Compression Effects of Number of Syllables on Korean Vowel

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ABSTRACT

The question of Korean rhythmic type is still a controversial issue (syllable-timed; stress-timed; word-timed). As a step toward solving the question, an experiment was carried out to examine compression effects in Korean. There has been a general belief that the increase of the number of following or preceding syllables causes compression of a vowel (or syllable) in many languages, and a marked anticipatory compression effect can be especially indicative of stress timing. The purpose of this research, therefore, was to obtain some evidence to determine whether or not Korean is stress-timed. The durations of the target vowel /a/ of the monosyllabic word /pap/ were measured at both word and sentence level. In general, marked anticipatory and backward compression effects on the target vowel were observed across one-, two- and three-syllable words in citation form, whereas the effects were neither marked nor consistent at sentence level. These results led us to claim that Korean is not stress-timed.

Keywords: Compression Effect, Syllable Number, Stress Timing

1. Introduction

It has been reported that the increments of the number of segments or syllables in a phonological unit - syllable, word, foot - cause compression of the segments (syllables). In particular, this temporal phenomenon has been used as a positive indicator to support stress-timing in a given language instead of physical isochrony between inter-stress intervals which has been disproved. This kind of study has been performed mostly in English [Lehiste, 1972; Klatt, 1973, 1976; Fowler, 1981], Swedish [Lindblom, 1968; Lindblom & Rapp, 1972, 1973] and Dutch [Nooteboom, 1972, 1973]. English, Swedish and Dutch are all known as stress-timed languages; therefore, the relatively great compression phenomenon commonly observed from these has been assumed to be an important timing factor for stress-timing. For instance, Lehiste [1972] measured the durations of the base words (e.g., *sleep*) in some sets of words (e.g., sleep - sleepy - sleeper - sleeping - sleepily - sleepiness - sleep heals - sleep refreshed - my sleep was disturbed). The results revealed that in almost all instances the base words were

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shortened when the utterance became longer. Through experiments using Swedish speakers and nonsense words such as *da:d - da:dad - da:dadad - dada:d - dadada:d*, Lindblom [1968] and Lindblom & Rapp [1972, 1973] also found that the stressed vowel shortens as the number of weak syllables added increases.

Korean has been regarded as syllable-timed [Martin, 1951], stressed-timed [Lee, 1982] or word-timed (the inherent durational pattern for words tends generally to be maintained in utterances) [Kim, 1994]. This confusing situation implies that we have no clear grasp of Korean rhythmic characteristics yet. The first claim comes from an impressionistic observation, and the second one is based only on the data obtained from isolated words or phrases. Lastly, relatively systematic experiments and data seem to support the third claim but it needs to be verified through more research.

The present research was designed to examine anticipatory *vs.* backward compression effects of a Korean vowel caused by the increase of the number of following or preceding syllables at both isolated word or phrase level and sentence level. As mentioned above, significant compression of a stressed syllable due to additional syllables could be adopted as evidence for stress-timing in a given language. Therefore, our experiment will focus on obtaining some evidence to judge whether Korean is stress-timed or not. Despite no physical evidence for the traditional rhythmic distinctions between languages [Roach, 1982; Dauer, 1983], syllable-timing and stress-timing are still generally regarded as two important axes in the classification of rhythmic types of many languages [Ramus, Nespor & Mehler, 1999; Low, Grabe & Nolan, 2000]. However, it is notable that they adopt timing factors (e.g., variability in vocalic and intervocalic intervals) other than physical isochrony between stresses or syllables in capturing rhythmic differences. In accordance with this, the present paper investigates compression effect as a process for discovering Korean rhythmic characteristics. This research includes two experiments, each of which was targeted at examining anticipatory *vs.* backward compression effects at isolated word or phrase level and at sentence level, respectively.

2. Experiment 1: Isolated Word or Phrase Level

2.1 Subjects

Six native speakers of Korean (three males and three females) served as subjects. They had a Seoul accent except for Speaker 6 who had a Kyungsang accent. Their ages ranged in the twenties and thirties. None had any speaking or hearing problems.

2.2 Materials and procedures

The target vowel was /a/ of the one-syllabic word /pap/ (where /p/ is a phonologically voiceless unaspirated lax stop in Korean). All speech materials thus had the one-syllabic word /pap/ in their initial position or final position. They consisted of one-, two-, three and four-syllable words and a nine-syllable phrase. In particular, we used four two-syllable words (i.e., "pɑpp^{h}ul" (/CV̲C-CVC/) *vs.* "pɑpc'a" /CV̲C-CV/ and "ipɑp" (/V-CV̲C/) *vs.* "k^{h}ongpɑp" /CVC-CV̲C/). They have different syllable structures and segment types, etc. Therefore, they were expected to yield somewhat different results from each counterpart. Table 1 shows the speech materials.

Table 1. Speech materials and English glosses

V1	pɑp /CVC/ 'rice' (one-syllable word)
V2	pɑpp^{h}ul /CV̲C-CVC/ 'a grain of cooked rice' (two-syllable word)
V3	pɑpc'a /CV̲C-CV/ 'a rice spatula' (two-syllable word)
V4	pɑpc'ukək /CV̲C-CV-CVC/ 'a rice spatula' (three-syllable word)
V5	pɑpphult'eki /CV̲C-CVC-CV-CV/ 'a grain of cooked rice' (four-syllable word)
V6	ipɑp /V-CV̲C/ 'rice' (two-syllable word)
V7	k^{h}ongpɑp /CVC-CV̲C/ 'bean-mixed rice' (two-syllable word)
V8	poripɑp /CV-CV-CV̲C/ 'barley-mixed rice' (three-syllable word)
V9	sengsənc^{h}opɑp /CVC-CVC-CV-CV̲C/ 'vinegary rice wrapped with fish' (four-syllable word)
V10, V11	pɑpc'ukək-iro t'in poripɑp /CV̲C-CV-CV-CV-CV-CVC-CV-CV-CV̲C/ 'barley-mixed rice scooped up with a spatula' (nine-syllable phrase)

The speech items were all linguistically meaningful Korean materials. Seven different lists of them were prepared in random order. The six subjects produced the seven lists at a normal rate, yielding a total of 462 tokens (11 items × 7 repetitions × 6 subjects). Recording was made using a high quality recorder and a microphone in a sound treated recording room. 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. The duration of the medial vowel /a/ in the key word "pap" was measured in all speech materials. Here the aspiration and the periodic pulse of the vowel were all added into the vowel duration. The vowel /a/ was sometimes partially or fully devoiced. In such cases, measurements were done from the release of the phonologically unaspirated lax stop /p/ to the end of the periodic pulse of the partially devoiced vowels or the formants of the fully devoiced vowels (the endpoint of F1 or F2, whichever lasted longer, was taken for measurement).

2.3 Results

2.3.1 Pooled Results

2.3.1.1 Anticipatory Compression Effects at Word or Phrase Level

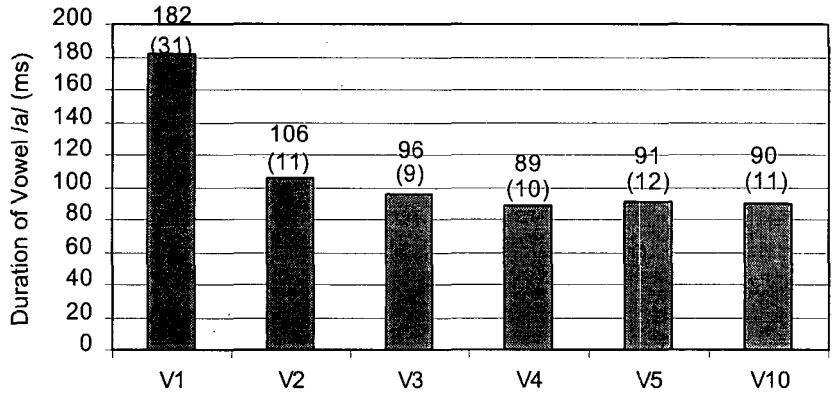

Figure 1. Anticipatory Compression Effects at Word or Phrase Level
Mean durations and (SD) of the word-medial vowel /a/ in the key /CVC/ word in one-, two-, three- and four-syllable words, and a nine-syllable phrase (Mean duration: aspiration + periodic pulse) (6 subjects, ms, n = 42)

Table 2. Anticipatory compression effects at word or phrase level. Significance: p-values from paired t-tests

	V2	V3	V4	V5	V10
V1	0.000***	0.000***	0.000***	0.000***	0.000***
V2	---	0.000***	0.000***	0.000***	0.000***
V3	---	---	0.000***	0.000***	0.000***
V4	---	---	---	0.115 ns	0.687 ns
V5	---	---	---	---	0.427 ns

*<0.05, **<0.01, ***<0.001, ns: non-significant

Figure 1 and Table 2 show that significant anticipatory compression effects on the duration of the vowel /a/ successively take place across one-, two- and three-syllable words (i.e., from V1 to V2: 41.8% or V3: 44.9%, and to V4: 51%). Of course, a substantial amount of the reduction would be due to the absence of final lengthening in two- and three-syllable words. By contrast, the compression stops in the three-syllable word and the duration of the vowel /a/ remains stable up to the nine-syllable phrase. Hence V4, V5 and V10 are not significantly different from each other by paired t-tests ($p>0.1$). A two-way analysis of variance between V4, V5 and V10 confirms that the number of syllables added does not significantly influence the duration of the preceding target syllable [$F(2, 108)=0.82$, ns]. It is interesting that V2 is significantly longer than V3 ($p=0.0005$ by a paired t-test), even though they are all bisyllabic words. This may be

because the two words have different syllable structures ("papp^{h}ul" /CVC-CVC/ *vs.* "papc'a" /CVC-CV/) and different types of phonemes (one is the aspirated stop /p^{h}/ and the other is the unaspirated affricate /c'/, although they are all tense phonemes) in onset position of the second syllable, etc. This, again, indicates that some factors other than the number of syllables added can exert their influence on the target syllable duration.

2.3.1.2 Backward Compression Effects at Word or Phrase Level

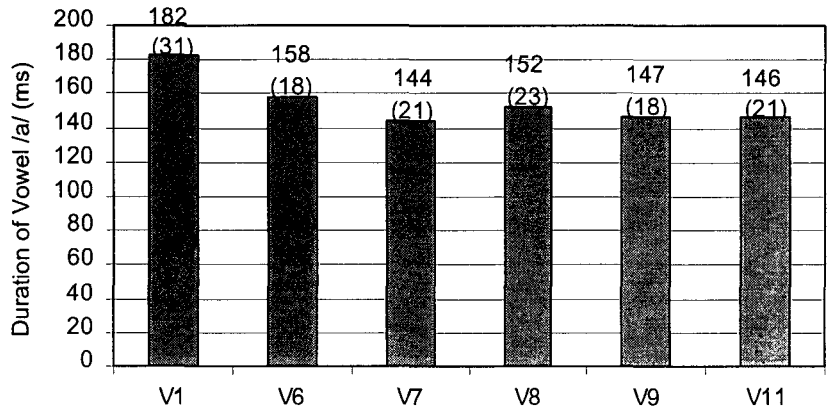

Figure 2. Backward Compression Effects at Word or Phrase Level
Mean durations and (SD) of the word-medial vowel /a/ in the key /CVC/ word in one-, two-, three- and four-syllable words, and a nine-syllable phrase (Mean duration: aspiration+periodic pulse) (6 subjects, ms, n=42)

Table 3. Backward compression effects at word or phrase level. Significance: p-values from paired t-tests

	V6	V7	V8	V9	V11
V1	0.000***	0.000***	0.000***	0.000***	0.000***
V6	---	0.000***	0.023*	0.000***	0.000***
V7	---	---	0.000***	0.123 ns	0.272 ns
V8	---	---	---	0.024*	0.009**
V9	---	---	---	---	0.484 ns

*<0.05, **<0.01, ***<0.001, ns: non-significant

Significant backward compression effect is observed in Figure 2 and Table 3 when another syllable is added to the one-syllable word "pap" (i.e., from V1 to V6: 13.2%, and to V7: 20.9%). The addition of more than one syllable, however, does not appear to induce clear compression in the duration of the target vowel, although slight reduction continues from V8 to V11. As in the above anticipatory compression, the two bisyllabic words "ipap" and "k^{h}ongpap" have significantly different durations in the target vowel /a/. Again, the plausible reasons are likely to be found in that they have different syllable

structures ("ipap" /V-CVC/ *vs.* "k^{h}ongpap" /CVC-CVC/), and different segments in the preceding syllables, and possible different stress patterns (either of the two syllables in "ipap" may be stressed, while the first syllable is stressed in "k^{h}ongpap"). On the other hand, the backward compression effect is not surprising from V6 (157.71 ms) to V8 (152.43 ms), considering the fact that V8 is not stressed, and moreover, it has two preceding syllables, which is likely to be interpreted as meaning that stress effects on vowel duration in Korean, if there is any, are not crucial.

2.3.2 Individual Results

Table 4. Mean durations of the word-medial vowel /a/ in the key /CVC/ word in one-, two-, three- and four-syllable words, and a nine-syllable phrase. (6 subjects, M: aspiration+periodic pulse) (ms, n = 7)

Items/Subjects	S1	S2	S3	S4	S5	S6
V1	239	174	167	167	162	165
V2	99	112	123	99	106	95
V3	102	99	114	93	99	95
V4	86	90	107	81	87	83
V5	85	90	114	82	89	85
V10	86	91	107	85	90	80
V1	239	174	167	167	162	165
V6	188	160	138	152	160	149
V7	180	144	127	137	145	127
V8	196	159	135	146	146	133
V9	173	161	137	145	147	122
V11	184	146	133	140	149	125

The general tendencies shown in the individual data are almost the same as those in the pooled data. However, some variability is found between speakers, or between pooled data and individual data. First, S1 pronounced V3 (102 ms) longer than V2 (99 ms), contrasted with other subjects. In addition, the two vowel durations (V2 *vs.* V3) were not statistically different in four (S1, S4, S5, S6) of the six subjects: $p > 0.05$ by paired t-tests for each subject. Thus, the significant difference between V2 and V3 in the pooled data seems likely to be non-significant or at least inconsistent when it is considered individually. Second, it is notable that S1 produced V1 markedly longer than the others. This can be attributed to personal speaking habits - S1 tends to lengthen final syllables more than the others. Third, S6 (Kyungsang speaker) yielded no markedly different results from those of others. In order to discover possible differences between accents with regard to compression effects, more speakers should be used.

3. Experiment 2: Sentence Level

3.1 Subjects

Subjects were the same as in the above experiment.

3.2 Materials and Procedures

Apart from the phrase speech items (i.e., V10, V11), all the speech materials of Experiment 1 are embedded in a carrier sentence "ce ..... cuseyo". (=Give me....., please.). Seven different lists of them were prepared in random order as in Experiment 1. The six subjects produced the lists at a moderate tempo, yielding a total of 378 tokens (9 items × 7 repetitions × 6 subjects). Including recording and measurements, every method and procedure used in this experiment was the same as those in the previous experiment.

3.3 Results

3.3.1 Pooled Results

3.3.1.1 Anticipatory Compression Effects at Sentence Level

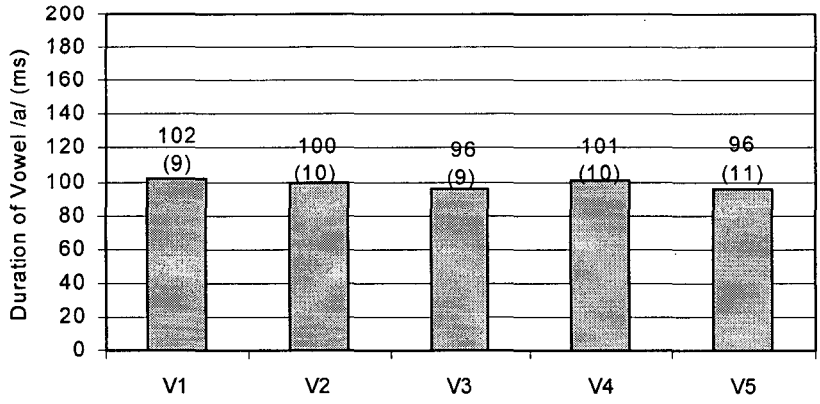

Figure 3. Anticipatory Compression Effects at Sentence Level
Mean durations and (SD) of the word-medial vowel /a/ in the key /CVC/ word in one-, two-, three- and four-syllable words embedded in a sentence "ce ..... cuseyo" (Mean duration: aspiration+periodic pulse) (6 subjects, ms, n=42)

Table 5. Anticipatory compression effects at sentence level. Significance: p-values from paired t-tests

	V2	V3	V4	V5
V1	0.088 ns	0.000***	0.257 ns	0.000***
V2	---	0.013*	0.439 ns	0.001**
V3	---	---	0.000***	0.948 ns
V4	---	---	---	0.001**

*<0.05, **<0.01, ***<0.001, ns: non-significant

As seen in Figure 3 and Table 5, it is most noticeable that statistically the monosyllabic word "pap" is not different from the bisyllabic word, "papp^{h}ul" and the three-syllable word, "papc'ukək" in the duration of the vowel /a/ (V1:V2, p = 0.088; V1:V4, p = 0.257 by paired t-tests). Overall, the anticipatory compression effect, which appeared significant across one-, two- and three-syllable isolated words, is very weak (when only V5, the shortest target vowel in the four-syllable word item is considered, the duration of the vowel /a/ shortens by just 5.5% compared with the one-syllable word "pap"), and inconsistent at sentence level.

3.3.1.2 Backward Compression Effects at Sentence Level

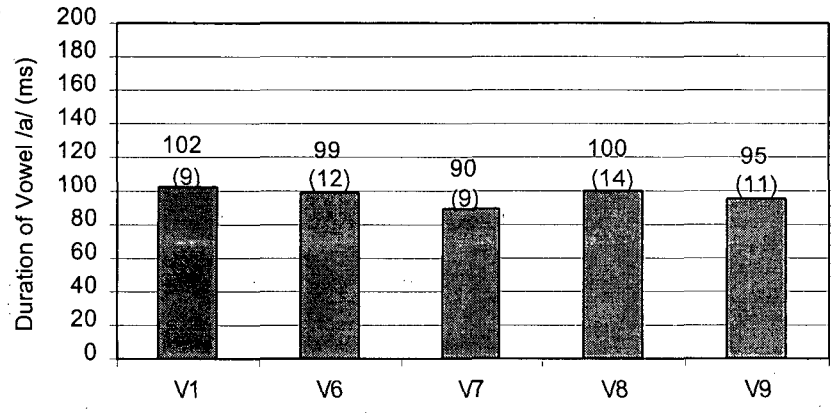

Figure 4. Backward Compression Effects at Sentence Level
Mean durations and (SD) of the word-medial vowel /a/ in the key /CVC/ word in one-, two-, three- and four-syllable words embedded in a sentence "ce..... cuseyo" (Mean duration: aspiration+periodic pulse) (6 subjects, ms, n=42)

Table 6. Backward compression effects at sentence level. Significance: p-values from paired t-tests

	V6	V7	V8	V9
V1	0.127 ns	0.000***	0.23 ns	0.000***
V6	---	0.000***	0.75 ns	0.014*
V7	---	---	0.000***	0.001**
V8	---	---	---	0.002**

*<0.05, **<0.01, ***<0.001, ns: non-significant

As in the case of the above anticipatory compression effects, the backward compression effects at sentence level are not clear. First of all, one of the two bisyllabic words, "ipap" and the three-syllable word, "poripap" were not different from the monosyllabic word "pap" in the duration of the vowel /a/ according to the results of paired t-tests (V1:V6, p=0.127; V1:V8, p=0.23). When only V9 with four syllables is taken

into account, it is reduced just by 6.3% compared to the vowel duration of the monosyllabic word "pap", and furthermore, the backward compression effect is not consistent, considering the mean durations obtained from the four speech items (i.e., V6, V7, V8, and V9).

3.3.2 Individual Results

Table 7. Mean durations of the word-medial vowel /a/ in the key /CVC/ word in one-, two-, three-, and four-syllable words embedded in a sentence "ce ..... cuseyo." (6 subjects, M: aspiration + periodic pulse) (ms, n = 7)

Items/Subjects	S1	S2	S3	S4	S5	S6
V1	97	99	117	96	103	100
V2	91	101	117	95	101	93
V3	90	98	108	90	98	94
V4	95	104	115	93	102	97
V5	91	93	116	91	96	91
V1	97	99	117	96	103	100
V6	84	91	111	103	110	96
V7	85	83	107	87	91	89
V8	83	89	120	104	108	94
V9	82	90	110	99	99	92

In five of the six subjects, the durational differences between V1, V2, V3, V4 and V5 were not significant by each one-way analysis of variance (S1: $F(4, 30)=1.65$, $p=0.187$; S2: $F(4, 30)=2.37$, $p=0.075$; S4: $F(4, 30)=1.23$, $p=0.318$; S5: $F(4, 30)=1.39$, $p=0.263$; S6: $F(4, 30)=2.02$, $p=0.117$). In the case of the remaining speaker S3 as well, the variance proved non-significant when the shortest item V3 is excluded or averaged with its counterpart V2 [$F(3, 24)=0.94$, $p=0.435$ or $F(3, 24)=1.81$, $p=0.172$].

V6, V7, V8 and V9 also did not show significant variance in three speakers (S1: $F(3, 24)=0.84$, $p=0.486$; S2: $F(3, 24)=1.89$, $p=0.157$; S6: $F(3, 24)=1.66$, $p=0.202$). Even the significant variance in the other three speakers, however, is not attributed to significant and consecutive backward compression, but to one or two vowels produced exceptionally short or long, compared to others (e.g., V8 is too long in S3; V7 is too short in S4 and S5).

Interestingly, unlike the pooled data, V1 is not the longest among the four speakers (S2, S3, S4, S5) not only statistically (by paired t-tests) but also in real mean duration. It may be indicative of non-significant (anticipatory or backward) compression effects at sentence level in Korean.

In the case of S4, every item from V2 to V9 was not statistically different from V1 in duration ($p>0.05$ by paired t-tests), and for all the nine items the different number of

syllables following or preceding them did not show a significant main effect by an analysis of variance in S6 [F (8, 54)=1.85, p=0.087].

4. Discussion

The results of the present experiment suggest that significant anticipatory compression occurs in the target vowel /a/ when one or two syllables are added to the right of the isolated monosyllabic word "pap", whereas the addition of more than two syllables yields no significant anticipatory compression to the target vowel. In particular, the first additional syllable induces a remarkable reduction in the target vowel. But this is assumed to be partly due to the loss of final lengthening rather than simply compression effect [Yun, 2000]. On the other hand, relatively weak but significant and continuous backward compression is observed when one, two or three syllables are added to the left of the isolated monosyllabic word. When it comes to the sentence level, however, the anticipatory and backward compression, if there is any, appears to be weak and inconsistent. The rhythmic type of a language should be sought at sentence level as well as at isolated word or phrase level. So it is not surprising that most studies concerning speech rhythm or timing have dealt with utterances longer than a word or phrase as their speech materials. Considering all, it seems to be difficult to claim that Korean is stress-timed, if significant anticipatory or backward compression effects especially at sentence level are used as evidence to support stress-timing. Moreover, it should be remembered that the anticipatory compression effect was not significant at isolated word or phrase level when the number of additional syllables was more than two. That is, Korean is not likely to be stress-timed. Here we need to be careful not to draw a hasty conclusion that Korean is syllable-timed, because non-stress-timing does not necessarily mean syllable-timing. We could not exclude the possibility that there are other rhythmic classes than the two traditional timing patterns [cf. Ramus, et al., 1999]. Furthermore, it is noted that the so-called stress-timed languages may not always show significant compression effects [Umeda, 1972; Harris and Umeda, 1974; Nakatani, O'connor & Aston, 1981]. Accordingly, a non-significant compression effect is not necessarily indicative of syllable-timing. In addition, the original hypothesis of syllable-timing has had little support, as compared with that of stress-timing [cf. Wenk & Wioland, 1982; Dauer, 1983; Fletcher, 1988; Arvaniti, 1994], apart from the validity of the dichotomy (stress-timing *vs.* syllable-timing) regarding speech timing. This research investigated whether Korean is stress-timed, and reports that Korean is not stress-timed. Despite this result, the question of the rhythmic type of Korean still remains unanswered. Therefore, further research is needed to get closer to the answer.

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