The Vowel Length as a Function of the Articulatory Force of the Following Consonants in Korean

Dae-Won Kim*

ABSTRACT

This study was designed to determine (1) the effects of the following stop consonant on the vowel length in isolated bi-syllabic words, (2) the mechanism which renders vowels longer in duration before lax stops than tense stops, (3) where the aspiratory interval is included, in the vowel portion or the preceding consonantal portion and (4) the influence of the preceding consonants upon the duration of the following vowel. Measurements were made of five timing variables on acoustic signals as three native Korean speakers uttered isolated bi-syllabic /VCV/ words in which the vowel was identical, /ɑ/, and the C slot was filled with bilabial stops. Findings: (1) the vowel length before the lax stops was significantly longer than before the tense stops, while the difference in the vowel duration between the tense stops was insignificant or negligible, (2) the vowel length varied as a function of the articulatory force of the following consonants, regardless of the phonological unit of syllable, (3) The aspiratory interval is interpreted as a portion of the preceding consonant and (4) The effects of the preceding consonants on the final vowel length were not rule-governed.

Keywords: Korean Vowel, Vowel Length, Force of Articulation, Korean Consonant

1. Introduction

A review of the existing literature reveals that there are different claims over the mechanism which renders vowels longer in duration before voiced than voiceless consonants. The first posits an inverse relationship between the vowel length and the force of articulation of the following consonants. In an experiment with French sounds, it was found that the duration of the vowel varied inversely as the force of

* Department of English Language Education, Pusan National University

articulation of the following consonant (Belasco, 1953, p. 1016; see also account by Fintoft, 1962, p.26). In other words, the anticipation of a consonant requiring a "strong" force of articulation will tend to shorten the preceding vowel since more of the total energy needed to produce the syllable is concentrated in the consonant. The second posits a durational compensation effect. It was claimed that there is a durational compensation effect, the vowel shortened when the duration of oral closure of the following consonant is long (Catford, 1977, p.201). In monosyllable words of English, such as 'back' and 'bag', there is a kind of compensatory factor in evidence, a certain fixed 'quantum' of duration being available for the monosyllable, the vowel lengthened when the duration of oral closure of the consonant is shortened. The third posits muscular activity of the same duration for vowels in both the voiced and voiceless environments (Leanderson & Lindblom, 1972). Under the hypothesis, the durational difference would then be effected by a difference in the timing of the onset of muscular activity of the following consonants in relation to the offset of preceding vowel activity: relatively earlier in the voiceless case and relatively later in the voiced case. The hypothesis, however, necessitates to explain the reason why there is a difference in the timing of the onset of muscular activity of the following consonants in relation to the offset of preceding vowel activity. The study (Leanderson & Lindblom, 1972) presents only the results of the mechanism which renders muscular activity for vowels longer in duration before the following voiced stops than before the voiceless stops. Thus, the hypothesis is difficult to accept as a reasonable explanation. The fourth posits a function of the [±voice] feature of the following consonant. In an experiment with English, French, Russian and Korean (Chen, 1970, p.157), it was claimed that vowel duration varies as a function of the [±voice] feature of the following consonant (for similar claims, see Chomsky and Halle, 1968, p.301; Halle and Stevens, 1967, p.269). However, this claim also does not seem to be a satisfactory explanation for the durational differential of vowels due to various factors. One of the reasons is the laryngeal configuration theory associated with a nonspontaneous voicing of a subsequent voiced consonant. A further discussion about this will follow on in the section of discussion.

In Korean, there are three types of stop consonant for each place of articulation: (1) lax unaspirated stops /b, d, g/, (2) tense unaspirated stops /p', t', k'/ and (3) tense aspirated stops /p^h, t^h, k^h/. As mentioned by Kim (1995, p.80), you need both 'aspiration' and 'tensity' simultaneously to distinguish the three types of Korean stops. This means that neither the aspiration nor the tensity is the primary feature. This is the same as "both." There are two types of tense stops. The tense stops are characterized by the presence or the absence of the feature 'aspiration'. Under the hypothesis of the durational compensation effect, aspiratory interval in bi-syllabic word / ́ɑp^hɑ/ should be interpreted as a part of the following vowel. The aspiratory interval is not a part of vocal tract closure, but a result of the release of vocal tract closure. However, there is little agreement on whether the aspiration portion should be interpreted as a part of the stop or that of the following vowel. Umeda (1975) claimed that the aspiration is included in the vowel portion, while Chen (1970) regarded the aspiratory interval as a part of the preceding plosive. In the study (Chen, 1970), Korean stops were characterized by the feature [$\pm$voice]. However, Korean stops are not characterized by the feature [voice] but by both [tensity] and [aspiration]. It is worthwhile to investigate into the effects of the following stop consonants on the vowel length in Korean in order to determine the mechanism for the variation of vowel length in the consonantal environment and whether the aspiratory interval is a part of the following vowel or a part of the preceding consonant.

We shall attempt to determine (1) the effects of the following stop consonant on the vowel length in isolated bi-syllabic words, (2) the mechanism which renders vowels longer in duration before lax stops than tense stops, (3) where the aspiratory interval is included, in the vowel portion or the preceding consonantal portion and (4) the influence of the preceding consonants upon the duration of the following vowel.

2. Method

2.1 Speech items

In order to gain a view of vowel length under environmental influence by a following lax and tense consonants, a series of isolated nonsense VCV words were constructed in which the vowel was identical, /ɑ/, and the C slot in VCV words was filled with the Korean bilabial stops: a lax unaspirated stop /b/, a tense unaspirated stop /p'/ and a tense aspirated stop /p^h/.

The constructed speech items are as follows:

/ába/ (nonsense word)
/áp'a/ (dad)
/ápʰa/ (painful)

A randomized list of words were recorded 6 times each at a normal speech rate. Vowel length is known to vary owing to a number of factors (Delatre, 1962). Care was taken to assure identical or similar prosodic patterns (pitch, stress, rhythm, etc.) for each speech item in order to minimize variability in duration due to supra-segmental features. Speakers read the speech items with stress on the initial vowel and with a falling intonation.

The Korean lax unaspirated stop is usually symbolized as /p/ by the use of the letter p within slashes. In this study, however, it is symbolized as /b/ in order to demonstrate its distinctive feature, 'laxness', as well as to differentiate from its tense counterparts, i.e., tense unaspirated stop /p'/ and tense aspirated stop /pʰ/. In the existing literature, usually the symbol /p/ is to represent [−voice] and [+tense], while the symbol /b/ is to represent [+voice] and [−tense]. In Korean, the feature [voice] is valueless, and /b/ represents [−tense] and /p/ [+tense].

2.2 Subjects

Three Korean native speakers served as subjects. Two (male and female) of the subjects have a near Seoul accent and one (male) of them has a Pusan accent. The Pusan accent is somewhat different from the Seoul accent in tone, but not in its phonological system. The subjects had no report of speaking problems. The speakers were not told the nature of the experiment.

2.3 Measurements

Measurements were made of the duration of pre-stop vowels, the duration of oral closure of stops, voice cessation time (i.e., the voicing interval from the onset of oral closure to the offset of regular pulsing on the audio signals), voice onset time and the duration of post-stop vowels as three Korean native speakers uttered the speech items. In order to obtain the timing variables, Soundscope 16 was used on Macintosh Quadra 650, combined with a Microphone, a Stereo-double Cassette Deck, and a

Stereo-Integrated Amplifier. The onset of the initial vowel was detected by the onset of regular pulsing on the audio signals. The moment of the oral closure for the stop consonant was detected by the sharp decrease of amplitude on audio signals and the release of the oral closure for the following vowels was detected by the onset of burst on audio signals. The starting point of voicing was detected by the onset of regular pulsing on audio signals. The moment of cessation of voicing was detected by the offset of voicing on audio signals. A total of 270 dependent variables (6 tokens x 3 subjects x 3 stop types x 6 variables) were measured.

2.4 Data analysis

A series of paired-t-test were performed on Statworks to determine if there is a significant difference between stop consonants in each dependent variable.

3. Results and Discussion

3.1 The effects of the stops on the preceding and the following vowel length

As seen in Table 1 and Table 2, the duration of the vowels before the lax stops was significantly longer than before the tense stops, regardless of the speaker, while the difference in the vowel duration between the tense stops was insignificant or negligible. Altogether, across six tokens and three subjects, the mean duration of the preceding vowels was in the order: before the lax unaspirated stops 〉 the tense unaspirated stops 〉 the tense aspirated stops. However, across subjects and tokens, the mean difference in the final vowel length between the lax stop and the tense stop was insignificant. The results agreed upon the previous finding (Peterson and Lehiste, 1960) that the influence of the preceding consonants upon the duration of the following vowel appears to be negligible. But the difference in the final vowel length between the two tense stops was significant and also there were inter-speaker differences in the effects of the consonants on the final vowel length. Thus, the results revealed that the effects of the preceding consonants on the final vowel length were not rule-governed or systematic.

3.2 The force of articulation of the following consonants

As seen in Table 1, overall the mean aspiratory interval was 53.9 ms for the tense aspirated intervocalic stop, 12.4 ms for the tense unaspirated intervocalic stop and 19.5 ms for the lax unaspirated intervocalic stop. A certain amount of the respiratory muscle activities should be required to produce the feature [aspiration] for the tense aspirated consonant. In Korean phonology, the 'aspiration' is an independent phonological marker for the tense aspirated stops, whereas it is redundant in the unaspirated stops. This means that in the isolated bi-syllabic /VCV/ word the aspiratory interval should be included in the preceding tense aspirated stop, that is, C. Supposing the force or energy required to produce a speech sound could be measured in terms of duration, the aspiratory interval can be added to the duration of oral closure for the amount of force or energy required to produce the tense aspirated stop. If that is the case, overall, the mean force of articulation for the tense aspirated stop consonant was 191.2 ms, which is greater than the oral closure intervals for the tense unaspirated stop (181.7 ms) and the lax unaspirated stop (72 ms). Overall, the mean difference in the force of articulation between the lax stops and the tense stops was significant (t = 9.870), whereas the mean difference between the tense stops was insignificant (t = .918). If the vowel length is considered as a function of the articulatory force of the following consonants, the vowel length would be in the order: before the lax unaspirated top 〉 the tense unaspirated stop 〉 the tense aspirated stop. Overall, the mean vowel length was observed to be 100 ms before the lax unaspirated stop, 64.7 ms before the tense unaspirated stop and 61.1 ms before the tense aspirated stop. The results suggested that the vowel length varied as a function of the articulatory force of the following consonants. When the aspiratory interval is interpreted as a part of the preceding stop consonant, there would be an inverse relationship between the vowel length and the force of articulation of the following consonants. However, if the aspiratory interval is interpreted as a part of the following vowel, there is no inverse relationship between the vowel length and the force of articulation of the following consonants. Overall the difference in vowel length between the tense stops was insignificant (t = 1.253), while the articulatory force of the tense unaspirated stop was significantly greater than the case of the tense aspirated stop. Thus, when the aspiratory interval is interpreted as a part of the following vowel, it is difficult to explain the variation of vowel length as a function of the articulatory force of the following consonant.

Under the hypothesis (Belasco, 1953), each syllabic unit would take relatively constant amount of articulatory force or energy to produce so that the energy expended on the vowel would vary inversely as the energy consumed by the subsequent consonant. Phonologically, the Korean bi-syllabic /V_1CV_2/ word like /ápʰa/ is syllabicated into /V_1\$$CV_2$/ where \$ indicates syllable boudary. Korean has a writing system in which there is one symbol for each phoneme. If Belasco (1953) holds true, the duration of the preceding vowel should be relatively constant, regardless of the following consonant since /V_1/ is an independent syllabic unit, but the reverse was true. The vowel length varied as a function of the articulatory force of the following consonants, regardless of the phonological unit of syllable. On the basis of the results, it can be assumed either that at the level of phonetics the bi-syllabic /V_1\$$CV_2$/ word has shifted to a bi-syllabic /V_1C\$$V_2$/ word or that an anticipatory articulation has taken place in duration, regardless of the phonological unit of syllable.

3.3 The durational compensation effect

As seen in tables I and II, the vowel length before the tense unaspirated stops was almost identical with the case before the tense aspirated stops. On the other hand, the tense unaspirated stops yielded a significantly greater duration of oral closure than the tense aspirated stops. Overall, the mean ratio of the duration of oral closure was 1 (the lax unaspirated stop) : 1.9 (the tense aspirated stop) : 2.5 (the tense unaspirated stop). This is agreeable with the previous findings (Kim, 1987) If the durational compensation effect works, the vowel length before the tense aspirated stop should be significantly longer than before the tense unaspirated stops. On the contrary, the vowel length before the tense aspirated stops was insignificantly different from that before the tense unaspirated stops (see the tables). This failed to support the hypothesis of the durational compensation effect (Catford, 1977, p.201). Under the hypothesis, the vowel shortened when the duration of oral closure of the following consonant is long. In other words, the vowel length is inversely related with the duration of oral closure of the following stops. The results imply that the hypothesis of the durational compensation effect has been rejected.

3.4 A function of the [± voice] feature of the following consonant

The hypothesis put forward by Halle and Stevens (1967, 269) is this: oral closure of the voiced stop consonant causes the supra-glottal pressure behind the constriction point to build up and consequently reduce the pressure drop across the glottis during phonation. In order to maintain continuous vocal fold vibration in the face of reduced pressure drop across the glottis, glottal opening must be widened. This laryngeal adjustment can be achieved only rather slowly. They report that the longer laryngeal adjustment time for the non-spontaneous voicing of a following voiced consonant would then lengthen the vowel (for the same account, see Chomsky and Halle, 1968, 301). The hypothesis, however, is difficult to accept as a satisfactory explanation for the mechanism which renders vowel longer in duration before the voiced or lax stops than before the tense stops. In /VCV/ words, an extra laryngeal adjustment is not required to maintain continuous vocal fold vibration during the voiced or lax stop. The vocal folds have been already suitably configured for the glottal pulsing during the preceding vowel and the state of glottal pulsing continues during the following voiced stops as long as a certain amount of airflow out of the glottis occurs. The vocal folds will continue oscillating as long as the pressure drop across them is greater than 2.039 cm H2O (i.e., 2,000 dyn/cm^2) if they are suitably configured (Ladefoged, 1964; Catford, 1977, p.29; Westbury and Keating, 1986, p.149; Westbury, 1983, p.1325). According to the data obtained, the mean 62.6% of the duration of the oral closure of the lax stop was devoiced.

4. Conclusion

Although a further investigation remains to take, the results suggest as follows:

(1) The duration of the vowels before the lax stops was significantly longer than before the tense stops, regardless of the speaker, while the difference in the vowel duration between the tense stops was insignificant or negligible.

(2) The vowel length varied as a function of the articulatory force of the following consonants, regardless of the phonological unit of syllable. In other words, the vowel length was inversely related to the articulatory force of the following consonants, regardless of the phonological unit of syllable.

(3) The aspiratory interval is interpreted as a portion of the preceding consonant.

(4) The effects of the preceding consonants on the final vowel length were not rule-governed.

Table 1. Means, averaged across six tokens, and standard deviations (SD) of the duration of pre-stop vowel (V_1), the duration of oral closure of a stop (DOC), voice cessation time (VCT), voice onset time (VOT), the duration of post-stop vowel (V_2) during isolated V_1CV_2 words of Korean (where S1, S2 and S3 indicate subjects).

Subj	items		V_1	DOC	VCT	VOT	V_2
S1	'aba	mean	107.8	98.8	36.8	14.2	174.6
		SD	6.09	13.18	11.49	5.21	11.95
	'apʰa	mean	58.0	165.0	−11.4	54.6	201.0
		SD	6.59	14:64	11.2	5.89	10.4
	'ap'a	mean	67.0	229.8	24.60	12.0	223.4
		SD	5.33	16.13	2.60	3.46	15.01
S2	'aba	mean	98.17	58.16	26.83	29.0	190.8
		SD	8.86	5.98	5.84	2.19	18.12
	'apʰa	mean	72.5	122.0	15.5	60.3	155.3
		SD	6.59	5.76	5.92	5.85	19.42
	'ap'a	mean	72.13	157.3	13.3	13.3	179.2
		SD	12.5	12.1	4.22	3.07	17.8
S3	'aba	mean	94.1	61.3	18.0	15.5	230.1
		SD	7.2	9.04	4.5	3.4	20.7
	'apʰa	mean	53.0	125.0	6.3	46.8	185.1
		SD	9.7	14.2	3.5	8.5	12.0
	'ap'a	mean	55.0	158.0	13.1	12.0	221.5
		SD	7.7	9.7	4.9	2.9	15.1
ALL	'aba	mean	100.0	72.7	27.2	19.5	198.5
		SD	7.03	22.6	9.40	8.19	28.5
	'apʰa	mean	61.1	137.3	3.46	53.9	180.4
		SD	10.12	24.0	13.6	6.77	23.20
	'ap'a	mean	64.7	181.7	10.3	12.4	208.0
		SD	8.77	41.6	4.96	0.75	25.04

Table 2. The results of paired t-test between stop consonants in the duration of pre-stop vowel (V_1), the duration of oral closure of a stop (DOC), voice cessation time (VCT), voice onset time (VOT), the duration of post-stop vowel (V_2) during isolated V_1CV_2 words of Korean (where S1, S2 and S3 indicate subjects).

Subj	items		V_1	DOC	VCT	VOT	V_2
S1	'aba :	p-value	.000	.001	.004	.001	.015
	'ap^{h}a	t-value	14.921	7.778	5.772	9.480	4.105
	'aba :	p-value	.001	.000	.003	.428	.000
	'ap'a	t-value	9.741	13.312	6.665	.881	16.231
	'ap^{h}a :	p-value	.154	.008	.048	.000	.053
	'ap'a	t-value	1.755	4.874	2.807	15.293	2.713
S2	'aba :	p-value	.004	.003	.000	.000	.007
	'ap^{h}a	t-value	4.991	5.458	19.164	14.335	4.351
	'aba :	p-value	.024	.019	.000	.000	1.990
	'ap'a	t- value	3.196	3.420	17.578	12.473	1.478
	'ap^{h}a :	p-value	.954	.604	.001	.000	.091
	'ap'a	t- value	.060	.553	6.688	16.217	2.092
S3	'aba :	p-value	.000	.001	.001	.001	.010
	'ap^{h}a	t- value	8.121	6.545	7.003	6.462	3.985
	'aba :	p-value	.000	.108	.000	.158	.022
	'ap'a	t- value	47.000	1.958	14.533	1.659	3.281
	'ap^{h}a :	p-value	.734	.069	.003	.000	.013
	'ap'a	t- value	.359	2.309	5.465	11.074	3.779
ALL	'aba :	p-value	.031	.000	.192	.008	.505
	'ap^{h}a	t- value	5.516	80.54	1.940	11.319	.806
	'aba :	p-value	.017	.010	.171	.239	.677
	'ap'a	t- value	7.611	9.870	2.093	1.659	.483
	'ap^{h}a :	p-value	.337	.049	.321	.007	.025
	'ap'a	t- value	1.253	4.333	1.307	11.625	6.185

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▲ Dae-Won Kim
Department of English Education, Pusan University
Changjun-Dong, Gumjong-Gu, Pusan 609-735, Korea
Tel: +82-51-510-2613 (O)
E-mail: dwokim@hyowon.pusan.ac.kr