The production and perception of word-level prosody in Korean*

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1. INTRODUCTION

This paper reports the results of an investigation into the production and perception of Korean word-level prosody. The production study examines the effects of syllable weight and syllable position on syllable duration, vowel duration, onset duration, coda duration, and fundamental frequency of Seoul Korean. We also examine what attributes of a syllable cause it to be perceived as prominent. The perception study examines how Korean word prominence is perceived by native speakers of English, Japanese, and Korean.

1.1. Stress as prominence in English

In English, stress is defined as "prominence" for relative distinctiveness of a linguistic unit (Jones, 1960) or is termed as "accent" for achieving linguistic prominence (Lehiste, 1970). According to Couper-Kuehlen (1986), stress denotes the perception of one linguistic unit which is somehow more prominent others. Incorporating previous definitions of stress, Beckman and colleagues (Beckman, 1986; Beckman, Edwards and Fletcher, 1992; and Beckman and Edwards, 1991) have taken the notion *stress* as prominence by describing stress and accent using one unified representation with four prominence levels (recited from de Jong, 1991: 6). As is well documented in previous studies, prominence is highly correlated with suprasegmental characteristics of speech sounds: prominent syllables or words have a conspicuous fundamental frequency change, longer duration and higher amplitude (Fry, 1955, 1958; Lieberman, 1960; Lehiste, 1970). Especially, a change in fundamental frequency is reported as the most reliable cue for prosodic prominence (Bolinger, 1958 for English; van Katwijk, 1974 for Dutch).

1.2. Korean word prominence

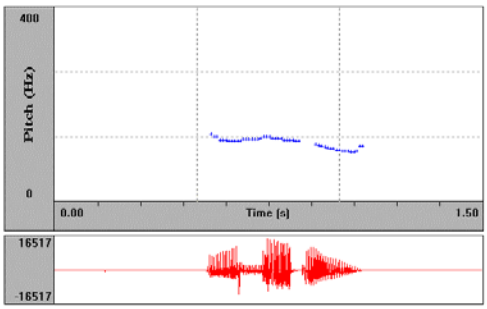
For Korean prosodic prominence, de Jong (1994) suggests that the so-called stress or word-level prominence in Korean can be an interpretation of an edge tone. Along the same line, Jun (1990, 1993, 1998) has developed a Korean Prosodic Model based on pitch contours following the Japanese prosodic models by Beckman and Pierrehumbert (1986) and Pierrehumbert and Beckman (1988). According to her model (1993, 1998), the delimitation of prosodic units is primarily determined by pitch contours *or tonal patterns*. She describes the tonal patterns of two important prosodic units in Seoul Korean, 1) Accentual Phrase (AP) and 2) Intonatational Phrase (IP): the AP has a phrase final rising pattern, a LH as in Figure (1b), and the IP may have one of several boundary

* For the purpose of this paper, we assume that CVC syllables are heavy syllables and CV syllables are light without any further explanation, since this is not the topic of the current paper: For the phonological status of coda consonant, J. H. Jun (1994) proposes that the Korean coda consonant is moraic; thus CVV and CVC syllables are heavy syllables. On the other hand, Tak (1997) analyzes that CV and CVC syllables are light in Korean. In addition, since the vowel length distinction seems to be lost in Seoul Korean, the syllable structure with a long vowel, or CVV syllable structure, is not considered in this study, either.

tones such as L%, H%, LH%, HL%, LHL%, and HLH%. However, when the final syllable of the AP is the IP final, the final rise of the AP is replaced by the IP boundary tones as in (1a)[1].

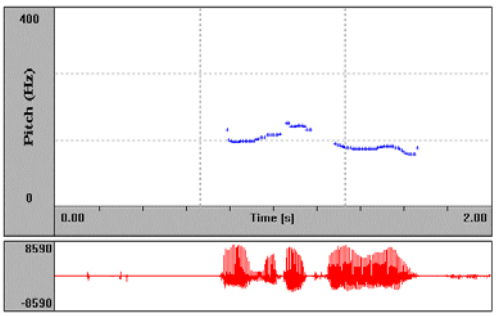
(1) Fundamental frequency contours depending on prosodic units

a.



[(L H L%)$_{AP}$] $_{IP}$
ma.mu.ri

b.



[(L H)$_{AP}$(L H L%)$_{AP}$]$_{IP}$
ma.mu.ri co.a.yo

In a phonetic study of Korean stress, Jun (1995a) reports that the second syllable is prosodically stronger, which could be interpreted as stressed. She also mentions that stress exists in the language since a certain syllable within a prosodic unit *the AP* shows higher fundamental frequency and greater amplitude. Since the prosodically strongest syllable of a word changes depending on its position within the AP, stress is a property of the AP.

Korean is quite unique in that claims about stress (or prominence) placement vary considerably from study to study. H. B. Lee (1973, 1985) and H. Y. Lee (1990) suggest that Korean is a stress language. They propose that Korean has a duration-based stress system where syllable duration plays a key role in locating stress, while the role of pitch pattern is only marginal in the decision of stress position. Along this line, Kim (1988) claims that Korean has a rightward right-headed iambic foot structure and it has moraic coda consonants. Thus, stress falls on the first syllable, if it is heavy, or it falls on the second syllable if the first syllable is light. Some examples are given in (2).

(2)	kyo:.do.so ‘prison’	si:.cang ‘market’	cam.ca.ri ‘dragonfly’
	H L L	**H** H	**H** L L
	nak.son ‘rejection’	i.ya.ki ‘story’	ke.ul ‘mirror’
	H H	L **L** L	L **H**

(H: heavy syllable; L: light syllables; underlined are stressed syllables; data from Kim, 1998)

On the other hand, Yu (1989) proposes Accent Placement Rules in Modern Korean. Accent falls on the leftmost heavy syllable, otherwise the rightmost light syllable. Examples are shown in (3).

[1] Please see Jun (1993, 1995a, 1995b, and 1998) for the detailed characteristics of the AP and the IP.

(3)

pa.ram ‘wind’	sa:.ram ‘people’	nun.bo.ra ‘snow storm’
L **H**	**H** H	**H** L L
a.u ‘younger sibling’	i.ma ‘forehead’	pi.hang.ki ‘airplane’
L **L**	L **L**	L **H** L

Previous studies claim that Korean prominence is weight-sensitive and duration based. In addition, syllable position seems to play a role in determining prominence of the words. In this study, a production experiment is carried out to fulfill two functions. 1) It examines syllable position and weight effects on duration and fundamental frequency which might indicate the presence of stress and, 2) it determines acoustic correlates to be used in a following perception test.

2. EXPERIMENT I: PRODUCTION

The goal of the first experiment was to examine the effects of syllable position and syllable weight on syllable duration, vowel duration, onset duration, coda duration and fundamental frequency of Seoul Korean.

2.1 Method

2.1.1. Subjects

Two male native speakers of Seoul Korean participated in the experiment. They were both graduate students at Indiana University. They were both in their early thirties and neither had any known speech or hearing disorders.

2.1.2. Stimuli

In a production experiment, stimuli included three-syllable words composed of combinations of heavy and light syllables. Given three-syllable words, it is logically possible to have eight different combinations in terms of syllable weight as in Table 1. All test words had the vowel [a] to minimize intrinsic durational differences.

(4) [Table 1] Stimulus material

No	Syllable weight	Word	Gloss
1	LLL	Ma.na.gwa	The capital of Nicaragua
2	LHL	Ja.jang.ga	Lullaby
3	LHH	Ma.gam.nal	Deadline
4	LLH	Na.ma.dam	Ms. Nah
5	HHH	Mal.jang.nan	Joke
6	HLL	Man.da.ra	The title of a movie
7	HLH	Kang.ma.dam	Ms. Kang
8	HHL	Man.dam.ga	Comedian

(H: heavy syllable; L: light syllable, ‘.’: syllable boundaries)

2.1.3. Procedure

Subjects were asked to read the test words five times at a comfortable speech rate. Test words were placed in two prosodic conditions, in isolation as a single IP, and in a sentential context as the first AP in a larger IP as shown in (5).

(5) Test words within two prosodic conditions

a. [**(ja.jang.ga)**$_{\mathbf{AP}}$] $_{IP}$ "A lullaby"

b. [(**ja.jang.ga)** $_{\mathbf{AP}}$ (pul.reo.ju.se.yo) $_{AP}$] $_{IP}$ "Please, sing a lullaby"

The list of test words was presented in Korean orthography. Fillers were included to avoid list effects. Before recording, subjects practiced reading randomly ordered test words to familiarize themselves with the materials. All recordings were made in the recording room in the Indiana University Linguistics Department. Recordings were analyzed using the software *SoundScope* on a Mac II in the Indiana University Phonetics Laboratory.

2.1.4. Measurement

Measurements were taken of syllable, vowel, and consonant durations. In addition, the fundamental frequency of each vowel was measured. For the fundamental frequency measurements, we measured three points of vowels: 1) the onset, 2) the steady-state portion and 3) the offset of each vowel. This study only reports the fundamental frequency values of the steady-state portions of vowels.

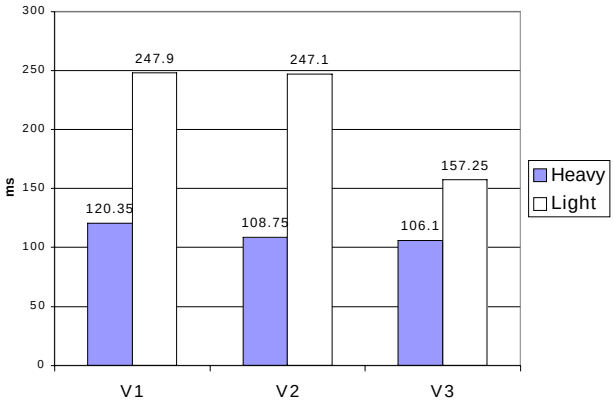
2.2. Results

2.2.1. Vowel duration

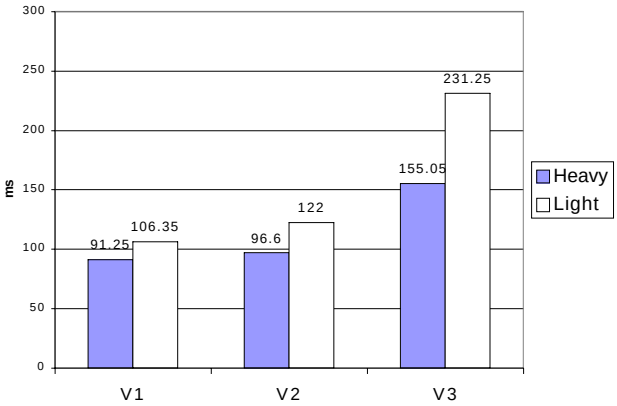
The results of the mean vowel duration as a function of syllable position are shown in (7).

(7) Mean vowel duration for each speaker

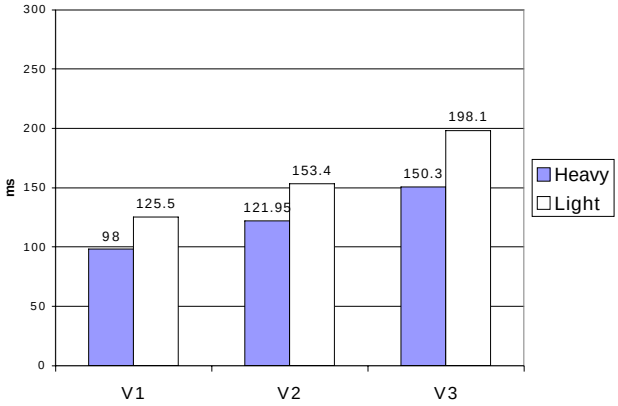
a. V-duration (Speaker 1: IP)



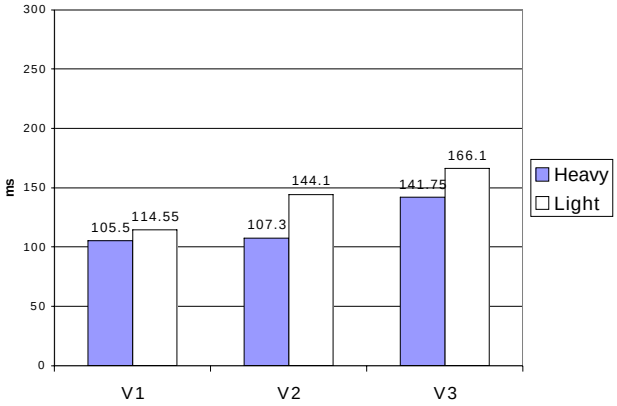
b. V-duration (Speaker1: AP)



c. V-duration (Speaker 2: IP)



d. V-duration (Speaker 2: AP)



(V1: initial vowel; V2: middle vowel; V3: final vowel;
Heavy: heavy syllable; Light: light syllable)

As seen in (7), the effect of syllable weight is salient: the combined mean vowel duration of light syllables were significantly longer than that of heavy syllables ($t(118)=4.094$, $p<0.001$ for Speaker 1; $t(118)=4.695$, $p<0.001$ for Speaker 2).

For the vowel duration of the IP for Speaker 1, a one-way ANOVA revealed that a significant difference among syllable positions for light syllables [$F(2, 57)=26.338$, $p<0.001$ for light syllables], while heavy syllables show a slightly larger than the 0.01 alpha level [$F(2, 57)=4.488$, $p=0.015$]. According to *post-hoc* tests, initial vowel duration showed the longest value for the IP light syllables.

For the vowel duration of the AP for the same speaker, there is a significant durational difference among syllable positions as well [$F(2, 57)=128.65$, $p<0.001$ for light syllables; $F(2, 57)=33.029$, $p<0.001$ for heavy syllables]: multiple comparisons showed that initial and medial vowel durations are significantly longer than final vowel durations for both light and heavy syllables.

Let us turn to speaker 2. For the IP condition, first, there was a significant durational difference among syllables for both heavy and light syllables [$F(2, 57)=55.151$, $p<0.001$ for light syllables; $F(2, 57)=32.026$, $p<0.001$]: final vowels are significantly longer than medial vowels, in turn, which are significantly longer than initial vowels for both light and heavy syllables.

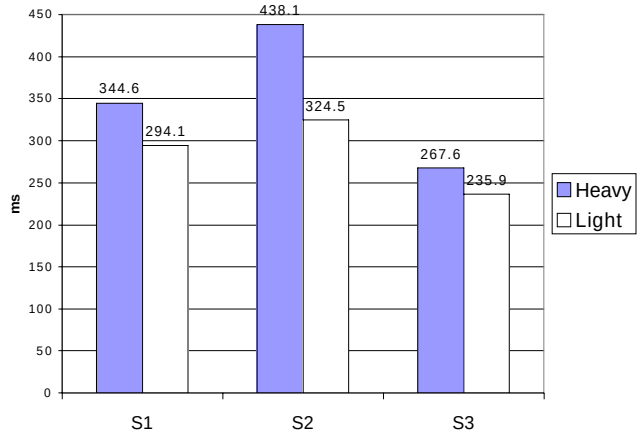
For the AP condition, there was also a significant difference in vowel duration among syllable positions across heavy and light syllables [$F(2, 57)=30.452$, $p<0.001$ for light syllables; $F(2, 57)=24.483$, $p<0.001$ for heavy syllables]: for light syllables, final vowels are significantly longer than medial vowels, and initial vowels are the shortest. For heavy syllables, however, final vowels are the longest, and there is no significant durational difference between initial and medial vowels.

2.2.2. Syllable duration

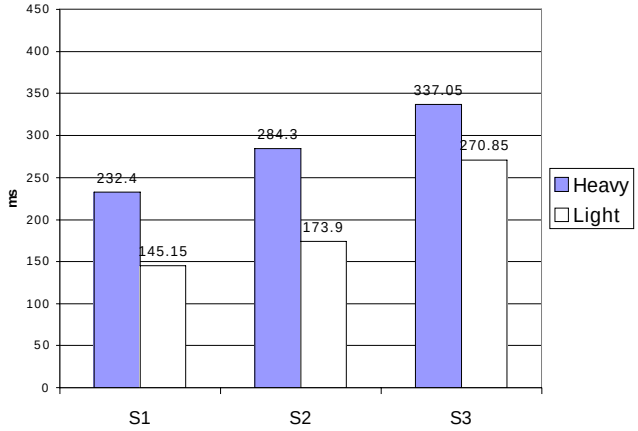
Like vowel duration shown above, there is a significant difference in syllable duration between light and heavy syllables; unlike vowel duration, however, heavy syllables are much longer than light syllables ($t(118) = -8.135$, $p<0.001$) as shown in (8).

(8) Mean syllable duration for each speaker

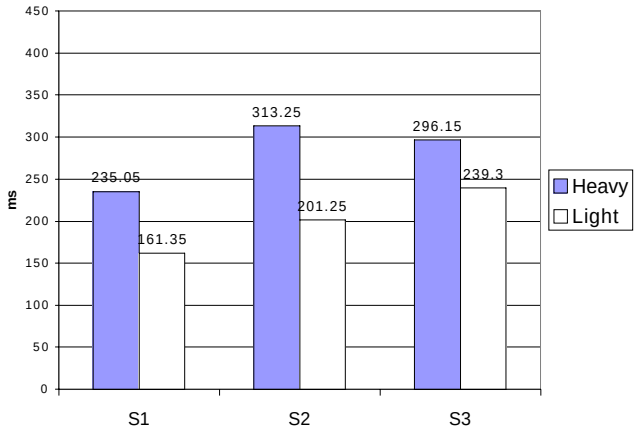
a. Syll-duration (Speaker 1: IP)



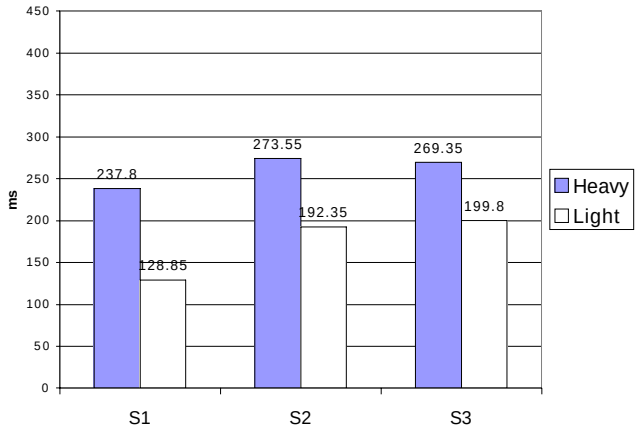
b. Syll-duration (Speaker 1: AP)



c. Syll-duration (Speaker 2: IP)



d. Syll-duration (Speaker 2: AP)



(S1: initial syllable; S2: middle syllable; S3: final syllable)

This is not surprising since heavy syllables have a coda. Let us take a closer look at speaker 1, first. For the IP condition, as shown in (8a), the syllable duration revealed a significant difference among syllable positions [$F(2, 57)=26.338$, $p<0.001$ for light syllables: $F(2, 57)=59.034$, $p<0.001$ for heavy syllables]: regardless of syllable weight, medial syllables are longer than other syllables.

For the AP condition, both light and heavy syllables showed significant differences in syllable duration as shown in (8b) [$F(2, 57)=71.899$, $p<0.001$ for light syllables; $F(2, 57)=50.377$, $p<0.001$ for heavy syllables]. Interestingly, this AP condition has the longest value on final syllables, like vowel durations for the AP, which is different from the IP condition.

Speaker 2 showed similar patterns to speaker 1. For the IP condition, as shown in (8c), both light and heavy syllables showed significantly different syllable durations depending on syllable positions [$F(2, 57)=34.976$, $p<0.001$ for light syllables; $F(2, 57)=53.806$, $p<0.001$) for heavy syllables]. For light syllables, final syllables are longer

than medial syllables, in turn, which are longer than initial syllables. However, for heavy syllables, there is no significant difference in syllable duration between medial and final syllables, which is, however, statistically longer than initial syllables.

For the AP condition, both light and heavy syllables showed a significant difference as a function of syllable position as in (8d) [F (2, 57)=33.630, p<0.001 for light syllables; F (2, 57)=7.868, p=0.001 for heavy syllables]. Multiple comparisons results showed that both medial and final syllables are longer than initial syllables across syllable weight.

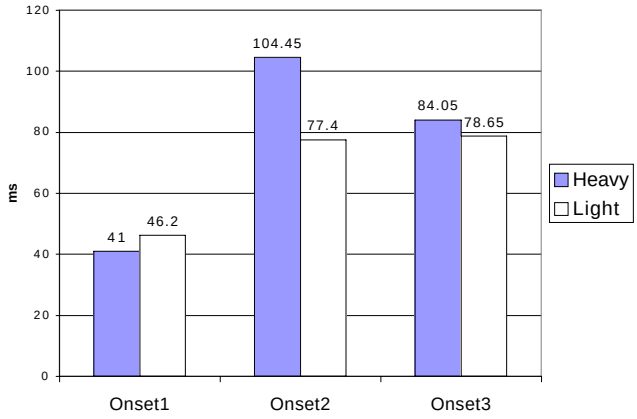
We have shown so far that there are not necessarily the same patterns between vowel and syllable durations. Heavy syllables showed the longest medial syllables with the longest final vowel duration. Thus, we turned to onset and coda durations to see durational patterns for internal structure of syllables.

2.2.3. Onset duration

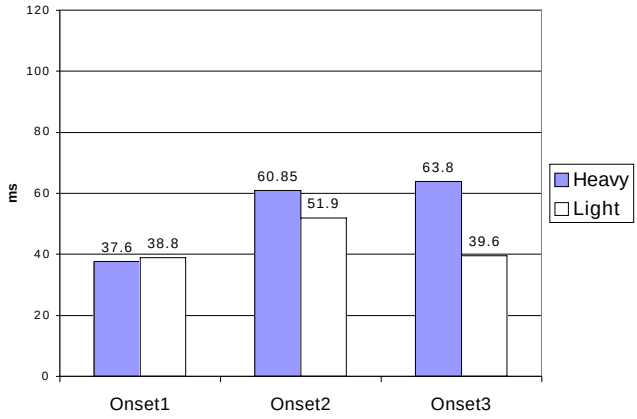
Average onset durations by each speaker are shown in (9).

(9) Mean onset duration for each speaker

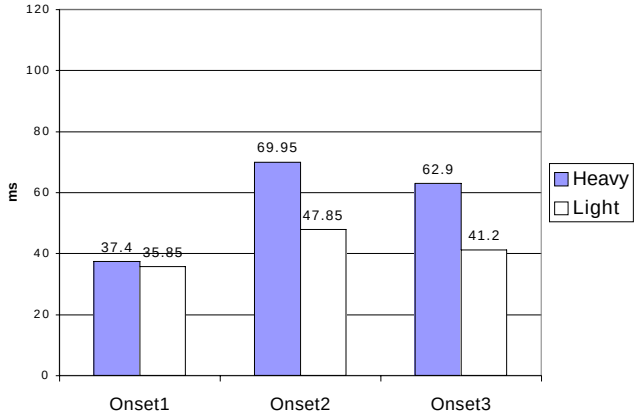
a. Onset-duration (Speaker 1: IP)



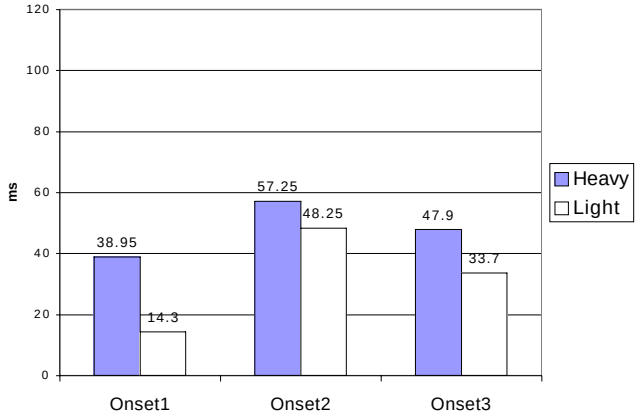
b. Onset-duration (Speaker 1: AP)



c. Onset-duration (Speaker 2: IP)



d. Onset-duration (Speaker 2: AP)



For speaker 1, as shown in (9a), there is a significant positional effect on onset durations regardless of syllable weight for the IP condition [F (2, 57)=12.413, p<0.001 for light syllables; F (2, 57)=19.414, p<0.001 for heavy syllables].

For the AP condition, heavy syllables showed a significant positional differences in onset duration [F (2, 57)=10.905, p<0.001] while light syllables did not [F (2, 57)=3.302, p=0.044] as shown in (9b). In general, onset duration in medial syllable position is longer than other syllables across syllable weight and phrasal conditions.

(9c) and (9d) showed mean onset durations for speaker 2; all across the board, medial onsets are longer than other positions. For the IP condition, only heavy syllables showed significantly different onset durations depending on syllable positions [F (2, 57)=14.570, p<0.001] while light syllables showed no significant differences [F (2, 57)=1.705, p=0.191].

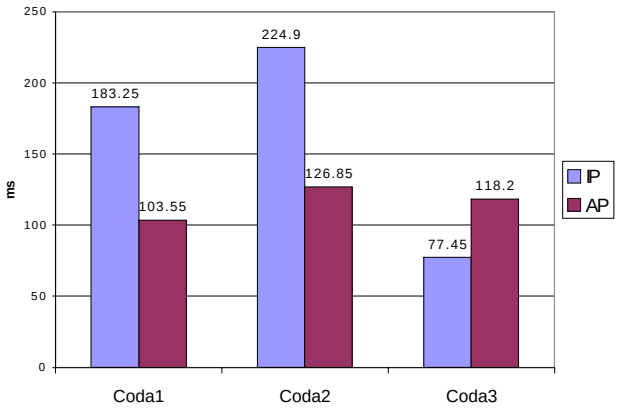
On the other hand, the AP condition showed a significant positional effect on onset durations for light syllables [F (2, 57)=9.925, p<0.001] and marginally significant differences for heavy syllables [F (2, 57)=4.344, p=0.18].

2.2.4. Coda duration

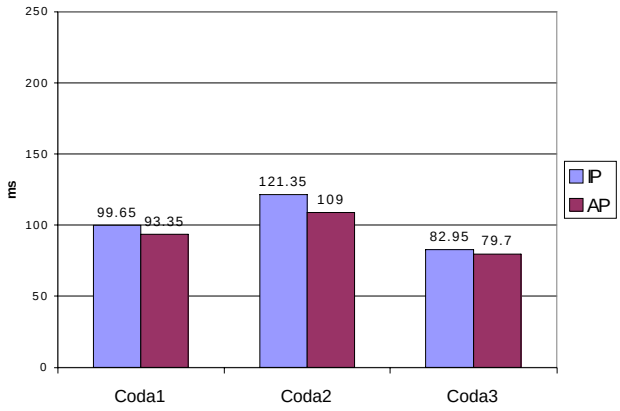
For coda duration, only heavy syllables were considered since light syllables have no codas. Following are results of mean coda duration for each speaker under different phrasal conditions.

(10) Mean coda durations for each speaker

a. Coda-duration (Speaker 1)



b. Coda-duration (Speaker 2)



As shown in (10), positional effects were maintained with longest medial codas. A one-way ANOVA revealed that there is a significant difference in coda duration for the IP [F (2, 117)=6.371,p=0.002], but not for the AP [F (2, 117)=0.357, p=0.701] for speaker 1 as shown in (10a).

As shown in (10b), however, Speaker 2 did not show any significantly different coda durations as a function of syllable position even though there is a tendency to have longest medial codas regardless of phrasal conditions [F (2, 117)=1.230, p=0.296 for the IP; F (2, 117)=0.805, p=0.449 for the AP].

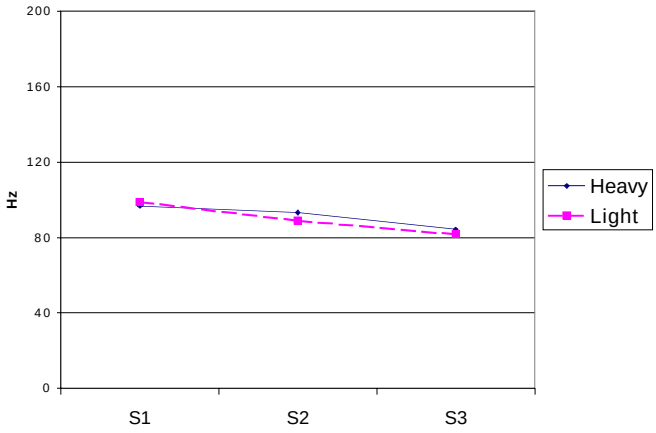
So far we have shown that durational differences are significant due to the effects of syllable position and syllable weight. In addition, these durational differences seemed to be highly affected by phrasal conditions. Lastly, we examined the effects of syllable position and syllable weight on the fundamental frequency in the following section, which is highly likely to be influenced by phrasal conditions as mentioned in section 1.

2.2.5. Fundamental frequency

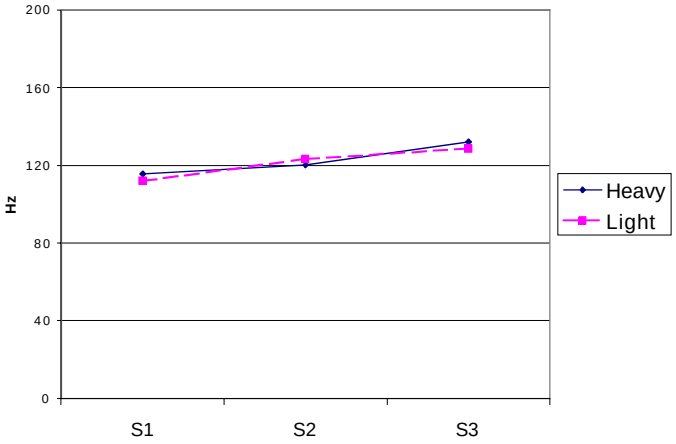
As previously mentioned, Korean prosodic units seem to be determined by pitch contours or *tonal patterns* (Jun, 1993, 1998). As shown in (1a & b), the AP has a phrase final rising pattern, or a *LH*, and the IP may have a LHL boundary tone for declarative sentences. Given this, we turn to the results of fundamental frequency patterns. The fundamental frequency contours by prosodic units and by speakers are shown in (11).

(11) Fundamental frequency contours for each speaker

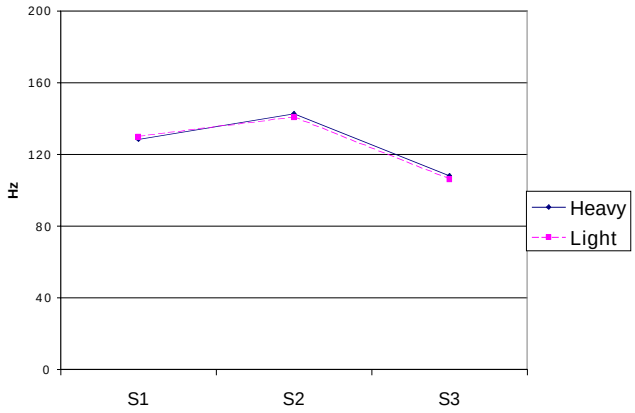
a. F0 (Speaker 1: IP)



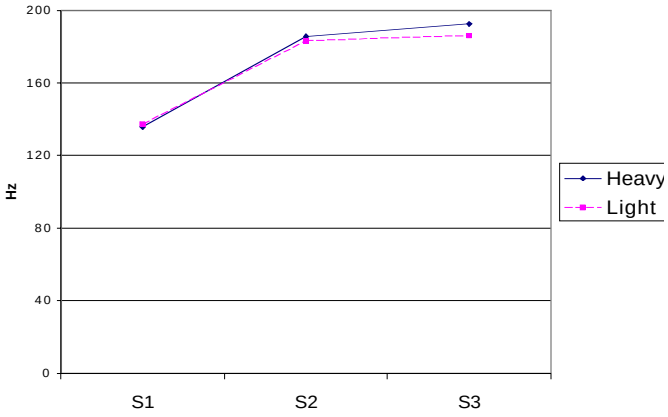
b. F0 (Speaker 1: AP)



c. F0 (Speaker 2: IP)



d. F0 (Speaker 2: AP)



As shown in (11), in general, the tonal patterns of each prosodic unit confirmed the previous studies in that the IP has a final fall while the AP has a rise.

However, there seemed to be a speaker-specific difference in these tonal patterns: For the IP condition, speaker 1 showed a falling tonal pattern with the highest value on the initial syllable whereas speaker 2 showed Low-High-Low tonal patterns, as in previous studies. For the AP, speaker 1 showed Low-High tonal patterns while speaker 2 showed Low-High-High tonal patterns.

There were no syllable weight effects on the fundamental frequency contours across the speakers and phrasal conditions [for speaker 1 ($t(58)=-1.089$, $p=0.278$ for the IP; $t(58)=0.638$, $p=0,525$ for the AP) and for speaker 2 ($t(58)=-0.259$, $p=0.796$ for the IP; $t(58)=-0.497$, $p=0.620$ for the AP)].

However, there was a significant positional effect on the F0. For the IP, speaker 1 showed higher F0 values on the first syllables [$F(2, 57)=70.773$, $p<0.001$ for light syllables; $F(2, 57)=26.224$, $p<0.001$ for heavy syllables]. For speaker 2, the F0 value on the second syllable is higher than that of initial syllable, which, in turn, was significantly higher than final syllables [$F(2, 57)=288.045$, $p<0.001$ for light syllables, $F(2, 57)=327.340$, $.p<0.001$ for heavy syllables].

As mentioned earlier, the AP final tonal pattern showed a rise, a *LH*, and the results confirmed this tonal pattern with the highest F0 values for final syllables across speakers [For speaker 1: $F(2, 57)=13.636$, $p<0.001$ for light syllables & $F(2, 57)=20.490$, $p<0.001$ for heavy syllables; for speaker 2: $F(2, 57)=288.045$, $p<0.001$ for light syllables & $F(2, 57)= 27.340$, $p<0.001$ for heavy syllables].

2.3. Discussion

For durational patterns, the final vowels were significantly longer than vowels in the first two syllable positions except for speaker 1's IP condition[2]. This durational difference was turned out to be a final lengthening effect by the post hoc analysis. Interestingly, for heavy syllables, medial syllable durations were noticeably longer than other syllables as far as syllable durations were concerned (except for speaker 1's AP condition). This might indicate that the second syllable position would be prominent or stressed. In addition, the durational patterns for the constituents of a syllable also showed that medial positions were different from other syllable positions. That is, coda durations and onset durations combine to give longer durations. Therefore, it might be possible to say that a second syllable position seemed to be favored for attracting prominence or stress just based on the durational patterns for heavy syllables.

This is not the case for vowel durations. Seemingly, there is a conflict in durational patterns between vowels and syllables. Vowel durations indicate an edge effect, that is, a boundary lengthening effect while syllable durations might reflect the prominence pattern of words, a head effect in Korean. Fundamental frequency patterns also seem to support these conclusions. In general, the medial syllable position shows higher F0 than other syllables, especially for speaker 2. That is, the peak of F0 is shown near onset of the second syllables.

Results of this study, however, seem to be problematic considering previous studies. According to Jun (1990, 1994), the AP initial segments were lengthened, which implied that the IP initial segment duration would show greater lengthening since the IP is higher than the AP in a prosodic higher in a prosodic hierarchy. Compared to these studies, our

[2] For the IP condition, speaker 1 seems to have the so-called 'strengthening strategy' for initial two syllables with longer vowel duration and higher fundamental frequency on those initial two syllables.

results seem to be contradictory. Since Jun's argument was based on the durations of lenis stops in the AP and I measured initial sonorant segment durations in the IP, this difference might be a possible reason for the different results.

3. EXPERIMENT II: PERCEPTION

In order to examine whether a certain syllable is perceived as prominent, a perception test was conducted. It seems reasonable to expect that a listener's linguistic background, to some extent, affects his judgment of prominence. The extent to which judgment is affected depends on the classification of the language in question as a stress, tone, or quantity language. It may be expected that listeners who speak a stress language, such as English, are more sensitive to some acoustic cues in stress judgment, while native speakers of pitch-accent languages like Japanese may use different acoustic cues in prominence perception (cf. Beckman, 1986).

In this perception test, native speakers of three different languages, English, Japanese, and Korean, participated as listeners. They were asked to indicate the most prominent syllable of utterance they heard.

3.1. Method

3.1.1. Subjects

Five native speakers each of English and Japanese, and six Korean native speakers participated as listeners in this perception test. They were selected from the Indiana University population. They were all naïve to the purpose of the test. They also reported no history of speech and hearing related impairments.

3.1.2. Stimuli and Procedures

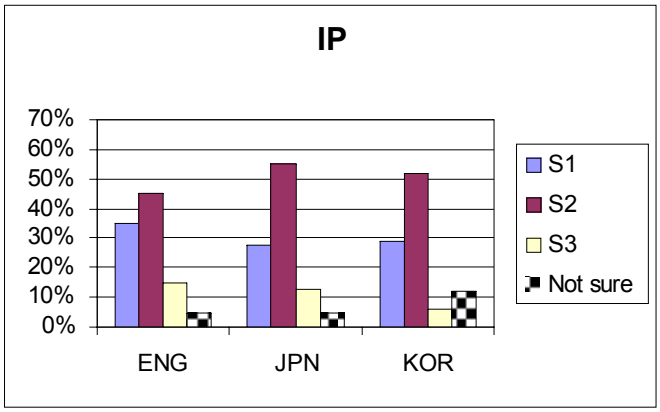
In the production experiment, two subjects participated. Of the two, speaker 2's speech data were presented to the listeners using a Sony mini disk cassette player[3]. Each word was repeated five times. Then, the listeners were asked to mark prominent syllables on answer sheets. If the listeners were not certain or would fail to mark any syllable, the words were repeated once more. Then, the number of responses for prominence was counted and its distribution was compared by syllable positions and by listeners.

3.2. Results

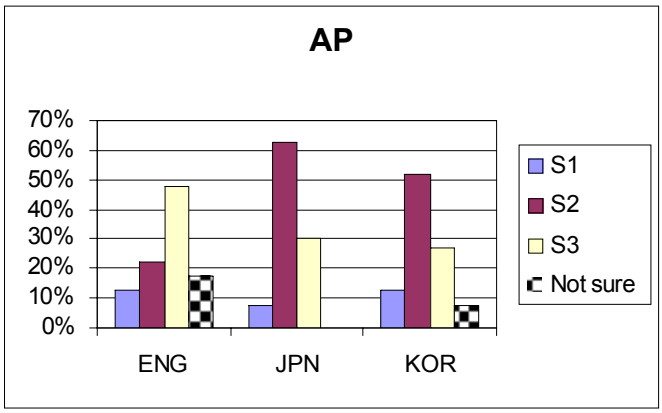
(12) shows the responses for prominence in the IP by listeners. The results indicated that medial syllables heard to be perceived as prominent across listeners. With a relatively high percentage, initial syllables were also marked as prominent following second syllables as shown below. Final syllables, however, did not seem to be favored for prominence for the IP. A few numbers of uncertainties for prominence were also observed, especially, among the Korean listeners.

[3] Compared to speaker 1, speaker 2 showed smaller range of variation in data values. Therefore, we used speaker 2's speech data for the perception test.

(12) Percentage for prominence by each listener in the IP



(13) Percentage for prominence by each listener in the AP



Turning to the results of the AP, as seen in (13), it was found that a greater number of responses indicated prominence on medial syllable positions regardless of listener group. A closer examination also revealed differences among listener groups: English listeners tended to choose final syllables as prominent, whereas Japanese and Korean listeners showed similar patterns favoring medial syllables.

3.3. Discussion

It is not surprising to find that different language speakers used different acoustic cues in perceiving prominence or stress. It is, however, interesting to see that they responded to the same speech data differently. As is well known, stressed syllables show longer duration, higher pitch and greater intensity in English (Fry, 1955, 1958; Lieberman, 1960; Lehiste, 1970). Based on the results of production and perception experiments, English speakers seem to use vowel lengthening, syllable duration and absolute pitch maxima in prominence perception: for the IP condition, they marked the second syllable as most prominent. Given the longest durations in syllables, onsets, and codas, and highest F0 values on second syllables, their choice for prominence seems to be based on the maximal duration and pitch contour or/and the combination of the two. For the AP, their choice for the final syllable as most prominent could well match the longest vowel duration and syllable duration, and highest F0 on final syllables. It may be difficult to

say which acoustic factor has a primary function in prominence perception for English speakers based on the results of this study. However, it may not be difficult to say that they are very sensitive to these acoustic factors and using these as phonetic cues.

Being speakers of an accented language, it is expected that Japanese listeners are more sensitive to pitch movement between syllables. Their perception data imply that they may use a relative change in pitch movement as a cue for prominence. In other words, they perceived as prominent or accented (or stressed), if there is any relatively big increase or decrease in pitch movement available between syllables.

For Korean listeners, based on their perception data, they showed a similar pattern to Japanese listeners implying that they might be more sensitive to relative pitch movement rather than to durational change. However, the results did not directly evidence this. Related with recent studies where Korean seems to lose vowel length distinction (Ingram and Park, 1997), durational factor may not play an important role in prominence perception.

4. CONCLUSIONS

In this study, a production test was carried out to fulfill two functions; 1) to examine syllable positional and weight effects on duration and fundamental frequency and 2) to determine which acoustic correlates could be used as perceptional cues in Korean word perception. Results indicate that syllable weight and syllable position play a key role in affecting durational patterns and intonational contours. The perception study examined the extent to which Korean word prominence is perceived by native speakers of English, Japanese, and Korean. Results show that second syllables of three syllable words seem to be perceived as prominent in Korean. First syllable positions can also be a strong candidate for word prominence perception. However, it is also clear from the present results that the prominence perceived by Korean listeners is not the same as by English listeners.

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