Phonation Type of Korean Stops

- Research Based On Data Retrieved From Unified Acoustic Parameter Database

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Abstract

Based on parameters retrieved from Unified Acoustic Parameter Database Platform *(developed by The Phonetic Lab, Institute of Ethnology & Anthropology, Chinese Academy of Social Sciences), this paper examined Korean (spoken in China) three-way contrast stops, called lenis, aspirated and fortis stops. Through research on acoustic parameters of following vowel including intensity of harmonics, voice quality, pitch onset & intensity as well as acoustic characteristics in sound-wave and spectrogram and referring to other scholars' research results of Korean (spoken in Korea) three-way contrast stops, we conclude that Korean three-way contrast stops differ in phonation types and the articulation mechanism works in whole syllable. Lenis stop belongs to slack voice and fortis stop belongs to modal voice.*

Key Words Korean Three-Way Contrast Stops, Phonation Type, Acoustic Parameter Database

1. Introduction

Among world languages Korean stops are unusual because they are three-way contrast stops (lenis, aspirated and fortis stops) and all are voiceless. What differentiate these stops, what are the phonation and aerodynamic mechanism differences, especially for lenis and fortis stops remain unclear for a long time. C. Kim(1970)and Park(2002)maintained that Korean three-way contrast stops have different laryngeal gestures: glottal opening is largest for aspirated stops, second for lenis stops and narrowest for fortis stops at the time of release of the oral closure and argued that the degree of aspiration of proportionally correlated with the degree of glottal opening. By observing fibrescope, Kagaya (1974) found that both fortis and aspirated stops are characterized by some intrinsic laryngeal gestures. Dart (1987) found that the production of the fortis stops is characterized by high intra-oral pressure before release and lower flow after the release. Cho & Keating (1999) found that lenis stops have less linguo-palatal contact and shorter duration than aspirated or fortis ones by using EPG. N.Han (1998) found that vowels after lenis stops have a breathy voice as indicated by positive H1-H2 value. The subject of above researches is Korean language spoken in Korea. Yu Hui (2008) found that fortis stops have strong aspiration, lenis stops have weak aspiration and fortis stops have no aspiration based on researching Korean three-way contrast stops spoken in China. Pitch onset of vowel after fortis stops is higher than lenis stops and fortis stops have longer closure time.

In the book *Sounds of the World's Languages* (Ladefoged & Maddieson 1996: 48), based on glottal opening (from maximum to minimum), Ladefoged and Maddieson classified eight phonation types: voiceless aspiration, voiced aspiration, slack voice ,modal voice , stiff voice , creaky voice, glottal closure, voiceless.

By examining, measuring and comparing of the Korean acoustic parameters retrieved from Unified Acoustic Parameter Database Platform, and taking reference of other researches about Korean stops, we conclude that the contrast of three-way stops is a phonation issue and such mechanism lasts in whole syllable including following vowels. Therefore, we mainly focus on the vowel carrying the phonation features, especially at the onset of vowel. Our conclusion is that fortis stops are modal voiceless and lenis stops are slack voiceless. Both consonant and vowel in lenis syllable are slack.

2. Experiment Description

Stimuli are consisted of 200 groups three-way contrast stops words (monosyllabic and disyllabic words, most are real Korean words). Table 1 is part of stimuli.

Table 1 Korean Three-Way Contrast Stop Words (part)

Group	Lenis Stop	Aspiration Stop	Fortis Stop
1	바 pa	파 pha	빠 p*a
2	발 pai	팔 phai	빨 p*ai
3	불 pur	풀 phur	뿔 p*ur
4	붐 pun	품 phun	뿜 p*un
5	반 pan	판 phan	빤 p*an
6	다 ta	타 tha	따 t*a
7	당 tang	탕 thang	땅 t*ang
8	다구 tagu	타구 thagu	따구 t*agu
9	다다 tata	타다 thada	따다 t*ada
10	다락 tarak	타락 tharak	따락 t*arak
11	공 kong	콩 khong	꽁 k*ong
12	굴 kul	쿨 khul	꿀 k*ul
13	간 kan	칸 khan	깐 k*an
14	광 kwang	쾅 khwang	꽝 k*wang
15	검 keom	컴 kheom	껌 k*eom

Recording was conducted using Notebook PC with high quality voice card and microphone. The speaker is female Korean, speaking standard Korean language (spoken by Korean nationalities in China). Data retrieved are syllables containing vowel a, i, o, u. Acoustic parameters are vowel duration, intensity, pitch onset, intensity of H1& H2(H1 and H2 are the first and second Harmonics of vowel), vowel quality (HNR, Shimmer, Jitter). Analysis approaches are: harmonics intensity comparison, voice quality comparison, acoustic parameter comparison, sound-wave & spectrogram comparison.

To retrieve H1 and H2, we position vowel at 50 ms after vowel onset. To retrieve vowel quality, we choose vowel segment between 50ms-100ms after vowel onset. The reason to choose vowel onset is that we expect vowel onset may carry more articulation cues, especially phonation characteristics of stops.

3. Harmonics Intensity Differences Comparison

Because F1 of vowel may affect intensity of low harmonics, we choose syllables with lower vowel a (with high F1 and less influence on low harmonics).

Table 2 Harmonics Intensity Differences dB

Syllable	H1-H2			④
	Lenis①	Aspirated②	Fortis③	=①-③
tagu	6.5	2.2	-1.2	7.7
tada	2.4	2.7	-1.3	3.7
tarak	18.4	1.7	-0.2	18.6
tak	5.9	0	0.6	5.3
tan	8.9	2.3	-2.7	11.6
tanseong	-1.4	2.2	-1.2	-0.2
tal	3.5	4.4	-1.9	5.4
tam	4.6	4.3	-1.4	6
tang	9	0	-1.8	10.8
taeban	3.4	0.6	-4.4	7.8
kan	12	6.2	-0.3	12.3
kae	1.5	0.7	-5.8	7.3
kang	9.5	3.2	-1.2	10.7
□am	11.6	3.6	-0.4	12
□a	1.7	1.9	-1.5	3.2
□aŋ	7.3	-0.5	-1.9	9.2
pa	6.5	-0.4	-2.2	8.7
pai	7.3	1.8	-0.9	8.2
pan	2.6	4.5	-1.5	4.1
pat	4	-1.1	-3.9	7.9
paŋ	6.5	3.1	1.4	5.1
ta	13	2.8	-0.9	13.9
taŋ	14.3	3.8	-1.7	16

In the above 23 samples, 22 from 23 of column① are positive, indicating vowel in lenis syllable is breathy vowel with wider glottal opening. Most values of Column ③ (21/23) are negative, indicating tense and laryngealized vowels. Column ② is similar with column①, also indicating wider glottal opening. The total samples of syllables containing vowel i, u, o, e are 27, the ratio of positive H1-H2 in lenis syllable is 22/27=81%. The ratio of negative H1-H2 in fortis syllable is 24/27=89%. Both results correspond with above assumption. But the ratio of positive H1-H2 in aspiration syllable is 9/27=33%, which contradicts with above results, implying that intensity of H1-H2 cannot be used in judging phonation types for aspiration syllable.

Considering column ④, there is only one exception (-0.2) in 23 samples, indicating different laryngeal gestures and phonation types between lenis and fortis syllable.

We also randomly chose 5 pairs of words to measure their H1-H2 at onset of vowel. In Table 3, all values in column④ are positive. The result is identical

to column④ in Table 2.

Table 3 Harmonics Intensity Differences at vowel onset

Syllable	H1-H2		④
	Lenis①	Fortis③	=①-③
pa	6	-2.7	8.7
pai	10.6	-1.9	12.5
pan	5.2	-1.6	6.8
ta	10.2	-1.4	11.6
taŋ	13	-1.3	14.3

4. Vowel Duration, Intensity And Pitch Onset

Table 4 Averaged Vowel Duration And Intensity

Vowel		a	i	u	o	Ave.
Lenis syllable	Duration	321	543	444	435	436
	Intensity	74	72	75	75	74
Fortis syllable	Duration	298	522	446	425	423
	Intensity	77	74	78	78	77
Sample		18	2	6	6	
Ratio_D		12/18	2/2	4/4	5/6	72%
Ratio_I		18/18	2/2	5/6	6/6	97%

Note:
Ratio_D: samples in which vowel duration of lenis syllable > vowel duration of fortis syllable/ all samples
Ratio_I: samples in which vowel intensity of lenis syllable < vowel intensity of fortis syllable/ all samples

Table 5 Averaged Vowel Duration In Different Syllables

Vowel		a	i	u	o
Lenis syllable	CV	375	558		359
	CVC	354	527	403	413
	CVCVC	260			
Fortis syllable	CV	345	548		357
	CVC	329	495	402	408
	CVCVC	254			

Table 4 and Table 5 show that intrinsic duration of vowels is sorted (from long to short) as i、u、o、a, indicating positive correlation with vowel height. Because low vowels need to open mouth wider, which is not economical based on economical articulation rule, therefore, articulator tends to shorten the vowel duration. It is possible that aspiration of vowel prolongs the duration in lenis syllable. Lower intensity of vowel in lenis syllable is due to wider glottal opening, which reduces the pressure of vocal cords as well as vibration amplitude. 97% of Ratio_I is strong evidence supporting the glottal opening differences between lenis and fortis stops.

The Pitch onset of vowel in lenis syllable is between 20-30 Hz lower than vowel in fortis syllable. There is no exception against this rule among 32 samples. The hidden phonation mechanism is same with above analysis of intensity. Wider glottal opening and lower pressure vocal cords lead to slow vibration and lower Pitch onset.

5. Vowel Quality

We mainly apply Jitter, Shimmer and HNR to measure voice quality. Their definitions are as follows:

Jitter: average absolute differences between the consecutive periods, divided by the average period.

Shimmer: average absolute differences between the amplitudes of consecutive periods, divided by the average amplitude.

HNR: general degree of acoustic periodicity.

Table 6 Average Jitter, Shimmer and HNR

Vowel		a	i	u	o
Lenis syllable	JIT.	0.85	0.25	0.40	0.43
	SHI.	9.95	2.88	4.48	4.03
	HNR	12.78	21.80	22.15	20.30
Fortis syllable	JIT.	0.72	0.41	0.38	0.43
	SHI.	4.08	8.70	2.21	3.17
	HNR	15.72	21.50	21.95	19.22
Ratio_S		17/18	1/2	5/6	4/6
Ratio_H		14/18	1/2	3/6	4/6

Note:
Ratio_S: samples in which vowel Shimmer of lenis syllable > vowel Shimmer of fortis syllable/ all samples
Ratio_H: samples in which vowel HNR of lenis syllable > vowel HNR of fortis syllable/ all samples

For vowel a, the exceptions of HNR are all from syllables with initial consonant /□/. This is because /□/ is affricate, which has aspiration segment reducing HNR of following vowel. This is also a cue of aspiration in the lenis syllable. One exception for Shimmer value is due to inaccuracy of articulation. For all vowels, Ratio_S reaches 27/32=84% and Ratio_H reaches 69%. Based on these data, we conclude that Shimmer is a good parameter to distinguish lenis and fortis syllables. Among four vowels, vowel a has the highest Ratio_S and Ratio_H and is the best samples to compare vowel quality. Jitter is good parameter to distinguish creaky voice instead of slack voice.

Figure 1 and Figure 2 show Shimmer & HNR of 23 samples including vowel a.

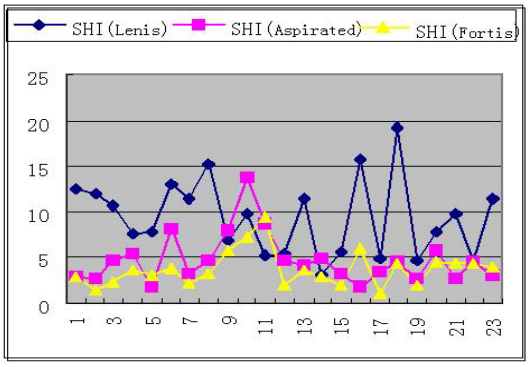


Figure 1 Shimmer in three contrast syllables

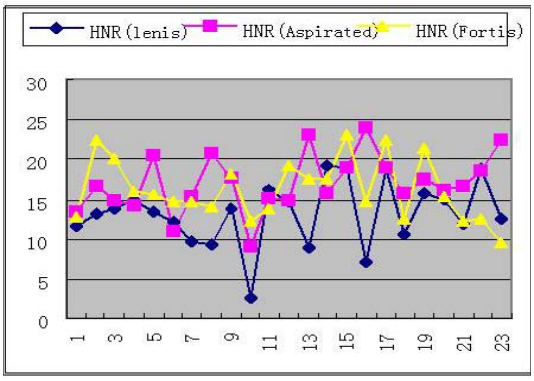


Figure 2 HNR in three contrast syllables

In Figure 1, for most Shimmer values, lenis syllables are the highest; aspiration syllables the second and fortis syllables the lowest. Because shimmer is highly related with aspiration, lenis syllable with high shimmer is slack voice. Aspiration syllables have the highest aspiration and widest glottal opening. Because we measure vowel quality at the onset of vowel, at which aspiration process is finished and only aspiration residue is leaked to vowel onset. This is also called vowel slackness. So, lenis syllable has more aspiration at vowel onset. Aspiration syllables and fortis syllables have similar shimmer values but remarkably differentiate with lenis syllables. In figure 2, In terms of HNR, aspiration syllables and fortis syllables are similar and lenis syllables have lowest HNR. In conclusion, both shimmer and HNR support the assumption that lenis syllables are slack voice and fortis syllables are modal voice.

6. Sound-wave and Spectrogram

The following sound-waves show the glottal pulses of vowel at the segment between 50 ms and 100 ms after vowel onset. For fortis syllable and aspiration syllable, amplitude is relatively stable and pulses are regular and smooth. For lenis syllables, however, pulses are irregular and rough indicating aspiration.

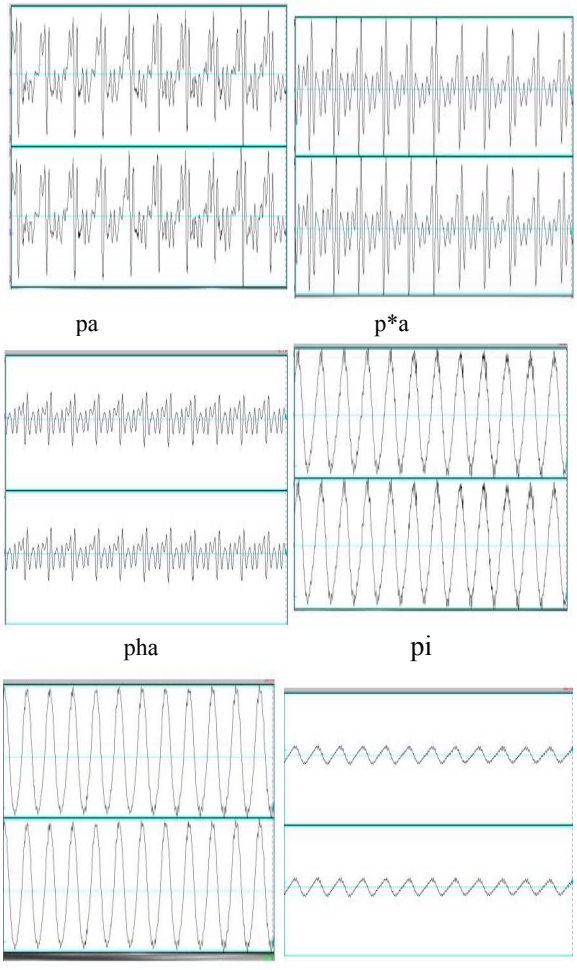


Figure 3 Sound-waves of vowels in three-way contrast syllables

Figure 4 demonstrates Spectrogram of lenis and fortis syllables. In lenis syllable, spectrogram is blur and the intensity in high frequency area is weak due to aspiration.

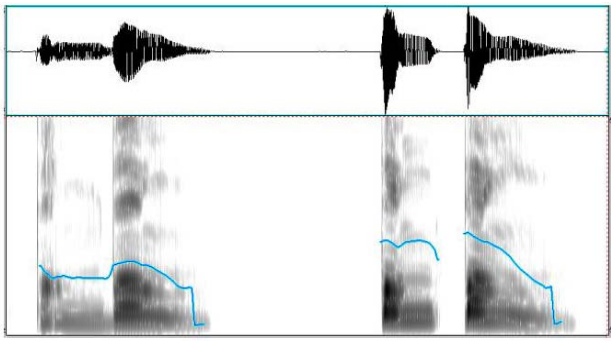
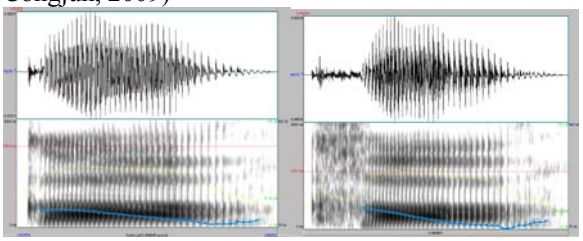


Figure 4 Spectrogram of lenis and fortis syllables

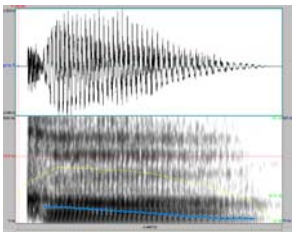
7. Vowel in the aspiration syllable

Are there any differences of vowels between aspiration and fortis syllables? In terms of average intensity, lenis syllable is 75.17, aspiration 75.67 and fortis 77.75. The first two are similar and remarkably lower than the last. I terms of pitch onset, aspiration syllables and fortis syllables are similar and about 20-30 Hz higher than lenis syllables. The pitch mode implies the similar laryngeal gestures and same phonation types between the two.

In fact, the similar three-way contrast stops also exist in Wa language. In figure 5,ko "start" (voiceless, fortis), k□o̤"correct"(voiceless aspiration), k□o□ "person"(slack, lenis) are such example. (Long Congjun, 2009)



ko "start" k^ho "correct"



k̤o̤ "person"

Figure 5 vowels in three-way contrast stop syllables in Wa

Therefore, the three-way contrast stops in Korean is an issue of phonation type. Due to aspiration leakage, vowels become slack in aspiration syllables. This is also the reason why acoustic characteristics (shimmer, HNR) of vowels in aspiration syllables and lenis syllables are similar. Vowel slackness caused by aspiration leakage of voiceless stop is the reason of tone differentiation of Wu Jiang dialects in southeast Tai Hu area, China. (Zhu Xiaonong, Xu Yue, 2008)

8. Discussion

Based on classical phonation theory, we retrieved, computed and compared acoustic parameters of Korean three-way contrast stops. Because Korean stops are all voiceless, we mainly retrieved acoustic characteristics in the onset of following vowel containing so called lenis-fortis information as expected. Through comparison of intensity of harmonics, vowel quality, pitch onset, intensity, sound-wave & spectrogram characteristics, we found that these features are corresponded with contrast of slack-modal voice phonation types. Korean three-way contrast stops also resemble with three-way contrast stops in Wa language. Therefore, we conclude that Korean three-way contrast stops is an issue of phonation type. Lenis syllable is slack voice and fortis syllable is modal voice.

Korean aspirated stops are generally regarded as modal voiceless. After comparing with other stops groups, we found that its glottal opening at the vowel onset is between that of lenis and fortis syllables and has aspiration, which makes following vowel slackness. Because fortis stop must contrast with lenis stop, it is justified to assume that Korean fortis syllable (modal voice) should be more tense than modal voice of other languages without contrast of lenis and fortis contrast. In fact, through hearing angle, Korean fortis syllables really sound laryngealized.

As for the transcription of lenis and fortis stops, according to transcription tradition, phoneme with special phonation should be annotated; so lenis stop and lenis vowel must be marked instead of fortis stop like other languages do (for slack voice, plus two dots under the phoneme symbol to mark slack phonation). However, whether stop or vowel is annotated, the hidden articulation mechanism behind lenis and fortis stops is phonation issue.

9. References

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