Some Phonetic Characteristics of Mid-vocalic Lax Stops and Pre/Post-stop Vowels in Korean*

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ABSTRACT

It has been claimed that Korean mid-vocalic voiceless unaspirated lax stops are phonetically realized with voicing throughout the oral closure phase. Acoustic measurements were undertaken to examine the claim with four Korean native speakers using /V_1CV_2/ words where the vowel (V_1 = V_2) was /i, ɑ, u/ and the C was voiceless unaspirated lax stops /p, t, k/. Findings: (1) During mid-vocalic stops /k/ and /p/ the vowel /u/ was accompanied generally by a significant increase in voice cessation time as percentage of the oral closure interval (PCT) than the vowel /ɑ/, regardless of subjects, whereas in mid-vocalic alveolar stop /t/ the effects of vowels on PCT were subject-dependent, (2) The effects of vowels on PCT were significantly greater in mid-vocalic /k/ than /p/, regardless of subjects, (3) The mean PCT, averaged across six tokens, ranged from 17 % to 100 %, giving overall mean 61 % in which the standard deviation was ± 30, and (4) Overall 67 % of the total of mid-vocalic unaspirated lax stops were produced with a substantial period of devocing and voicing lag. Considering these results, it is difficult to agree with the existing claims that Korean voiceless unaspirated lax stops are phonetically realized with voicing throughout the oral closure phase. Other phonetic variables, including the durations of pre/post-stop vowels, voice onset time, voice cessation time, and the duration of oral closure, were measured.

Keywords: voicing, Korean intervocalic lax stop, Korean vowel, duration

1. Introduction

A review of the existing Korean phonetics and phonology reveals that Korean voiceless unaspirated lax stops are phonetically realized with voicing throughout the oral closure phase (e.g., Zong, 1973; Kagaya, 1974; Han and Witzman, 1970; Kim, 1965; Lee, 1969; Ladefoged, 1973). For example, in a study with two Korean speakers using a fiberscope technique combined with an audio microphone (Kagaya, 1974), it was

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claimed that for Korean intervocalic lax stops voicing was maintained throughout the utterance, i.e., isolated /VCV/ words where the vowel was /i/ or /e/, although one of the two speakers without exception produced intervocalic lax stops with devoicing during the oral closure interval and appreciable voicing lag. Moreover, the data obtained from the speaker were excluded, since it was judged that the data were unacceptable. Probably he just followed the earlier claims that for Korean intervocalic lax stops voicing is maintained throughout the utterance.

However, in a study using various techniques with isolated /VCV/ words where the vowel was /ɑ/, Kim (1987) found that the Korean voiceless unaspirated lax stops were manifested generally with a substantial period of devoicing during the oral closure phase: overall (across 3 subjects with near Seoul accent, 3 places of articulation, 2 stresses, and 5 repetitions) the mean devoicing interval as percentage of the duration of oral closure was 72.3 % in isolated words; 42.1 % in sentences). Only two out of the total of 90 cases of isolated utterances were fully voiced. The rest (98 %) were produced with a substantial period of devoicing and appreciable voice onset time (about 10 ms). The results in sentences also were similar to the case with the isolated words. The difference between Kim's findings (1987) and the earlier claims may be due mainly to the fact that the earlier claims are based generally on an impressionistic way of observations. In the study (Kim, 1987), however, attentions were confined to the single vowel /ɑ/, and the possible effects of vowel types on voice cessation time as percentage of the oral closure interval (PCT) have not been considered. The round vowel /u/, for example, is produced with a small hole between the lips, which may bring about an incomplete closure during mid-vocalic unaspirated lax stops, particularly, bilabial stops. Vowels with the feature [round] may affect PCT during the oral closure of midvocalic unaspirated lax stops. This study was designed to determine (1) the effects of vowel types on PCT during midvocalic unaspirated lax stops, (2) whether or not Kim's findings (1987) hold true, and (3) the timing variables of midvocalic lax stops and vowels of /VCV/ words. The timing varaiables of segments may be useful for programming a communication system. For the possible effects of vowel types on VCT, attentions will be confined to three vowels /ɑ, i, u/. The vowels are considered to be maximally opposed in production and perception, and they are found in all languages (Schane, 1973).

2. Method

Subjects

Four Korean native speakers with Pusan accent served as subjects. They are all female college students with no report of speaking problems.

Speech items

Isolated /V_1CV_2/ words (V_1 = V_2) were constructed, in which the V was /ɑ, i, u/ and the C was the Korean unaspirated lax stops /p, t, k/. The constructed speech items are as follows:

/ipi/, /iti/, /iki/
/ɑpɑ/, /ɑtɑ/, /ɑkɑ/,
/upu/, /utu/, /uku/

The subjects produced the constructed items six times each with a certain interval at the rate of normal speech before a microphone. The items produced by the subjects were recorded on the cassette tape. A total of 216 utterances (6 tokens x 3 vowels x 3 stops x 4 subjects) were produced.

Instrumentation and measurement

The following six acoustic variables during isolated /V_1CV_2/ words were measured on audio signals.

(1) The duration of pre-stop vowel (V_1)
(2) The duration of oral closure of stops (DOC)
(3) Voice Cessation Time (VCT), i.e., voicing interval from the onset of oral closure to the offset of regular pulse during the oral closure phase
(4) VCT as percentage of DOC (PCT)
(5) Voice Onset Time (VOT)
(6) The duration of post-stop vowel (V_2)

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 moment of the oral closure 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, and the moment of cessation of voicing was detected by the offset of voicing on audio signals. A total of 1296 dependent variables (6 tokens x 4 subjects x 3 places of articulation x 3 vowels x 6 variables) were measured. VCT was measured to obtain PCT.

3. Results and discustion

The duration of pre-stop vowels (V1) and post-stop vowels (V2)

Table I, II, and III showed that the durations of V_1 in isolated /V_1CV_2/ utterances were inconsistent due to inter-speaker differences, occasional differences, etc. Across six tokens, the mean durations of V_1 ranged from 52 ms to 153 ms, giving overall mean 120 ms, averaged across six tokens, four subjects, three vowel types, and three stop types. The results, associated with the range of the duration of V_1, are agreeable with Kim's findings (1987) in which observed mean, averaged across five tokens, values for the duration of stressed V_1 in isolated /V_1CV_2/ words, where the C was unaspirated lax stops /p, t, k/ and the V (V_1=V_2) was /ɑ/, ranged from 55 ms to 124 ms, giving overall mean 86 ms. In the study, he found that the duration of V_1 was a significant feature for tense-lax distinction between post-vowel stops. The durations of vowels followed by tense stops were significantly shorter than those followed by their lax cognates. As seen in Table I, II, and III, the variabilities in the duration of V_2 resulted generally from between-speaker differences, occasional differences, etc. The range of the mean (across six tokens) duration of V_2 was from 196 ms to 292 ms., giving overall mean 252 ms. Overall, the mean ratio of the duration of pre-stop vowels and post-stop vowels was 1 (V_1) : 2.5 (V_2).

Table I. The mean phonetic variables and standard deviations (SD) of vowels and lax stops during isolated Korean V_1CV_2 words where the V was /i, ɑ, u/ and the C was an unaspirated lax bilabial stop /p/ (n = 6, V_1 = the duration of pre-stop vowels, DOC = the duration of oral closure of stops, VCT = Voice Cessation Time, PCT = VCT as % of DOC, VOT = Voice Onset Time, V_2 = the duration of post-stop vowels).

Subjects		S1		S2		S3		S4		ALL	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
/ipi/	V_1	153 ms	14.8	88	6.5	82	4.0	82	7.3	101	34.5
	DOC	90 ms	9.1	72	13.7	63	16.6	71	9.5	74	11.4
	VCT	42 ms	11.7	68	14.7	47	21.9	26	5.8	46	17.3
	PCT	47%	13.1	94	20.3	75	34.9	37	8.3	62	23.5
	VOT	14 ms	1.9	2.0	4.8	8.0	5.0	12	4.5	9	5.3
	V_2	282 ms	35.4	278	29.2	197	15.3	249	4.6	252	39.2
/ɑpɑ/	V_1	153	16.6	102	8.1	69	6.3	91	11.7	104	35.6
	DOC	84	5.8	55	3.2	64	8.7	57	10.5	65	13.2
	VCT	32	8.0	40	14.5	29	16.3	26	12.6	32	6.0
	PCT	38	9.5	73	26.5	45	25.3	45	21.8	49	9.3
	VOT	12	1.2	7	9.1	11	6.6	11	3.4	10	2.2
	V_2	240	35.7	272	16.5s	196	17.7	271	13.1	245	35.7
/upu/	V_1	114	15.6	87	8.3	89	13.7	117	10.3	102	15.9
	DOC	97	13.3	68	5.1	72	24.4	50	10.2	72	19.4
	VCT	50	3.9	68	5.1	53	35.9	50	10.2	55	8.6
	PCT	51	4.0	100	0	73	49.5	100	0	77	12
	VOT	23	3.3	0	0	12	10.5	0	0	9	11.0
	V_2	274	21.2	250	45.1	213	31.6	268	21.1	251	27.5

The duration of the oral closure (DOC)

Table I, II, and II showed that across six tokens the mean DOC of mid-vocalic unaspirated lax stops in unstressed position ranged from 50 ms to 97 ms depending upon subjects, with overall mean 70 ms, averaged across six tokens, four subjects, three vowels, and three stops. The effects of the place of articulation for stops and vowel types on the DOC was generally inconsistent. Two subjects made the speaker-dependent effects of the place of articulation. S_1 produced significantly greater DOC for /p/ than /t/ and /k/, meanwhile S_4 yielded significantly less DOC for /p/ than /t/ and /k/. However, S_2 and S_3 showed the insignificant effects of the place of articulation on DOC. In general, however, the results related with the range of DOC are agreeable with Kim's findings (1987) in which across five tokens the mean values of DOC ranged from 61 ms to 96 ms, giving overall mean 83 ms, averaged across three subjects, three places of articulation, and five tokens. DOC significantly differentiated unaspirated lax stops in intervocalic position from their tense counterparts (Kim, 1987). This means that DOC of intervocalic stops could be a linguistically or acoustically significant feature for tense-lax distinction.

Table II. The mean phonetic variables and standard deviations (SD) of vowels and lax stops during isolated Korean /V_1CV_2/ words where the V was /i, ɑ, u/ and the C was an unaspirated lax alveolar stop /t/ (n = 6, V_1 = the duration of pre-stop vowels, DOC = the duration of oral closure of stops, VCT = Voice Cessation Time, PCT = VCT as % of DOC, VOT = Voice Onset Time, V_2 = the duration of post-stop vowels).

Subjects		S1		S2		S3		S4		ALL	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
/iti/	V_1	129 ms	9.0	97	17.3	100	13.4	86	5.2	103	18.3
	DOC	77 ms	7.0	75	6.1	68	5.3	88	8.1	77	8.3
	VCT	29 ms	3.4	75	6.1	34	6.4	17	3.9	39	25.2
	PCT	37%	4.3	100	0	50	9.4	19	4.3	50.4	32.7
	VOT	16 ms	5.7	0	0	11	2.9	14	3.9	10	7.1
	V_2	280 ms	32.2	284	23.2	205	8.3	281	14.3	263	38.4
/ɑtɑ/	V_1	134	10.2	81	5.9	76	10.9	91	11.4	95	26
	DOC	75	5.8	55	4.4	52	6.7	61	9.3	61	10.2
	VCT	26	4.5	43	13.1	47	13.6	14	4.2	33	15.3
	PCT	34	5.9	78	23.7	90	26	23	6.9	53.5	25.2
	VOT	10	3.0	8	6.3	4	5.7	8	2.3	8	2.5
	V_2	244	90.8	263	16.9	213	29.8	292	35.5	253	33.2
/utu/	V_1	114	23.8	52	12.1	93	9.4	79	10.0	85	26
	DOC	74	5.7	70	3.6	67	7.8	81	8.8	73	6.1
	VCT	34	5.2	63	12.8	43	15.6	26	5.6	42	15.9
	PCT	46	7.0	90	18.3	64	23	32	6.8	56.8	21.7
	VOT	21	2.7	6	1.6	11	10.7	14	2.2	13	6.3
	V_2	290	19.4	278	12.2	105	18.8	283	29.1	239	89.5

Voice Onset Time (VOT)

As seen in Tables I, II, and III, in unaspirated lax mid-vocalic stops VOT was generally dependent of subjects, and considerable effects of vowel types on VOT were observed. For example, S_1 produced overall mean 17 ms for VOT, while S_2 yielded overall mean 4 ms for VOT. S_1 gave 92 % of unaspirated lax stops with a substantial period of devoicing and an appreciable voicing lag. On the other hand, S_2, yielded 68 % of unaspirated lax stops with voicing throughout the oral closure phase, which in turn resulted in a short VOT in average. Thus, the speaker-dependent VOT seems to have been caused by inter-speaker differences in the production of fully voiced stops with no VOT. In general, during mid-vocalic unaspirated lax stops the vowel /u/ showed an increase in the production of fully voiced stops, except for the case with /t/, whereas for the vowel /ɑ/ the reverse was true. The alveolar stop /t/ yielded the inconsistent effects of vowels on the production of fully voiced stops. However, overall (across six tokens, four subjects, and three stops) the mean ratio of fully voiced mid-vocalic stops between vowels was 3.8 (/u/) : 2.1 (/i/) : 1 (/ɑ/). Across three stops, three vowels and six tokens, the range of mean VOT was from 4 ms (S_2) to 17 ms (S_1), with overall mean 10 ms (SD = ± 10).

Table III. The mean phonetic variables and standard deviations (SD) of vowels and lax stops in isolated Korean V_1CV_2 words where the V was /i, ɑ, u/ and the C was an unaspirated lax velar stop /k/ (n = 6, V_1 = the duration of pre-stop vowels, DOC = the duration of oral closure of stops, VCT = Voice Cessation Time, PCT = VCT as % of DOC, VOT = Voice Onset Time, V_2 = the duration of post-stop vowels).

Subjects		S1		S2		S3		S4		ALL	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
/iki/	V_1	181 ms	23	93	10.6	120	13.1	83	9.6	119	44
	DOC	86 ms	30.2	89	5.2	62	9.8	85	17	81	12.5
	VCT	44 ms	24.5	89	5.2	61	8.9	27	4.8	55	26.4
	PCT	51%	28.5	100	0	98	14.3	31.7	5.6	68.7	32.8
	VOT	44 ms	10.3	0	0	1	3.3	14	9	15	20.6
	V_2	298 ms	17.1	322	35.8	218	24.6	280	26.4	279	44.5
/ɑkɑ/	V_1	137	23	99	10.5	102	16.7	101	8.7	110	18.2
	DOC	59	11	56	6.0	50	4	82	4.6	62	14
	VCT	13	1.2	31	3.5	20	8.8	14	3.9	19	8.3
	PCT	22	2.0	55.3	6.2	40	17.6	17	4.71	31.6	13.4
	VOT	15	2.8	18	5.7	11	3.1	7	2.1	13	4.8
	V_2	260	20.0	307	33.1	218	24.6	285	38.7	268	38.2
/uku/	V_1	150	17.3	73	8.0	103	16	76	12.4	100	35.7
	DOC	63	22.9	68	10.6	64	12.8	87	8.8	71	11.2
	VCT	63	22.9	68	10.6	64	12.8	39	27.7	59	13.2
	PCT	100	0	100	0	100	0	44.8	31.8	82.9	18.7
	VOT	0	0	0	0	0	0	18	9.4	5	9.0
	V_2	305	89.4	180	19.8	245	19.9	252	9.7	245	51.0

Voice cessation time as percentage of oral closure interval (PCT)

Table I, II, III, and IV reveal that the effects of vowel types on the mean values for PCT, averaged across six tokens, were generally greater in the mid-vocalic unaspirated lax stop /k/ than /p/, regardless of subjects and that in mid-vocalic unaspirated lax alveolar stops /t/ the effects of vowel types on PCT were inconsistent due to between-subject variabilities. Table IV also shows that during mid-vocalic unaspirated lax stops /k/ and /p/ the round vowel /u/ was accompanied generally by a significant increase in PCT than the vowel /ɑ/, regardless of subjects, except for the case with S_3 in which the effects of vowels on PCT were insignificant in mid-vocalic /p/. The increase of fully voiced stops results in an increase of the value for PCT since PCT for fully voiced stops is 100 %. The speakers presented 79 % of the total of the mid-vocalic /k/s in /uku/ utterances with voicing throughout the oral closure phase, meanwhile the same speakers yielded 58 % of the total of /p/s in /upu/ utterances with voicing throughout the oral closure phase. The vowel /u/-related increase in PCT during mid-voalic stops /p/ and /k/ may have something to do with the feature [round] and [back] of the vowel /u/. The mid-vocalic stops /k/ and /p/ might have taken on the feature [round] and [back], respectively, which in turn might have resulted in an incomplete construction of the oral closure allowing air flow out of the glottis for voicing throughout the oral closure phase. Some of the fully voiced stops might have been made through a careless incomplete construction of the oral closure. In /ɑkɑ/ utternaces, the speakers without exceptions produced mid-vocalic /k/s with a substantial period of devoicing and appreciable voicing lag, and the same speakers gave 83 % of the total of /p/s in /ɑpɑ/ utterances with a substantial period of devoicing and appreciable voicing lag. In bilabial stops /p/ the ratio of the mean values for PCT between vowels, averaged across six tokens and four subjects, was 1.6 (/u/) : 1.3 (/i/) : 1 (/ɑ/), and in velar stops /k/ it was 2.6 (/u/) : 2.1 (/i/) : 1 (/ɑ/). The range of mean PCT, averaged across six tokens, was from 17 % to 100 %, giving overall mean 60 % (SD = ± 30).

Table IV. Statistical results of the effects of vowel types on PCT during mid-vocalic unaspirated lax stops (* indicates that p ≤ 5%).

Subjects		S_1		S_2		S_3		S_4	
	vowels	t	sig.	t	sig.	t	sig.	t	sig.
/p/	i : ɑ	1.145	0.279	1.650	0.130	1.938	0.081	0.898	0.390
	i : u	0.848	0.416	1.000	0.341	0.450	0.662	14.053	0.000*
	ɑ : u	2.323	0.043*	2.188	0.052*	1.310	0.220	8.206	0.000*
/t/	i : ɑ	0.755	0.467	2.879	0.016*	4.663	0.001*	0.675	0.515
	i : u	1.417	0.187	1.560	0.150	1.228	0.248	2.122	0.060
	ɑ : u	2.191	0.053*	0.687	0.508	8.012	0.000*	1.717	0.117
/k/	i : ɑ	5.155	0.000*	10.558	0.000*	1.000	0.341	3.568	0.005*
	i : u	10.952	0.000*	0.000	1.000	8.704	0.000*	0.970	0.355
	ɑ : u	47.145	0.000*	10.558	0.000*	8.704	0.000*	2.362	0.040*

The results of PCT relating to alveolar stop /t/ suggest that the features of vowels have insignificant impacts on the oral closure during alveolar stops. As mentioned in the section of VOT, overall the mean ratio of fully voiced mid-vocalic stops between vowels was 3.8 (/u/) : 2.1 (/i/) : 1 (/ɑ/). In mid-vocalic unaspirated lax stops where the vowel was /ɑ/, overall (across four subjects, three stops, and 6 tokens) 86 % of the total of mid-vocalic stops were produced with a substantial period of devoicing and vocing lag (see Table I, II and III). This is agreeable with Kim's findings (1987) in which 98 % of the total of mid-vocalic stops were manifested with a substantial period of devoicing and voicing lag. However, overall (across six tokens, three vowels, three stops, four subjects) 67 % of the total of mid-vocalic unaspirated lax stops were produced with a substantial period of devocing and voicing lag. Thus, considering these results and Kim's findings (1987), it is difficult to agree with the earlier claims that Korean voiceless unaspirated lax stops are phonetically realized with voicing throughout the oral closure phase (e.g., Zong, 1973; Kagaya, 1974; Han and Witzman, 1970; Kim, 1965; Lee, 1969; Heo, 1972: Ladefoged, 1973). The voicing appears to be one of potential phonetic correlates of intervocalic lax stops. The underlying physiological mechanisms for PCT are considered to be complicate. All else being equal, including position, stress, etc., they may include (1) supraglottal cavity expansion, (2) the glottal resistance, (3) the respiratory muscle activities generating air flow out of the lungs which gradually increases the air pressure against the oral closure, (4) [a combination of two of these factors], or (5) a combination of all of these (Kim, 1989, p. 242).

Summary

The duration of V_1 and V_2. Across six tokens, the mean durations of V_1 ranged from 52 ms to 153 ms, giving overall mean 120 ms, averaged across six tokens, four subjects, three vowel types, and three stop types. The range of the mean (across six tokens) duration of V_2 was from 196 ms to 292 ms., giving overall mean 252 ms. Overall (across four subjects, three vowel types, three stop types and six tokens), the mean ratio of the duration of pre-stop vowels and post-stop vowels was 1 (V_1) : 2.5 (V_2). In general, the inconsistent resutls of V_1 and V_2 resulted generally from between-subject differences and ocassional differences.

The duartion of oral closure (DOC). Across six tokens the mean DOC of mid-vocalic unaspirated lax stops in unstressed position ranged from 50 ms to 97 ms depending upon subjects, with overall mean 70 ms. The effects of the place of articulation for stops and vowel types on the DOC was generally inconsistent depending upon subjects. S_1 produced significantly greater DOC for /p/ than /t/ and

/k/, meanwhile S_4 yielded significantly less DOC for /p/ than /t/ and /k/. S_2 and S_3 showed the insignificant effects of the place of articulation on DOC.

Voice onset time (VOT). VOT was generally dependent of subjects, and there were considerable effects of vowel types on VOT. Across three stops, three vowels and six tokens, the range of mean VOT was from 4 ms (S_2) to 17 ms (S_1), with overall mean 10 ms (SD = $\pm$ 10). *Voice cessation time as percentage of the oral closure interval (PCT).* During mid-vocalic stops /k/ and /p/ the vowel /u/ was accompanied generally by a significant increase in PCT than the vowel /ɑ/, regardless of subjects, whereas in mid-vocalic alveolar stop /t/ the effects of vowels on PCT were subject-dependent. The effects of vowels on PCT were significantly greater in mid-vocalic /k/ than /p/, regardless of subjects. The mean PCT, averaged across six tokens, ranged from 17 % to 100 %, giving overall mean 61 % in which the standard deviation was $\pm$ 30. In mid-vocalic unaspirated lax stops where the vowel was /ɑ/, overall (across four subjects, three stops, and 6 tokens) 86 % of the total of mid-vocalic stops were produced with a substantial period of devoicing and voicing lag (see Table I, II and III). This is agreeable with Kim's findings (1987) in which 98 % of the total of mid-vocalic stops were manifested with a substantial period of devoicing and voicing lag. However, overall 67 % of the total of mid-vocalic unaspirated lax stops were produced with a substantial period of devocing and voicing lag. Considering these results and Kim's findings (1987), it is difficult to agree with the earlier claims that Korean voiceless unaspirated lax stops are phonetically realized with voicing throughout the oral closure phase (e.g., Zong, 1973; Kagaya, 1974; Han and Witzman, 1970; Kim, 1965; Lee, 1969; Heo, 1972: Ladefoged, 1973). The voicing during intervocalic lax stops appears not to be allophonic, i.e., rule-governed, but it is rather one of potential phonetic correlates of the intervocalic lax stops. The range of the mean values for timing variables, overall mean values, and the mean ratios may be useful in programming a communication system.

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