Acoustic Studies of Devoiced Vowels in Korean

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INTRODUCTION

Linguists have generally accepted the devoicing of vowels within the phonological boundary as an allophone of the voiced vowel, and recent studies of devoiced vowels have frequently treated it as a characteristic of the Japanese language.

It is known that the high vowel /i/ and /u/ between voiceless consonants are often devoiced in many Japanese dialects (Bloch, 1950; Han,1962; Sawashima, 1971; Hirose,1971; Fromkin,1983). Han mentioned that the devoicing depends on whether the vowel is accented or not and on which type of voiceless consonants are adjacent to it.

According to MAEKAWA(1989), the high vowel preceded by voiceless consonant is influenced not only by a following voiceless consonant but also by voiced vowel and this occurs at a normal speaking rate and at a faster speaking rate.

Concerning the interrelation between the glottal width and the acoustic characteristics on the spectogram of a devoiced vowel, the fiberopic observations of Sawashima (1971) find a wide opening of the glottis without any gesture of adduction throughout the period of a devoiced vowel; also, this time segment shows turbulent noise with some characteristic formant patterns on the spectogram.

The electromyographic data by Hirose(1971) prove that the difference in the laryngeal condition in the presence or absence of vowel devoicing depends on the inherent difference in the motor command.

The study of vowel devoicing in Korean was briefly mentioned by Hirose (1974). His electromyographic and fiberopic research showed that the interarytenoid muscle (INT) activity was markedly suppressed for the voiceless segments of [si] after an initial increase for the voiced segment in a carrier sentence /ikɔsi__ ita/ (This is___). The test words consisting of voiceless lenis or glottalized consonants were inserted into a sentence. In this phonetic environment, the glottal gesture of the voiceless segment [si] seemed to be wide open.

The primary purpose of the present study was to investigate the acoustic properties of some devoiced vowels in Korean.

Method and procedure.

The current method was processed by the Mac Speech Lab II System (Fig.1) , implemented on a MacintoshII Cx. The subjects selected were 5 males and 5 females who are native speakers of Cholla dialect. The corpus was composed of 28 meaningful words that contained the devoiced vowel /i/ between voiceless consonants. The test words were pronounced successively with a pause between consecutive utterances. Table 1 shows the list of test words.

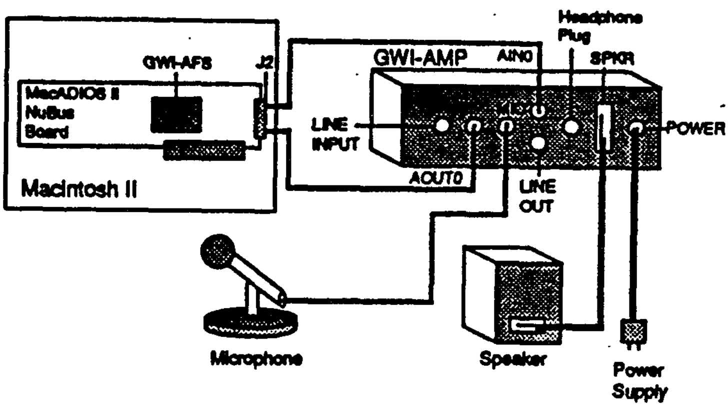


Fig. 1. Mac SpeechLab System.

Table 1. The list of the test words.

/sip^{h}ita /	" be chewed"
/sit^{h}e/	" the times"
/sik^{h}ita/	" let do"
/sit͡sikωn/	" be very sour"
/sit͡s^{h}ikkωn/	" be a little sour "
/ts^{h}it͡s^{h}ita/	" drew a line upwards"

Results

It is not yet clear if the high vowel /i/ between voiceless consonants in Korean can be devoiced or not. Fig. 2 shows a sound spectogram for a representative sample with devoicing of the high vowel /i/ between the fricative /s/ and the lenis affricate /t͡s/. It takes notice of the fact that in high frequencies regions of [si̥] in a time segment, vowel-like formants with intensified F3 and F4 can be similar to the F3 and F4 of the vowel [i] followed by the affricate[t͡s]. Morever, devoiced vowel segments were observed in the form of turbulent noise with some vowel /i/ like formant patterns in the F2 and F3 regions.

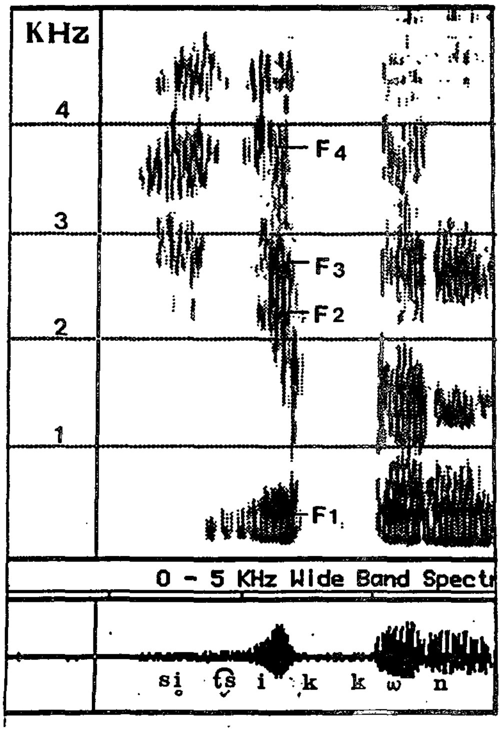


Fig. 2. Sound spectrogram of the test word [si̥t͡s^{h}ikωn]

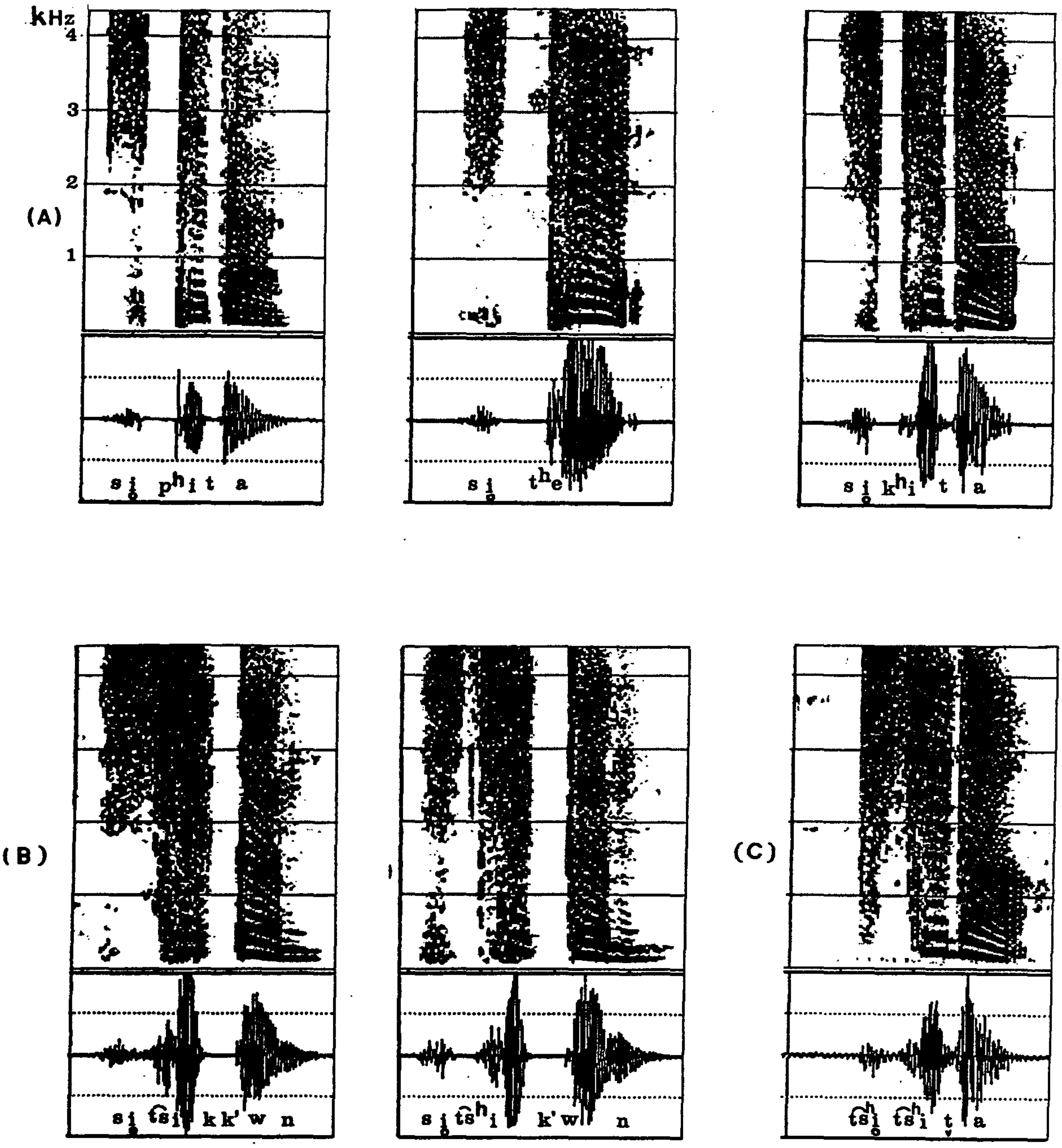
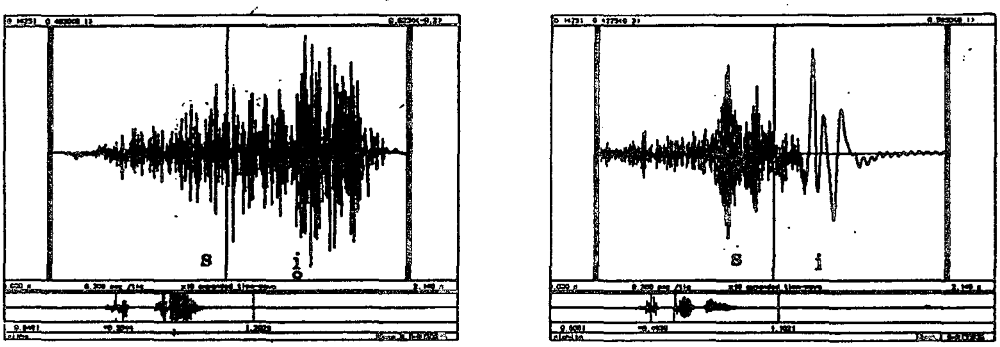


Fig.3. The spectrograms of the devoicing of the vowel /i/ between the fricative /s/ and aspirated stop (A), between the fricative /s/ and aspirated or lenis affricate(B) and between the two aspirated affricative consonants (C).

However, the fundamental frequency with harmonics did not appear on the spectogram. Fig. 3 shows the spectograms of the devoicing of the vowel /i/ between the fricative /s/ and the aspirated stop (A), between the fricative /s/ and the aspirated or lenis affricate (B), and between the two aspirated affricate consonants (C). It is mentioned that the devoiced vowel in the case of [sip^{h}i̥ta], [sik^{h}i̥ta] was shown a vowel-like quality on the spectrogram just before the beginning of oral closure.

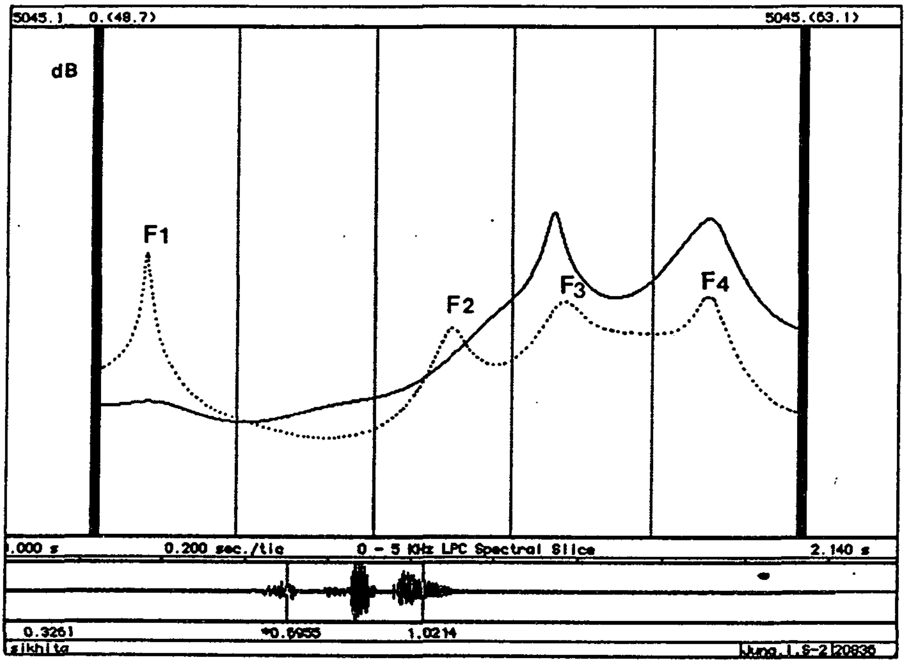
Fig. 4 indicates a pair of wave-forms with the devoiced vowel [i̥] and the voiced vowel [i], respectively. The vowel [i] occurs briefly through periodic segments in the last part of aperiodic segments, while the devoiced [i̥] continues aperiodic noise through all the segments [si̥].

Fig.4. A pairs of wave-forms with the devoiced vowel [i̥] and the vowel [i] respectively.



As for the LPC curves (Fig. 5), the intensities of F1 and F2 of the vowel [i] are higher than those of the devoicing vowel [i̥], while the intensities of F3 and F4 of vowel [i] is lower than those of the devoiced vowel [i̥]. Moreover F3 and F4 areas of the devoiced vowel [i̥] are similar to those of the vowel [i] as mentioned before. Thus we may assume that when the glottal

Fig.5. The LPC curves of the devoicing vowel and the vowel /i/. The line represents the frequency curve in the case of vowel devoicing [i̥] The dotted line show the vowel /i/.



constriction was narrower for the devoiced vowel in comparison with the adjacent fricative or aspirated consonant, the glottal gesture keeps a slightly open position , and at the same time the laryngeal flows quickly, thus the vocal folds cannot contact for vibration under this particular phonetic condition. Table 2 shows the durations of the turbulent noise containing the devoiced vowel [i̥] or the vowel [i] by the subjects, its rate among the total duration of test words , and the ratio of VOT in the case of the (devoiced) vowel segment with respect to the VOT of voiceless consonants preceding the second vowel /i/ in [C1V1C2V2 ...] environment. Table 3 indicates the average percentage of devoiced vowel cases in test words for males and females with the ratio of VOT. Devoicing of vowels /i/ took place twice as ofthe more for the females than for the males,

parameter / context		duration						percentage	
		1	2	3	4	5	6		
/sipʰita/		noise	v/d.vow	oral cl	exp	f.vow	w.total	1 / 6	4 / 1
M	T	101	0	91	30	60	487	21%	30%
M	K	124	13	97	47	54	652	19%	38%
M	N	124	17	101	44	40	534	23%	35%
M	D	94	17	94	50	37	544	17%	53%
M	J	128	17	84	47	27	531	24%	37%
mean		114.2	12.8	93.4	43.6	43.6	549.6	21%	38%
F	A	71	27	101	40	71	524	14%	56%
F	U	84	10	101	30	64	480	18%	36%
F	I	87	24	84	30	67	497	18%	34%
F	M	114	34	87	54	67	608	19%	47%
F	R	84	17	87	20	91	521	16%	24%
mean		88	22.4	92	34.8	72	526	17%	40%
/sitʰe/									
M	T	94	0	104	54	91	343	27%	57%
M	K	104	0	128	67	165	464	22%	64%
M	N	134	0	97	44	148	423	32%	44%
M	D	118	0	111	54	151	434	27%	46%
M	J	121	0	114	54	151	440	28%	45%
mean		114.2	0	110.8	54.6	141.2	420.8	27%	48%
F	A	104	0	87	50	141	382	27%	48%
F	U	104	0	141	51	97	393	26%	49%
F	I	101	0	111	54	148	414	24%	53%
F	M	111	37	131	30	161	470	24%	27%
F	R	81	30	138	27	198	474	17%	33%
mean		100.2	13.4	121.6	42.4	149	426.6	23%	42%
/sikʰita/									
M	T	104	0	57	51	64	480	22%	49%
M	K	138	0	91	40	44	601	23%	29%
M	N	118	0	94	21	50	487	24%	18%
M	D	114	0	44	47	37	464	25%	41%
M	J	124	0	47	50	77	501	25%	40%
mean		119.6	0	66.6	41.8	54.4	506.6	24%	35%
F	A	77	34	94	50	44	484	16%	65%
F	U	101	0	81	71	44	467	22%	70%
F	I	84	0	67	64	54	457	18%	76%
F	M	111	0	67	44	81	551	20%	40%
F	R	77	27	87	30	94	544	14%	39%
mean		90	12.2	79.2	51.8	63.4	500.6	18%	58%
/sitsʰikwn/									
M	T	94	0	67	51	53	511	18%	54%
M	K	94	0	94	94	94	622	15%	100%
M	N	138	0	101	24	50	638	22%	17%
M	D	104	0	57	64	40	544	19%	62%
M	J	118	0	91	6	44	581	20%	5%
mean		109.6	0	82	47.8	56.2	579.2	19%	44%
F	A	60	34	94	30	40	564	11%	50%
F	U	74	0	84	27	44	511	14%	36%
F	I	94	44	54	47	37	618	15%	50%
F	M	97	37	64	57	37	625	16%	59%
F	R	81	0	74	37	37	591	14%	46%
mean		81.2	23	74	39.6	39	581.8	14%	49%
/sitsikk wn/									
M	T	57	64		47	64	232	25%	82%
M	K	168	0			74	242	69%	0%
M	N	77	30		50	84	241	32%	65%
M	D	144	0			74	218	66%	0%
M	J	94	54		54	44	246	38%	57%
mean		108	29.6	0	30.2	68	235.8	46%	28%
F	A	54	47		67	54	222	24%	124%
F	U	81	67		81	74	303	27%	100%
F	I	97	0		91	74	262	37%	94%
F	M	54	42		60	40	196	28%	111%
F	R	101	64		34	77	276	37%	34%
mean		77.4	44	0	66.6	63.8	251.8	31%	86%
/tsitsita/									
M	T	91	0	57	30	81	430	21%	33%
M	K	91	0	30	57	71	447	20%	63%
M	N	60	54	54	74	67	413	15%	123%
M	D	104	0	44	81	17	353	29%	78%
M	J	118	0	40	108	40	497	24%	92%
mean		92.8	10.8	45	70	55.2	428	22%	75%
F	A	54	37	71	44	47	413	13%	81%
F	U	74	0	97	77	91	591	13%	104%
F	F	77	44	47	97	77	538	14%	126%
F	M	64	37	71	81	64	581	11%	127%
F	R	64	54	74	60	91	638	10%	94%
mean		66.6	34.4	72	71.8	74	552.2	12%	108%

Table. 2. The durations of the turbulent noise containing the (devoiced) vowels of the subjects, its rate among the total duration of test words and the ratio of VOT in the case of the (devoiced) vowel segment with respec to the VOT of voiceless consonants preceding the second vowel /i/.

and consequently devoiced vowels occurred 51% of the time in the phonetic environment.

Table 3. The average percentage of devoiced vowels for males and females with respect to the ratio of Voice Onset Time .

para / t.word	M	F	mean	Devoicing				Vocing			
				male		female		male		female	
				t.n.duration	VOT ratio	t.n.duration	VOT ratio	t.n.duration	VOT ratio	t.n.duration	VOT ratio
/sipʰita/	20%	0%	10%	21%	70%	0%	100%	21%	59%	17%	60%
/sitʰa/	100%	100%	100%	27%	62%	23%	58%	0%	100%	0%	100%
/sikʰita/	100%	60%	80%	24%	65%	20%	38%	0%	100%	15%	48%
mean	73%	53%	63%	24%	62%	14%	65%	7%	86%	11%	69%
/sit͡sʰikʼwn/	100%	40%	70%	19%	56%	14%	59%	0%	100%	14%	47%
/sit͡s ikkʼwn	40%	30%	30%	68%	100%	37%	6%	32%	32%	29%	8%
/kʰikʰik/	40%	0%	20%	32%	27%	0%	100%	21%	19%	17%	-16%
/t͡sʰit͡sʰita/	80%	20%	50%	24%	33%	33%	-4%	15%	-23%	12%	-7%
total mean	69%	36%	51%	31%	58%	18%	51%	13%	45%	14%	34%

The average duration of turbulent noise containing the devoiced [i̥] in the total duration of the word is longer than that of turbulent noise preceded by the vowel [i]. The ratio of the noise duration of the devoiced [i̥] is 31 % for males and 18% for females, while that of a voiceless consonant preceded by the vowel [i] is 13% for males and 15% for females. It is mentioned that the proportion of VOT containing the devoiced vowel [i̥] to VOT of the voiceless consonant following the second vowel [i̥] is 50% longer (58% for males and 51% for females) than that of VOT preceded by the second vowel [i]. (45% for males and 34% for females).

These data confirm that the longer duration of turbulent noise containing the devoiced vowel [i] is one of the characteristics of vowel devoicing and that high airflow in this phonetic condition can cause vowels to devoice.
Concerning the influence of the vowel devoicing adjacent to the voiceless consonant (Table 4), the rate of the devoiced vowel [i̥] is influenced by the preceding consonants as follows:

Fricative [s] > Aspirated affricate [t͡sʰ] > Aspirated stop [kʰ]

The ratio of the devoiced [i̥] is influenced by the following consonants: (1) the vowel [i] between the fricative [s] and the aspirated affricate; (2) the vowel [i] between the fricative [s] and the aspirated stop ; (3) the vowel [i] between the fricative and the lenis affricated ; (4) the vowel [i] between two aspirated affricates ; (5) the vowel [i] between two aspirated stops.

Table 4. The order of occurrence ratio for the devoiced vowel adjacent to voiceless consonants

		preceding con		
		s >	$\widehat{ts}^h$ >	k^h
following con	1	t^h		
	2	k^h		
	3	$\widehat{ts}^h$		
	4		$\widehat{ts}^h$	
	5	$\widehat{ts}^h$		
	6			k^h
	7	p^h		

Conclusion

It is not yet conclusive whether the devoicing of vowels orginates from a dialectal phenomem or the rate of speech. But the present study by means of experimental methods shows some characteristics of devoiced vowels in some phonetic environments.

The devoicing of vowels usually occurs in the high vowel when it is adjacent to the fricative noise level consonants.

Acoustic examinations reveal that the wave forms do not show any distinction between the voiced/devoiced segments, and that the intensified formant-like vowel in the high frequency regions F3, F4 and F5 of the devoiced vowel [i̥] preceded by the fricative /s/ segment appears in contrast to the vowel /i/ preceded by the voiceless consonant. Moreover, vowel-like harmonics showed up in some devoiced vowel cases, but the vocal pitch did notappear in this phonetic environment. We can thus assume that the glottal gestures of this phonetic environment do not maintain the adduction position and the laryngeal puff flows quickly with high pressure. Consequently the duration of the turbulent noise containing the devoiced vowel [i̥] is considerable longer.

It is mentioned that the rate of the devoicing vowel [i̥] was comparatively high between the fricative /s/ and the aspirated consonant.

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