onset of the first vowel for HH, and near the offset of the second vowel for LH. In other words, among the three tones, the tone HL has early Min and Peak, and tone LH has late Min and Peak. The tone HH had early Min but late Peak, which means that the pitch rises early but falls late for HH. S-E Chang (2003, 2007) argued that the tone HH often, but not always, had a plateau-shaped pitch pattern. Such a plateau-shaped pitch pattern also suggests

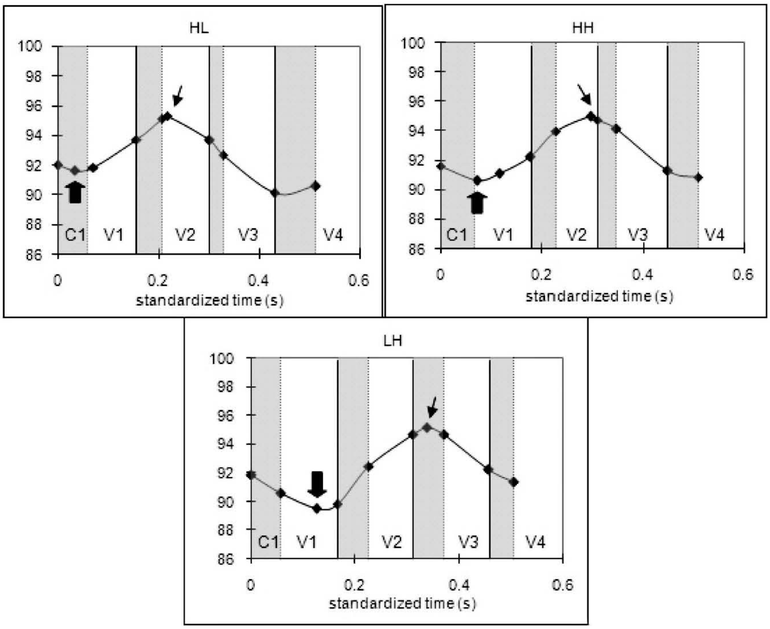

Figure 5. Mean contours of the target phrases, with three lexical tones HL, HH and LH on the first two syllables: Consonant portions shaded, and F0 Peaks and Mins marked with thin and thick arrows, respectively.

the early rise and late fall of pitch. In the current data, however, such a plateau-shaped pattern was rarely observed; most pitch contours had less steep but clear Peaks.

3.2. Phonological Vowel Length

This section shows how F0 scaling and alignment are correlated with phonological vowel length. NK Korean has a vowel length contrast, but it exists only in those words that have a "doubly-linked H" (J Jun et al. 2006), or HH informally, on the first two syllables, so minimal pairs of a short vowel and a long vowel with tone HH were compared. The current data reveal that F0 Peak comes farther away from the phrase onset in a long vowel than a short vowel, but the Peak timing is constant relative to the segmental context across the vowel lengths. That is, the apparent later realization of the Peak in the long vowel has to do with the Peak timing adjustment, moving in sync with the offset of the vowel, in accordance with the vowel duration.

Figure 6 shows two pitch contours with a short vowel (V) and a long vowel (V:) on the initial syllable. In this figure, arrows indicate the F0 Peaks of the two vowel length conditions. The dotted vertical lines indicate the offset of the first syllable which has distinct vowel lengths. The lighter line indicates the short vowel condition, whereas the darker line indicates the long vowel condition.

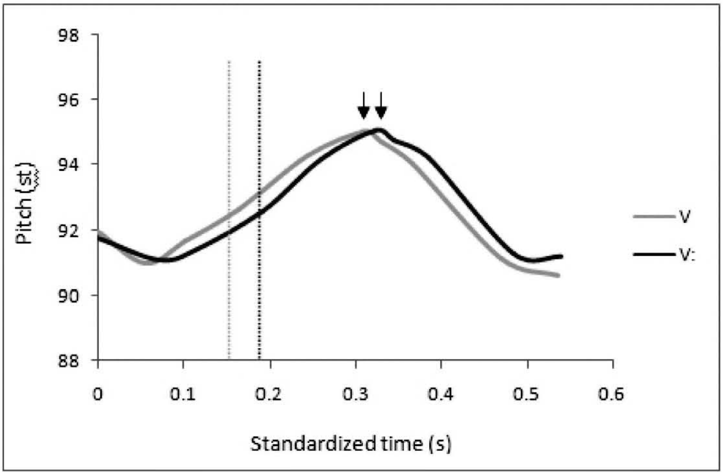

Figure 6. Pitch contours of target phrases with short (V) versus long (V:) vowel on the initial syllable: dotted vertical lines indicate the offset of the first syllable.

We can see from Figure 6 that the general contour seems slightly shifted rightwards for the case of the long vowel (V:). In other words, both the Peak and Min are realized farther away from the phrase onset for the long vowel, which is statistically significant ($p<.0001$ for Peak and $p=.0093$). Noteworthy is that the mean difference in vowel duration between the long and short vowels is about 27 ms, and the mean difference in the Peak location is about 25 ms. This suggests that the Peak delay in the long vowel has something to do with its longer vowel duration. Further, it also suggests that the F0 Peak is in sync with the offset of the vowel rather than the onset of the vowel or the phrase. This becomes clearer if the pitch contours are plotted against the segments as in Figure 7. In this figure, the shaded portions indicate consonants, and the solid vertical lines mark syllable boundaries. We can see that the alignment of the Peak and the Min relative to the segmental context is roughly the same. The Peak is aligned around 20ms before the offset of the second vowel in both vowel conditions. The observation that the relative alignment against segments is quite constant across the vowel lengths is also statistically supported. Wilcoxon Signed Rank tests run on the difference populations of [C3 – Peak time] (see the rightward arrows in Figure 7) and [Peak – V2 time] (see the leftward arrows in Figure 7) reveal that the mean distance between the Peak and the onset of the second vowel (V2) or between the Peak and the offset of the second vowel (= C3) was not significantly different between the vowel conditions

(p = .8677 for [C3 – Peak time] and p = 0.5650 for [Peak – V2 time]).

In the meantime, F0 scaling has nothing to do with the phonological vowel length difference; the Peak F0 is not statistically significant (p = .2330).

An interesting finding is that only three out of five speakers produced the vowel length significantly differently, although all of them were expected to have the vowel length contrast. The other two speakers seemed to have neutralized the vowel length. It is interesting that it has been generally known that NK Korean preserves both tonal and vowel length contrasts but the current data show that even NK Korean speakers neutralize the vowel length distinction. Vowel length neutralization is more common in other varieties of Korean. As observed by S-N Lee (1960, as cited in M-S Jung 2002), vowel length neutrali-

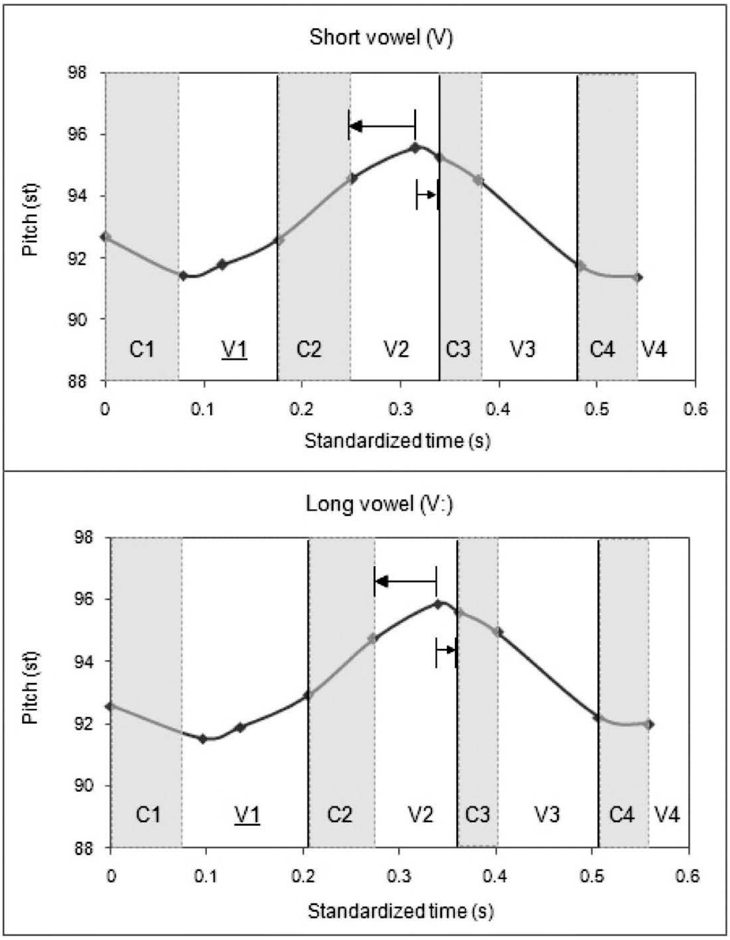

Figure 7. Mean contours of the target phrases with short (top panel) and long vowel on the initial syllable: Consonant portions shaded.

zation started a long time ago in Seoul Korean. Whether the vowel length is contrastive in Modern Korean is still debatable. However, it seems generally accepted that at least in younger speakers, the contrast is almost neutralized (M-S Jung 2002 and references therein) in Seoul Korean. With the two speakers excluded, the mean difference in vowel duration and normalized Peak timing is 10 ms greater on average in the three speakers than for all five speakers.

3.3. Vowel Height and Intrinsic Duration

This section explores whether there is a correlation between F0 and vowel height in NK Korean as observed in English (Taylor 1933). This section also explores any correlation between intrinsic vowel duration and F0 peak timing.

Figure 8 shows general pitch contours of the target phrases for three vowel conditions. The pitch contours were drawn by interpolating mean values of all the segment and pitch targets. In this figure, it is clearly shown that the pitch contours for the three vowel heights are different mainly in terms of the F0 Peak, while the post-Peak falling contours are mostly overlapping. When it comes to the F0 scaling, the Peak is highest with the high vowel and lowest with the low vowel. When it comes to the Peak alignment, the Peak is realized closest to the phrase onset for the high vowel and farthest for the low vowel. T-tests run on the differences of [High V– Low V] with respect to F0 Peak time and Peak F0 showed that the Peak time and Peak F0 of the High Vowel were significantly different from those of the Low Vowel. The Peak was significantly closer to the phrase onset ($p < .0001$), and the Peak F0 was significantly higher for the high vowel than the low vowel ($p < .0001$).

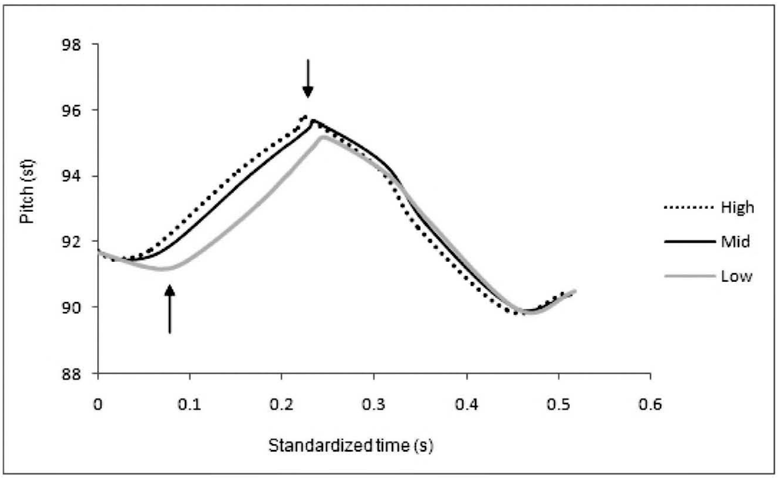

Figure 8. Mean contours of the target phrases for three vowels, High, Mid and Low, on the initial syllables with the tone HL.

When it comes to the Peak alignment, the variability has to do with the intrinsic vowel duration. An analysis of variance run on the distance between the Peak and the V1 offset shows that the three vowel heights are not signifycantly different in terms of the Peak timing relative to the first vowel offset (p

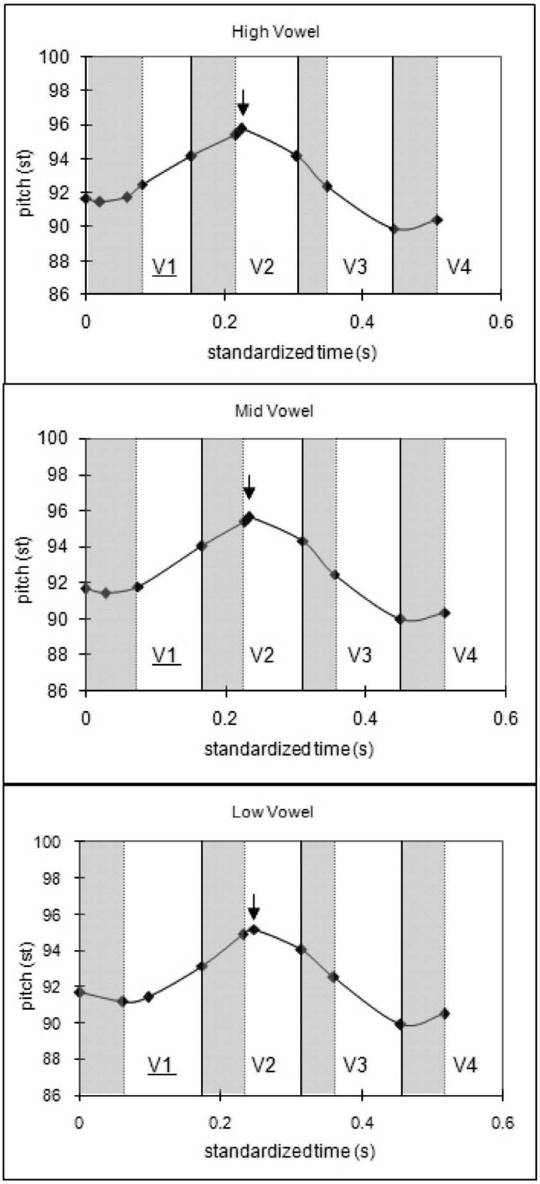

Figure 9. Mean contours of the target phrases for High (top), Mid (middle) and Low vowel on the initial syllables: Consonant portions shaded.

= .6380). That is, the peak is placed in an identical distance from the offset of the accented first vowel. In other words, the Peak location co-varies along with the accented vowel offset. This correlation between vowel duration and Peak time is confirmed in Figure 9, where three pitch contours are plotted against segmental contexts. In this figure, segmental compositions are displayed with partitions, of which shades refer to consonants and non-shades indicate vowels. With those partitions, the three mean pitch contours look roughly identical in that the F0 Peak is aligned right after the onset of the second vowel in all three vowel conditions.

4. Discussions

4.1. Peak Delay

This study has shown that F0 Peak, the most prominent phonetic correlate of accent H*, does not position within the H* accented syllable in NK Korean. Rather, the F0 Peak of a singly-linked H* is realized slightly *after* the offset of the phonologically associated syllable.[6] In this study, the F0 Peak of tone HL was delayed about 60 ms on average from the offset of the first syllable, whereas the Peak of LH was delayed about 27 ms on average from the offset of the second syllable. This discrepancy between the phonological association and phonetic realization should not be confused with the phonological association; it cannot suggest that the pitch accent is in fact associated with the next syllable.

F0 peak delay is in fact a common tonal behavior observed in different languages. It refers to a mismatch between the phonological association and the phonetic realization of tone. Silverman and Pierrehumbert (1990) found that F0 peak associated with prenuclear H* often occurred after the syllable with the pitch accent. Similar F0 peak delay relative to the stressed or accented syllable was observed in Mexican Spanish (Prieto et al. 1995), Greek (Arvaniti et al. 1998), Chichewa (S-A Kim 1999), and Mandarin Chinese (Xu 1999). Xu (1999) argued that peak delay occurs due to the "articulatory constraint that limits how fast the larynx can reverse the direction of pitch movement" (p.1881).

The articulatory constraint may explain the greater degree of Peak delay with HL than with LH in NK Korean (see Figure 5) such that HL, immediately preceded by phrase-initial lowering (= Min), may be more limited in temporal space so the Peak may have to be pushed further to the right, as

[6] Although the current study shows that the F0 Peak location is correlated with the vowel duration in the open syllable, F0 Peak location is in fact correlated with the syllable offset instead of vowel offset whether the syllable is open (CV) or closed (CVC) (see H-S Lee 2008).

temporal space so the Peak may have to be pushed further to the right, as opposed to LH whose H is phonologically farther away from the initial lowering. However, despite the language-independent nature of the articula-tory constraint, the presence and the degree of peak delay may still depend on languages. For instance, Seoul Korean may not have peak delay (de Jong 1994) and South Kyeongsang Korean may or may not have peak delay depending on the lexical tone type (S-E Chang 2007). Thus, the Peak delay in NK Korean needs to be explained by its language-specific phonetic implementation as well as its lexical tone system.

4.2. Segment-tone Correlation

This study has shown that there is a correlation between the accentual F0 peak location and the duration of the accent-bearing vowel in NK Korean. Whether the vowel is phonologically long or short, F0 peak is located roughly the same distance from the offset of the vowel in question. Moreover, whether the vowel is intrinsically long or short, as in low and high vowels, respectively, the F0 peak is also located roughly the same distance from the offset of the vowel.

It must be the regular correlation between the F0 realization and the segmental context that makes it possible to retrieve lexical tones correctly despite the F0 peak delay. Since the peak delay is consistent relative to the segmental context, native speakers know that they need to adjust the delay relative to the segmental landmarks, and they know which syllable the F0 Peak actually belongs to.

More and more studies have been published to show that phonetic implementation is not language-independent. For instance, Ladd (2004) argued that "segmental anchoring" of tone varies across languages with only very small differences and that such small differences should be accounted for by language-dependent phonetic implementation. In this regard, the segment-tone correlation needs to be carefully examined in each language for identifying the phonetic correlates of phonological tones for the language. As NK Korean is drawing more attention in the phonetics field, detailed phonetic characteristics of lexical tones need to be identified for an accurate description of its prosodic system. This study is only one study on the segment-tone correlation in NK Korean, and the results are still limited in that the phonetic tone alignment issue was addressed only in the sentence-medial and phrase-initial contexts. Further studies are desired for the comprehensive understanding of the phonetic realization of NK Korean tones.

5. Conclusion

This paper has shown that "singly-linked H" of North Kyeongsang Korean is phonetically realized with a delayed F0 peak. The F0 peak comes after the offset of the tone-bearing syllable. The peak delay is greater when a singly-linked H is linked with the phrase-initial syllable than when it is linked further away from the phrase onset. "Doubly-linked H" of North Kyeongsang Korean is phonetically realized with its F0 peak in the middle of the second vowel of the phrase.

This paper has also shown that accentual F0 Peak location is correlated with phonological and phonetic segment duration in North Kyeongsang Korean. The F0 Peak moves horizontally in accordance to the segment duration, which were either phonologically or phonetically determined, keeping its distance from the syllable offset constant. Peak F0 is also correlated with intrinsic vowel duration such that higher vowel, or intrinsically short vowel duration, has higher F0 in North Kyeongsang Korean.

This study is limited in the number of native speakers who participated in the experiment as well as the morphosyntactic and prosodic conditions that the data were elicited. Therefore, more systematic studies will be necessary for a comprehensive and accurate description of phonetic realizations of the North Kyeongsang Korean pitch accent system.

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Received: September 1, 2010
Revised version received: December 1, 2010
Accepted: December 3, 2010