Initial-syllable lengthening of an utterance-internal phrase in Korean

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ABSTRACT

This study reports anti-hierarchical initial-syllable lengthening of an utterance-internal phrase in Korean. That is, the phrase-initial syllable (e.g., /a/ of "apa-do" or /ma/ of "mapa-do") starting with a voiced phoneme (i.e., vowels or voiced consonants) manifests itself as significantly longer when it is preceded by another phrase without a pause than when it leads an utterance or follows a pause utterance-internally. The phenomenon was examined with regard to two other factors: (1) tempo and (2) tenseness of the consonant (/p, p′, pʰ/) following the target syllable /a/. First, the effect of tempo on initial lengthening was not significant. Apart from the statistical significance, however, a tendency was observed, i.e., the slower the tempo is, the greater the lengthening. By contrast, the faster the tempo is, the higher the ratio (%) of lengthening. Second, contrary to our expectations, initial-syllable lengthening was even greater before tense stops /p′, pʰ/ than before lax stop /p/ regardless of tempo, and it was remarkable when it comes to the ratio (%), which means that initial lengthening is free of the pre-consonantal vowel shortening effect. Final-syllable lengthening is a pre-boundary marker, while the initial-syllable lengthening is regarded as a post-boundary marker of a phrase.

Keywords: initial-syllable lengthening, voicing, pause, tempo, tenseness

1. Introduction

1.1. Boundary (edge) effects

It is well known that syllables in pre-prosodic or pre-syntactic boundaries show temporal variations compared to those in non-boundary positions. In many languages, *final-syllable* (or *final-segment*) *lengthening* (*prepausal lengthening*) has been observed (e.g., Spanish: Delattre, 1966; German: Delattre, 1966; Swedish: Lindblom, 1968; English: Oller, 1973; Klatt, 1975; Wightman et al., 1992; French: Crompton, 1980; Fletcher, 1991; Japanese: Hoequist, 1983; Italian: Farnetani & Kori, 1990; Korean: Yun, 1992; Jun, 1995). Oller (1979, p. 331) provides the general

definition of final-syllable lengthening: "syllables occurring just before utterance, clause, phrase or word boundaries are longer than phonotactically similar syllables not occurring before such boundaries." This phenomenon seems to occur before the phrase and clause boundaries not only with a physical pause in the acoustic signal, but also without it (Klatt, 1976).

Whilst many studies to investigate the boundary effects have mainly been performed from an acoustic point of view, relatively recent studies are approaching the effects more likely from an articulatory point of view (e.g., Pierrehumbert & Talkin, 1992; Fougeron & Keating, 1996, 1997; Keating, 1997; Byrd, 1998; Byrd & Saltzman, 1998; Fougeron, 1998; Cho, 1998, 2004; Keating, Wright & Zhang, 1999; Byrd, Kaun, Narayanan & Saltzman, 2000; Fougeron, 2001; Cho & Keating, 2001; Keating, Cho, Fourgeron & Hsu, 2003). In addition, these studies focus more on the left edge of a prosodic or syntactic unit than the right edge in which many studies based on acoustic data have traditionally been interested. They also commonly report that the left edge of a prosodic

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or syntactic unit reveals a hierarchically cumulative strengthening or lengthening from syllable initial to utterance initial.

1.2. Variability of the cumulative initial strengthening

As mentioned above, researchers have found the hierarchical strengthening/lengthening, but they have also realized the post-boundary effect is not so robust. With regard to the variability of initial strengthening, some factors have been suggested: segment type, articulator, speaker, constituent and language (Fougeron, 2001; Cho & Keating, 2001; Cho, McQueen & Cox, 2007). Among these, segment type is the most notable. For instance, Fougeron (2001) observed that the articulation of the French stops /n, t, k/ and lateral /l/ is clearly affected by prosodic position while that of vowels is less affected and that of fricative /s/ least affected.

The second factor is articulator type or data type. With regard to this, Fougeron (2001) reported that linguopalatal contact for the French nasal /n/ varies more depending on prosodic positions than nasal flow. Similar results were obtained from Korean (Cho & Keating, 2001): linguopalatal contact and seal duration for nasal /n/ are greater in higher domain-initial positions while nasal energy shows the opposite pattern.

The third factor is speaker. Speakers are not always identical in the hierarchical domain-initial strengthening of prosodic positions in spite of the general trend for strengthening across many speakers. Fougeron & Keating (1997), for example, reports inter-speaker variability in the amount of linguopalatal contact for initial /n/: Speaker 1, Wi = Si; for Speaker 2, IPi = PPi; for Speaker 3, Ui = IPi and PPi = Wi. Besides, the three speakers revealed different patterns of distinction between the five prosodic positions in other data as well.

The fourth factor is constituent. The basic idea of the consonant initial strengthening is that the prosodic position effect is hierarchically cumulative, i.e., the higher the prosodic domain, the more initial strengthening. However, prosodic positions or levels are not always consistently distinguished from each other in the articulation of its initial segment. In general, the farther the relationship between two levels, the bigger the differences of strengthening between them (e.g., Fougeron, 2001; Keating, Cho, Fourgeron & Hsu, 2003; Cho & Keating, 2001).

Another factor can be language. For example, Korean tense and aspirated consonants show stronger strengthening word-medially than word-initially for their oral articulations,

which seems to be specific to Korean (Cho & Keating, 2001).

1.3. Anti-hierarchical acoustic temporal variation

Unlike articulatory strengthening, acoustic duration does show a fairly consistent exception to the hierarchical variations in prosodic initial positions: voiced segments do not lengthen after a pause, e.g., utterance initial. For instance, Fougeron & Keating (1997) suggested the average acoustic durations of initial /n/'s in the five prosodic domains (Ui, IPi, PPi, Wi, Si) as additional evidence to support their hypothesis of the hierarchically cumulative initial strengthening in English. However, the U-initial /n/, which is preceded by a pause, was exceptional to the hierarchical strengthening. The anti-hierarchical acoustic temporal variation is found in other languages as well (e.g., French: Fougeron, 2001, Keating, Cho, Fourgeron & Hsu, 2003; Korean: Cho & Keating, 2001). As a possible reason for the anti-hierarchical acoustic temporal variation, Fougeron (2001) suggested that after a pause, it may take some time for aerodynamic conditions for voicing to be set, which induces shortening of acoustic duration of voiced segments (e.g., Lisker & Abramson, 1964; Flege, 1982). It is interesting that a voiceless consonant as well as a pause causes the anti-hierarchical temporal variation. For example, in the two sentences – "**nɛbəbɛn** fed them" and "One deaf **nɛbəbɛn**" – the utterance-medial /n/ is not longer than the utterance-initial /n/, although speakers did not pause between words (see Fig. 4a, p. 475, Cho & Keating, 2009). It is thought that the voiceless fricative /f/ in the word "deaf" preceding the utterance-medial /n/ functioned as a kind of pause to block the continuation of voicing from the preceding vowel /e/ to the following /n/. Therefore we can say that as a result of the blocking, the utterance-medial /n/ did not lengthen as the utterance-initial /n/ did not. To sum up, a pause (or a preceding voiceless segment) delays the voicing onset of the following voiced segments.

1.4. Targets of this study

The above literature review reveals that voiced segments preceded by a pause do not lengthen, and the possible reason is suggested – it takes time for aerodynamic conditions for voicing to be set after a pause (e.g., Fougeron, 2001). This results in the exception to the hypothesis of hierarchically cumulative strengthening or lengthening of domain initial segments – the highest domain initial (Ui) segment, which is expected to be the longest, is the shortest in acoustic duration.

An utterance initial segment definitely has a preceding pause. Thus, the feature voicing of the initial segment and a preceding pause are two prerequisites for the anti-hierarchical acoustic temporal variation.

This study first aims at confirming the anti-hierarchical acoustic temporal variation at syllable level that is more perceptible to hearers and speakers. We compare utterance-initial syllable and the initial syllable of an utterance-internal phrase, i.e., phrase-initial syllable with no preceding pause. Therefore, we hypothesize that a syllable starting with a voiced phoneme (consonant or vowel) will be shorter in utterance-initial position than in the initial position of an utterance-internal phrase with no preceding pause. Here, we use a new term, **initial-syllable lengthening** for the lengthening of the initial syllable of a phrase with no preceding pause relative to that of a phrase with a preceding pause. Now, we can say that while voicing and a preceding pause are prerequisites for the anti-hierarchical acoustic temporal variation, voicing (i.e., voiced initial segments) and no preceding pause are the absolute or direct conditions (factors) for the initial-syllable lengthening.

Aside from the absolute or direct factors (i.e., voicing and no preceding pause), there can be some other relative or indirect factors for the post-boundary initial-syllable lengthening. Among others, the present research investigates the plausible effects of tempo (speech rate) and the type (tense/lax) of phoneme (consonant) following the target syllables. The general effects have been known of speech rate and consonant type on the duration of adjacent vowels in Korean, but not the effects on the anti-hierarchical initial-syllable lengthening that this study first reports. Duration varies as a function of tempo, i.e., the faster the shorter, the slower the longer. The question is thus how the initial-syllable lengthening (i.e., a durational variation) is affected by tempo variations. That is, we investigate whether the target syllables linearly shorten or lengthen according to tempo or yield some other typical variations. For this, we observe the amount and ratio (i.e., the durational increments in the utterance-internal phrase divided by the duration of the utterance-initial syllables) of the lengthening in three different tempos (fast, normal, slow). On the other hand, duration of the preceding vowel or syllable varies with the tenseness feature of the following consonants in Korean (Kim, 1965; Kim, 1987; Han, 1996; Oh & Johnson, 1997; Oh, 1998; Yun, 2004, 2009, 2010). That is, a vowel or syllable suffers reduction before a tense (or voiceless) consonant (henceforth, we call this phenomenon as preconsonantal vowel (or syllable) shortening).

We therefore question how the initial-syllable lengthening varies with the tenseness feature of the following consonants. Especially, the initial-syllable lengthening and preconsonantal vowel shortening are opposite durational variations; so, it is intriguing to examine how the two variations affect each other when they simultaneously occur on the same syllable (vowel) in each of the three different tempos.

2. Method

2.1. Subjects

The subjects were eight (i.e., two male and six female) native speakers of Seoul Korean, who were in their twenties or thirties when the recording was conducted. They comprised four postgraduates, three undergraduates of Reading University and two postgraduates' spouses. The periods of their stays abroad ranged from four months to two years, except one subject who had spent more than five years in America and Britain.

2.2. Materials and procedures

Five words were chosen as speech stimuli. They were /apa/, /mapa/, /sapa/, /ap'a/ and /apʰa/, out of which /apa/, "the Swedish vocal group ABBA", /sapa/ "this world", /ap'a/ "daddy" and /apʰa/ "a vendor; an exclamation when we feel painful" were real words, but /mapa/ was a nonsense word. As mentioned above, we aim to confirm the anti-hierarchical acoustic temporal variation at syllable level, for which the utterance initial syllable and the internal phrase-initial syllable are compared in duration. Therefore, the target syllables should be measurable irrespective of the position. Korean stops and affricates are all voiceless and their acoustic duration cannot be measured when preceded by a pause. This is why we chose /a/, /ma/, and /sa/ as test syllables, excluding syllables beginning with stops or affricates. In particular, the syllable /a/ with no onset was included, as we are interested in the syllable level unlike the existing literature that focuses on the initial consonant segments. Each of the target words was embedded twice (the first and third phrases) in a sentence frame consisting of four phrases (....-do / sakwa-ril / ....-chərəm / joahanda.) ".... likes apples like ...., too." (see Table 1). In particular, items 1, 4 and 5 – Korean plosives /p/, /p'/, /pʰ/ in /apa/, /ap'a/ and /apʰa/ have the same place of articulation (bilabial) but different manners of articulation, i.e., /p/: phonologically lax unaspirated, /p'/: tense unaspirated, /pʰ/: tense aspirated – were included to see possible effects of consonant type on the initial lengthening.

One reading list, in which two sentences embedding items 2 and 3 (/maba/ and /saba/) were alternately written five times, was given to the subjects. They delivered it at their normal rate of speech, producing a total of 160 tokens (2 items × 2 positions (1st and 3rd phrase) × 5 repetitions × 8 subjects). Another list, where three sentences carrying items 1, 4, and 5 (/apa/, /ap'a/ and /apʰa/) were written in five different orders, was prepared. The subjects delivered the list at their slow, normal and fast rate of speech, yielding a total of 720 tokens (3 items × 2 positions (1st phrase and 3rd phrase) × 5 repetitions × 3 rates (slow, normal and fast) × 8 subjects). It is notable that some of the subjects in this experiment consistently or intermittently put a pause in phrase boundaries when they read the materials at slow rate (refer to Jun, 1993; Kim, 2009 for the effect of speech rate on phrasing in Korean). However, no control was given to them, as we wanted to obtain more natural speech. Slow speech, for most speakers, normally meant speaking slowly with no pause between phrases, but depending on speakers, it could also be speaking slowly, putting a pause between phrases. Recording was conducted using a high quality recorder and a microphone in the sound treated recording room of the Speech Research Laboratory at Reading University. The recording was digitised onto a Sun Sparcstation at a sampling rate of 16 kHz with 16 bit resolution and saved as files to be processed by the software package WAVES+/ESPS. From the files, waveforms and spectrograms were generated.

Table 1. Speech materials for Experiment

item 1	**a**pa-do sakwa-rɨl **a**pa-chərəm joahanda. "*apa* likes apples like *apa*, too."
item 2	**ma**pa-do sakwa-rɨl **ma**pa-chərəm joahanda.
item 3	**sa**pa-do sakwa-rɨl **sa**pa-chərəm joahanda.
item 4	**ap'**a-do sakwa-rɨl **ap'**a-chərəm joahanda.
item 5	**apʰ**a-do sakwa-rɨl **apʰ**a-chərəm joahanda.

2.3. Measurements

Measurements were taken of the duration (ms) of initial syllables of all the five target words /mapa/, /sapa/, /apa/, /ap'a/, and /apʰa/, using waveforms and spectrograms. First, the target syllable /ma/ was measured from the beginning (the onset of the regular pulse) of the nasal /m/ to the end of the formants 1 and 2 of the following vowel /a/ (at the same time, the beginning of the closure of the following stop /p/). It was an additional cue for segmentation that the boundary between /rɨl/ and /ma/ is

normally dented in the waveform (refer to Figure 1). Second, the syllable /sa/ was measured from the beginning of the frication of /s/ to the end of the formants 1 and 2 of the following vowel /a/ (at the same time, the beginning of the closure of the following stop /p/). Finally, the target syllable /a/ was measured from the onset of its regular pulse to the end of the formants 1 and 2 (at the same time, the beginning of the closure of the following stops /p/, /p'/, and /pʰ/). Especially in the third phrase, the shapes of the formants and waveforms were important in deciding of the boundary between /rɨl/ and /a/. That is, the formants 1 and 2 of /rɨl/ are relatively level and the interval between them is wide, while the 1st formant of /a/ shows a rising and falling movement (like a bow) and the interval between the 1st and 2nd formants is narrow. Also the boundary between /rɨl/ and /a/ is often dented in the waveform as between /rɨl/ and /ma/. In addition, /rɨl/ and /a/ reveal waveforms with notably different shapes and sizes. That is, the following /a/ suddenly shows a much bigger waveform (more energy) than that of the preceding /rɨl/. All of these cues were considered to decide the boundary between /rɨl/ and /a/ in the 3rd phrase.

Figure 1 with a waveform and a spectrogram shows an example of the measuring points of duration. The speech material of Figure 1 is *mapa-do sakwa-rɨl mapa-chərəm joahanda*. "*mapa* likes apples like *mapa*, too." The bold lines in the Figure indicate the beginning and end of the target syllables "ma".
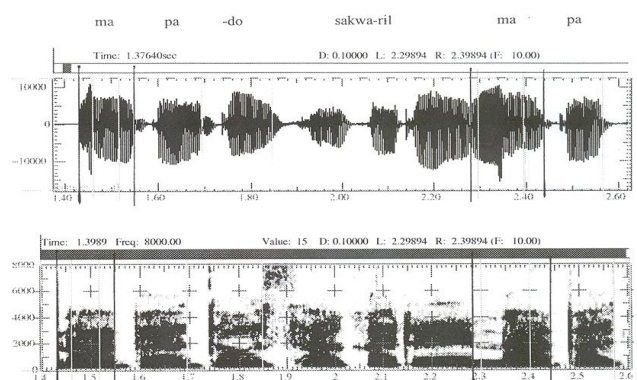

Figure 1. A set of waveform and spectrogram

2.4. Analyses of the data

The data obtained were analysed by repeated measures (henceforth, RM) ANOVAs (analyses of variance) followed by post-hoc pairwise comparisons (p = 0.05). That is, the effects of factors voicing, word, tempo, and (consonant) type were tested on the durational differences of the target syllables between the

first and the third paragraphs. RM ANOVAs with the same factors were conducted on the rates of the durational increase/decrease as well. The rates of increase/decrease were calculated through dividing the increments/decrements in the third phrase by the duration of the target syllables in the first phrase, i.e., ((duration in the 3rd P - duration in the 1st P) / duration in the 1st P) × 100. Effect size was also estimated by η^2 analyses that provide the proportion of variance associated with the main effects and interactions in an ANOVA study (Brown, 2008), and therefore, we know how large the degree of contribution of the factors is. Besides, paired t-tests were done to compare the target syllable durations between the 1st analyses that provide the proportion of variance associated with the main effects and interactions in an ANOVA study (Brown, 2008), and therefore, we know how large the degree of contribution of the factors is. Besides, paired t-tests were done to compare the target syllable durations between the 1st phrase and the 3rd phrase.

3. Results and discussion

The results consistently showed the initial-syllable lengthening of an utterance-internal phrase (i.e., the initial syllable of a phrase starting with a sonorant proves itself noticeably longer when it is preceded by another phrase without a pause than when it leads an utterance or follows a physical (real) pause which blocks the continuity of pronunciation between two neighbouring phrases). We will firstly describe voicing effect on the initial lengthening, and secondly the effects of two other factors (tempo and consonant type (tenseness)) on it in a separate section.
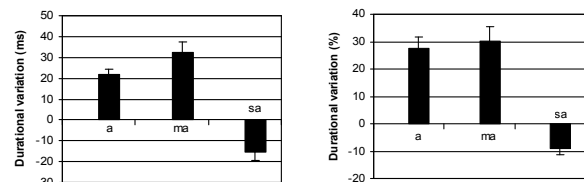
3.1. Voicing effect on initial lengthening

We investigated items 1, 2 and 3 (i.e., /a/, /ma/, /sa/) produced at normal rate, with regard to the initial lengthening of an utterance-internal phrase. As seen in Table 2, the occurrence of initial lengthening was crucially determined by the voicing feature of the first phoneme of the target words. The initial syllables (/a/, /ma/) starting with voiced phonemes in the third phrase yielded about a 28 - 30% durational increase relative to those of the first phrase, i.e., ((duration in the 3rd P - duration in the 1st P) / duration in the 1st P) × 100. By contrast, the syllable (/sa/) in the third phrase shortened by about 9% compared to that in the first phrase. So /ma/, which is shorter than /sa/ in the first phrase (t = -14.179, p < 0.001),

becomes similar to /sa/ in the third phrase (t = 1.021, p = 0.314) by paired t-tests. The three sentences were produced under the same conditions including tempo, and syntactic structure, etc. The only difference between them was the feature voicing in the first phoneme of each target word, i.e., /a/ and /m/ are voiced while /s/ is voiceless, which induced the opposite results. These were statistically supported. That is, one-way RM ANOVAs showed that the factor Voicing had a main effect on both duration [F (1, 7) = 72.605, p < 0.001, η^2 = 0.912] and ratio (%) [F (1, 7) = 60.678, p < 0.001, η^2 = 0.896].

Table 2. Voicing effect on initial lengthening of an utterance-internal phrase (I.Syl.: initial syllable; Mean durations of the target syllables (SD's) (ms, normal rate)

I.Syl.	1st Phrase	3rd Phrase
a	85 (14)	107 (13)
ma	120 (21)	153 (13)
sa	166 (14)	150 (13)

(a) Durational difference (3rd P - 1st P) (b) Ratio ((3rd P - 1st P) / 1st P) × 100

Figure 2. Voicing effect on initial lengthening of an utterance-internal phrase (ms, %)

On the other hand, one-way RM ANOVAs with Word as a factor showed that there was a significant main effect on both the durational variation [F (2, 14) = 77.304, p < 0.001, η^2 = 0.917] and the ratio (%) [F (2, 14) = 42.387, p < 0.001, η^2 = 0.858] of the initial syllables (/a/, /ma/, /sa/). Post-hoc comparisons first identified that /a/ and /ma/ were differentiated from /sa/ both in the amount of lengthening (p < 0.001) and in the ratio (%) (p < 0.001). That is, the negative durational variation (i.e., decrement) in /sa/ is strikingly distinguished from the positive variations (i.e., increment) in the other two words (/apa/, /mapa/). However, there was no significant difference between /a/ and /ma/ not only in the ratio (p = 1), but also in the amount of lengthening (p = 0.165). Hence, the graphically marked difference in lengthening between /a/ and /ma/ (i.e., /a/ of /apa/ showed only two thirds of lengthening, compared to /ma/ of /mapa/, see Figure 2(a)) was statistically non-significant.

Besides, it is noted that the degree of lengthening of /a/ or /ma/ is greater than that of shortening of /sa/, and it becomes more marked in the ratio (%) (cf. Figures 2(a) and (b)).

3.2. Tempo and phoneme type effects on initial lengthening

The durational data pooled across the eight speakers from items 1, 4, and 5 (i.e., /apa/, /ap′a/, and /ap^{h}a/) were analysed with reference to tempo and phoneme type (tense/lax) effects on initial lengthening. Table 3 summarises durational variations in the target syllable /a/ followed by three different types of bilabial stops (/p, p′, p^h/) in three different speech rates (slow, normal, fast), and Figure 3 shows the durational variations, i.e., initial lengthening (durational differences between 1st P and 3rd P) and their increase-ratios – ((duration in the 3rd P - duration in the 1st P) / duration in the 1st P) × 100 – according to tempo and phoneme type respectively.

Table 3. Tempo and Phoneme type (tenseness) effects on initial lengthening (Mean durations (SD's) of the target syllables /a/; /p/: lax; /p′, p^h/: tense; S: Slow; N: Normal; F: Fast)(ms)

Item	Tempo	1st P	3rd P
ap**a**	S	143 (46)	165 (47)
	N	85 (14)	107 (13)
	F	75 (14)	94 (12)
ap′**a**	S	82 (24)	107 (34)
	N	59 (11)	85 (10)
	F	52 (11)	73 (11)
ap^h**a**	S	88 (21)	114 (31)
	N	61 (12)	91 (12)
	F	55 (13)	77 (11)

Before we start analysing the data, it should be remembered that slow rate of speech was relatively inconsistently realised with different reading styles (i.e., with or without a pause at phrase boundaries) between and within speakers. Due to the inconsistent reading styles, there were even observed some durational decreases (initial shortening) in the third phrase relative to the first phrase in the speakers who frequently or sometimes put a pause at phrase boundaries in slow rate. Therefore, we need to consider that the durational differences and ratios in slow tempo are not reflecting the ideal initial lengthening that can be obtained from a consistent reading style

without a pause at the boundaries (i.e., the durational differences and ratios in slow tempo are of somewhat limited validity, compared with those in normal or fast tempo).

(a) Durational difference (3rd P - 1st P)　(b) Ratio ((3rd P - 1st P) / 1st P)×100

(c) Durational difference (3rd P - 1st P)　(d) Ratio ((3rd P - 1st P) / 1st P)×100
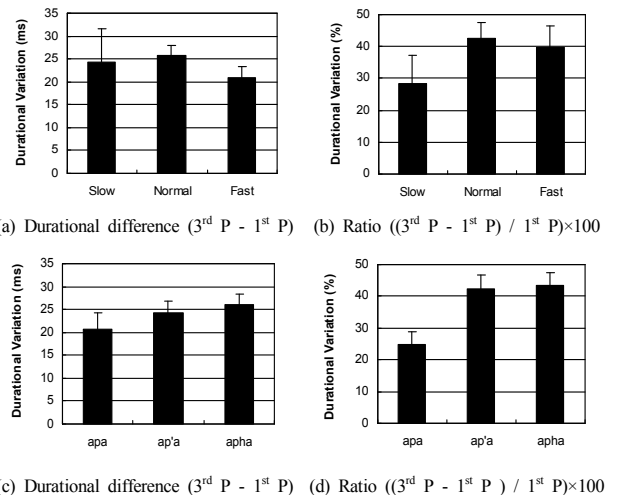
Figure 3. Tempo and Phoneme type (tenseness) effects on initial lengthening (ms, %)

As seen in Table 3 and Figure 3(a), durational differences do not seem to gradually increase or decrease according to tempo across the three types of phoneme (/p/, /p′/, /p^h/). RM ANOVAs with Tempo and Type as factors showed that the factor Tempo had no significant main effect on the durational differences (increments) [$F_{(2, 14)}$ = 0.262, p = 0.774, η^2 = 0.027] and no post-hoc pairwise comparisons were significant between the group-means of durational differences according to the three tempos (i.e., fast *vs.* normal: p = 0.275; fast *vs.* slow: p = 1; normal *vs.* slow: p = 1). In spite of the non-significant statistical differences, however, a tendency seems to exist. That is, if we limit the data to those of normal and fast rates of speech that were produced with no pause between phrases, it becomes clear that the slower the tempo is, the greater the lengthening (i.e., greater durational differences (increments) in normal tempo than in fast tempo).

As on the durational differences, RM ANOVAs with Tempo and Type as factors showed that the factor Tempo had no significant main effect on the increase-ratio (%) [Tempo: $F_{(2, 14)}$ = 1.067, p = 0.37, η^2 = 0.091]. The results of post-hoc pairwise comparisons for the group mean ratios also did not distinguish them according to tempo (i.e., fast *vs.* normal: p = 1; fast *vs.* slow: p = 1; normal *vs.* slow: p = 0.542). That is, despite the fairly great differences, the three group-mean ratios were statistically similar to each other (refer to Figure 3(b)).

Nevertheless, it is likely that the faster the rate of speech is, the higher the ratio (%) of lengthening (not absolutely but relatively). Therefore, although the bar of fast tempo is still shorter or lower than that of normal tempo in Figure 3(b), the durational ratio between them gets closer, i.e., from 1:0.81 in Figure 3(a) to 1:0.94 in Figure 3(b). In addition, while the bar of slow tempo is only a little shorter than the highest bar of normal tempo in Figure 3(a), it becomes quite shorter than that of normal tempo and even that of fast tempo in Figure 3(b). This should be ascribed mainly to the remarkably lengthened initial syllable /a/ in the first phrase due to the slow rate of speech (see Table 3), and partly to some speakers' reading styles giving a pause at boundaries in slow rate.

Overall, tempo effect seems to be the strongest in normal rate of speech – normal tempo yields the greatest initial syllable lengthening especially in the ratio (%) – though we take into consideration some possible unrealised lengthening in slow tempo due to the irregular reading styles.

On the other hand, regardless of speech rate, the durational increments of the target syllable /a/ in the third phrase relative to the first phrase are, surprisingly, a little greater when the syllable is followed by the tense stops /p′, pʰ/ than when it is followed by the lax stop /p/ (see Table 3 and Figure 3(c)). However, the differences were not statistically significant. That is, the RM ANOVAs with Tempo and Type as factors revealed that the factor Type had no significant main effect [F (2, 14) = 2.235, p = 0.144, η^2 = 0.035]. As in the Tempo effect, post-hoc pairwise comparisons did not significantly distinguish the group-means according to the three types (i.e., /apa/ vs. /ap′a/: p = 0.838; /apa/ vs. /apʰa/: p = 0.204; /ap′a/ vs. /apʰa/: p = 1). On the other hand, it is worth noting that the interaction of Tempo × Type was not significant [F (4, 28) = 0.231, p = 0.918, η^2 = 0.003], i.e., tempo effect on the durational differences does not significantly change regardless of phoneme type, and vice versa.

Importantly, phoneme type (tense/lax) effect is more salient in the ratio of increments than in the durational increments (differences) themselves (cf. Figure 3(c) and Figure 3(d)). This is statistically identified. The RM ANOVAs with Tempo and Type as factors revealed that unlike on the durational differences, the factor Type had a significant main effect on the ratio (%) [Type: F (2, 14) = 27.352, p < 0.001, η^2 = 0.176]. Post-hoc pairwise comparisons also showed that the mean ratio was significantly lower when the lax stop /p/ follows the initial vowel /a/ than when the tense stops /p′, pʰ/ follow it, while the

two mean ratios in the tense stops /p′, pʰ/ were quite similar to each other (i.e., /apa/ vs. /ap′a/: p = 0.003; /apa/ vs. /apʰa/: p < 0.001; /ap′a/ vs. /apʰa/: p = 1 (refer to Figure 3(d)). Therefore, tenseness effect on initial lengthening is likely to be more related to the ratio than the real durational increase. This largely results from the initial vowel /a/ already shortened due to the following tense consonants /p′, pʰ/ in the first phrase. When divided by the shortened initial vowel /a/ of the first phrase, the even longer increments before tense consonants have to yield higher ratios of increase. As in the durational differences, the interaction was not significant between Tempo and Type [F (4, 28) = 0.543, p = 0.705, η^2 = 0.007], i.e., type effect on the ratio does not significantly change regardless of tempo, and vice versa.

It is well known that a vowel shortens before a tense (or voiceless) consonant. However, the so-called force of articulation of the following consonant does not seem to directly influence the lengthening of the preceding initial syllable. In other words, provided that the pre-consonantal vowel shortening is a kind of coarticulation, the coarticulation between the preceding vowel (syllable) and the following consonant is not likely to start until initial lengthening ceases. That is, during initial lengthening, the preceding initial syllable becomes free from the tenseness effect of the following consonants. This is conjectured from the fact that even a greater extent of lengthening of the preceding initial syllable is observed when it is followed by the tense consonants /p′, pʰ/ than by the lax consonant /p/ (see Table 3 and Figure 3(c)). Therefore, it is reasonable to say that the tenseness effect on initial lengthening is not a direct but **an indirect** or **passive effect**; or rather it could be called **an anti-tenseness effect**.

3.3. Post-boundary initial lengthening vs. pre-consonantal vowel shortening

It is surprising that contrary to our general expectations – the tenseness feature of the following consonants /p′/ and /pʰ/ would block or at least weaken initial syllable lengthening, the amount and ratio of lengthening is greater before the tense consonants (/p′/ and /pʰ/) than before the lax one (/p/). This, however, does not mean that the pre-consonantal vowel shortening does not occur in the utterance-internal phrase. That is, irrespective of tempo, the initial syllable /a/ of /ap′a/ or /apʰa/ is still markedly shorter than that of /apa/ in the third phrase as well as in the first phrase (see Table 3). What should be noted is that initial lengthening in the third phrase is even greater before tense

consonants. As a result, the durational differences between the preceding vowels (syllables) before tense/lax consonants become a little smaller in the 3rd phrase than in the 1st phrase. Also the durational ratio between the vowel durations becomes closer in the 3rd phrase (i.e., 1:0.57:0.62 in the 1st phrase → 1:0.65:0.69 in the 3rd phrase at slow rate; 1:0.69:0.72 → 1:0.79:0.85 at normal rate; 1:0.69:0.73 → 1:0.78:0.82 at fast rate) due to the post-boundary initial lengthening (see Table 3). Now we can say that when post-boundary initial lengthening and pre-consonantal vowel shortening co-occur in a syllable, the former is not affected by the latter. Rather, the former even slightly weakens the latter.

3.4. Summary

The initial-syllable lengthening of a sentence-internal phrase is conditioned by the two factors – (1) no inter-phrasal pause; (2) voicing of the first segment of the initial syllable. That is, the initial lengthening occurs only when a voiced segment (i.e., sonorants: vowels or voiced consonants) leads the sentence-internal phrase preceded by no pause. Therefore, voicing and no pause are direct and absolute factors to the post-boundary phenomenon.

On the other hand, initial lengthening is also affected by two other factors – (3) speech rate; (4) phoneme type (tenseness) of the consonant in the onset position of the second syllable of the sentence-internal phrase. Unlike voicing and no pause that are direct and absolute factors, speech rate and tenseness are indirect and relative factors to initial lengthening.

First, speech rate does not give a significant effect on initial lengthening, but a tendency is observed: (1) in general, the slower the rate of speech is, the longer the lengthening (i.e., bigger increments in slow and normal tempos than in fast tempo); (2) by contrast, the faster the rate of speech is, the higher the ratio (%) of lengthening (not absolutely but relatively). It is noted that the ratio is far smaller in slow rate than those in normal and fast rates. Overall, normal rate is likely to yield the greatest increments in both the real lengthening and the ratio.

Second, it is notable that the amount of initial lengthening is even greater before the tense stops /p′, pʰ/ than before the lax stop /p/. Phoneme type (tenseness) effect is more salient in the ratio of increments than in the durational increments (differences) themselves. In the first phrase, i.e., in the utterance-initial position, the target syllable /a/ substantially shortens before the following tense consonants, while it, if still

markedly shorter before tense consonants, becomes free from tenseness effect (pre-consonantal vowel shortening) during its lengthening in a sentence-internal phrase, i.e., anti-tenseness effect.

4. Conclusion

Studies concerning post-boundary initial strengthening and lengthening have used domain-initial consonants such as /t, n, s/, and stressed that the strengthening and lengthening are generally hierarchically cumulative in spite of some variability. The literature, however, also reveals that acoustic duration of initial voiced segments after a pause is fairly consistently exceptional to the hierarchy, from which this study starts. But unlike the previous studies focusing on segments (mainly consonants), we compared utterance initial syllable and the initial syllable of a sentence-internal phrase to examine the anti-hierarchical acoustic temporal variation at syllable level.

The results of our experiment first show a temporal phenomenon: **initial-syllable lengthening**. That is, the phrase-initial syllable starting with a voiced phoneme manifests itself as markedly longer when it is preceded by another phrase without a pause than when it leads an utterance or follows a pause utterance-internally. One may say that an utterance-initial syllable and an utterance-internal phrase-initial syllable differ not only by the presence of a preceding pause but also by their strength in the prosodic hierarchy. As reviewed earlier, however, an utterance-initial (i.e., a higher) position generally has stronger strengthening than a phrase-initial (i.e., a lower) position; therefore, the weaker strength at phrase-initial position is very unlikely to be the reason for the acoustic lengthening at the phrase-initial syllable, as less articulatory energy is expected to induce shorter duration. All in all, it is difficult to suppose that the factor is something other than a pause for the durational difference between the U-initial and the U-internal phrase-initial syllables. Moreover, the literature suggests a possible reason for the non-lengthening at post-pausal position (not only utterance initial position but also any other position with a preceding pause) – a pause (or a preceding voiceless segment), which blocks the continuity of pronunciation between two neighbouring phrases, is presumed to delay the voicing onset of the following voiced segments.

Besides, we tested the initial lengthening with regard to two more factors – tempo and phoneme type (tenseness) of the consonant following the target syllables.

Duration is closely related to tempo – the faster the shorter, the slower the longer. However, initial lengthening, which is a durational variation under the effect of tempo, did not gradually increase or decrease according to tempo variation. It is mainly due to the pause some speakers consistently or intermittently put between phrases in slow tempo, and the pause weakened the lengthening. On the other hand, the ratio (%) of lengthening was markedly smaller in slow tempo than that in normal tempo and even that in fast tempo. It is mainly because as tempo becomes slow, the target syllable /a/ lengthens greater in the utterance-initial phrase than in the utterance-internal phrase. All in all, we can say that initial lengthening does not simply vary as a function of tempo. In other words, temporal variation results in a new environment for initial lengthening.

With reference to the consonant type (tense/lax) effects, we particularly focused on the conflict between the initial lengthening and the pre-consonantal vowel (syllable) shortening. Contrary to our expectations, initial syllable lengthening is even a little greater before tense stops than before lax stops, and this becomes remarkable and significant in the ratio of lengthening. This can be interpreted as meaning that initial syllable lengthening precedes pre-consonantal vowel shortening when they co-occur on the same syllable.

It is generally accepted that (word, phrase, clause and sentence) final-syllable lengthening functions as a prosodic or syntactic marker (Oller, 1973, 1979; Klatt, 1975, 1976). Now the initial-syllable lengthening of a sentence-internal phrase will be regarded as an additional prosodic or syntactic marker. Together with final-syllable lengthening in the preceding phrase, initial-syllable lengthening in the following phrase must help two succeeding phrases to be distinguished when no pause exists between them. What is more, final lengthening is not great at the end of an AP (accentual phrase) (Koo, 1986; Jun, 1995, 1998) and AP boundaries hardly have a pause unless it is the last phrase of an IP (intonational phrase) in Korean (Jun, 1998). Therefore, if a voiceless phoneme or a pause does not lead an utterance-internal phrase, the initial-syllable lengthening should play an important role as a post-boundary marker of a phrase in Korean. On the other hand, a pause is clearly a boundary marker between phrases and the typical high pitch of voiceless phonemes (i.e., stops, affricates and fricatives) will signal the beginning of an utterance-internal phrase instead of the initial-syllable lengthening.

Speakers are assumed not necessarily to use long acoustic duration after a pause (either utterance-initially or -internally) as one of their speaking tactics. Rather than that, articulatory (initial) strengthening and lengthening (e.g., relatively strong articulatory energy, longer articulatory duration and larger spatial contact between articulators) may be more important and consistent as a marker of the beginning of utterance or phrase for both speaker and hearer. On the other hand, the findings of this study can be used for speech synthesis. Finally, if initial-syllable lengthening is observed in other languages as well, the temporal phenomenon will be worth noting from a cross-linguistic point of view as well as from a language-specific point of view.

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