ANN.BULL.RILP(1991)No.25, 17-31

LARYNGEAL ADJUSTMENTS FOR KOREAN STOPS, AFFRICATES AND FRICATIVES - AN ELECTROMYOGRAPHIC STUDY

Kihwan Hong*, Seiji Niimi, and Hajime Hirose

Abstract

It is generally known that in Korean there is a three-way distinction in both manner and place of articulation classified as glottalized, lenis and aspirated consonants, and there are several reports differentiating these three manner categories with acoustical and physiological research. However, there has been no electromyographic study of the PCA muscle for the production of these three types of Korean consonants in the literature. For this study, the authors investigated the role of the intrinsic laryngeal muscles, and the results indicated that the aspirated consonants appear to be characterized by a marked and earlier activation of the PCA and a reactivation of VOC muscles before the voice onset of the following vowel; lenis consonants by a moderate activation of the PCA and a reactivation of the VOC; the glottalized consonants are characterized by little or no activation of the PCA and a marked reactivation of the VOC. It seems reasonable to conclude that the PCA muscle plays an important role in the production of consonants before the voice onset of the following vowel, especially for aspirated and lenis consonants.

Introduction

The Korean stop consonants are classified into three groups according to place of the articulation, i.e. labial, dental and palato-velar, and three types according to manner of articulation, i.e. aspirated, lenis and glottalized. The same manner classification applies also to the affricates, while the fricatives can be classified into two types, glottalized and lenis. All stops and affricates may occur in word-initial position to be realized as voiceless, while in word-medial position, lenis types are usually manifested by voiced allophones.

There have been many reports on efforts to clarify the acoustical and physiological properties that differentiate these manner categories. Umeda and Umeda[1] studied the Korean stops, affricates and fricatives with sound spectrography, but they studied only the Seoul and Taegu dialects, and their results indicated that these two dialects are different in their acoustic properties in that the transition of the vowel portion is forced and long in the Seoul dialect, while in the Taegu dialect it is characterized by a reinforcement of the higher frequency components. Furthermore, the fundamental frequency at voice

* Department of Otolaryngology -Head and Neck Surgery
School of Medicine, Chonbuk National University.
Republic of Korea

onset after both glottalized and aspirated consonantd was higher than that for the lenis consonants in both dialects. However, there has been no report on the fundamental frequency and other spectrographic characteristics of the Cholla dialect.

Han and Weitzman[2] reported in their speech synthesis and perception studies that lenis and glottalized stops differed primarily in terms of a gradual versus a relatively rapid intensity build-up of the following vowel after the stop release.

Lee and Smith[3] measured both the intraoral and subglottal air pressure simultaneously during the production of the three kinds of Korean stops. They found that the subglottal pressure was higher for the aspirated stop than for the other two stops.

Lee and Smith also compared the dynamic pattern of the subglottal pressure slope for the three categories and found that the aspirated stop showed the most rapid increase in subglottal pressure in the time period immediately before the stop release. They concluded that the highly aspirated stop was the most dynamic in this respect.

Kagaya[4] reported fiberscopic and acoustic studies of the Korean stops, affricates and fricatives. He mentioned that the glottalized type may be characterized by a completely adducted state of the vocal folds, stiffened vocal folds and the abrupt decreasing of the stiffness near the voice onset, increasing subglottal pressure and/or a lowering of the glottis before plosion, while the aspirated type may be characterized by an extensively abducted state of the vocal folds and a heightened subglottal pressure. On the other hand, none of these positive gestures are observed for the lenis type.

Hirose, Lee and Ushijima[5] reported on the laryngeal control in Korean stop production with electromyographic studies, and their results indicated that the aspirated stop appeared to be characterized by a marked suppression of all the adductor muscles immediately before the articulatory release, the forced type by a sharp increase in VOC activity before the stop release, (which presumably resulted in an increase in the inner tension of the vocal folds as well as in a constriction of the glottis during or immediately after the articulatory closure), and the lenis stop by a less predominant suppression of the adductors and no transient increase in VOC activity before release.

Hirose, Park and Yoshioka[6] reported an electromyographic study of the laryngeal adjustment for the Korean stops, and they found the following. 1) The pattern of VOC activity appeared to characterize the three different types of Korean stops. 2) For the production of the forced stops, the VOC muscle showed a marked increase in activity with a relatively earlier timing before the onset of the following vowel. (3) When a final stop was followed by a syllable-initial lenis or glottalized stop, the electromyographic pattern for the cluster resembled that for an initial glottalized stop.

The purpose of the present study was to investigate electromyographically the

action of the intrinsic laryngeal muscle for the production of Korean stops, affricates and fricatives in syllable-initial position, and especially the
PCA and the VOC muscle activity.

Method

1. Subject and Speech materials

One native Korean speaker of the Chonbuk dialect was the subject in this experiment.

Test words were prepared so as to place the consonants in different phonological environments, and were all meaningful words with one exception. The following are test utterences.

1) dental stops

aspirated: /t^hepeksan/ (name of a mountain)

lenis: /tetehan/ (large scaled)

glottalized: /t'et'elo/ (occasionally)

2) palato-velar stops

aspirated: /k^hul/ (nonsense word)

lenis: /kul/ (oyster)

glottalized: /k'ul/ (honey)

These words were uttered in the frame sentence /ikæsi --- ita/ (This is ---)

3) affricates

aspirated: /c^het^{h}ek/ (choice)

lenis: /cec^{h}eki/ (sneezing)

glottalized: /c'ec'ehan/ (small scaled)

4) fricatives

lenis: /silwm/ (anxiety)

glottalized: /s'ilwm/ (wresling)

These words were uttered in the frame sentence /ikəsi --- ita/ (This is ---)

2. EMG Experiment

The EMG recordings were made using hooked-wire electrodes. The electrodes were inserted into the VOC muscle percutaneously and inserted into the PCA muscle perorally. With the electrodes in position, the subject read the utterance samples twelve to fifteen times each, with the speaking rate and intensity being kept as constant as possible within the natural ranges of the subject.

The EMG signals were recorded on a multichannel data recorder simultaneously with the acoustic signals and the automatic timing marker. The signals were then reproduced and fed into a computer after appropriate rectification and integration. The EMG signal from each electrode pair was averaged over more than 6 selected utterance of each test sentence with reference to a line up point on the time axis representing a predetermined speech event. In the present experiment, the vowel onset after the consonant release in each test word was used for the line-up.

Results

Figs. 1-A,B,C show samples of the averaged EMG curves of the activity of the PCA and VOC muscles for three different dental stops in syllable-initial position followed by the vowel /e/ with its acoustic waveforms. Fig. 1-D is a schematic drawing of the averaged EMG curves. The zero on the abscissa marks the line-up point for the voice onset of the following vowel. Fig. 1-A shows the averaged EMG signals for the aspirated /t^h/ stop followed by vowel /e/, Fig. 1-B for the lenis /t/ stop and Fig. 1-C for the glottalized /t'/ stop.

We can note in Figs. 1-A,B,C,D for the stops that the activation of the PCA before the voice onset of the follwoing vowel is most marked for the aspirated followed by the lenis consonant, but little or none for the glottalized consonant , and that all activities of the PCA muscle for the three type dental stops are suppressed for the production of the vowel. The timing of the activation of the PCA muscle is earliest for the aspirated consonant, followed by the lenis and the glottalized consonants. The suppression of the

activity of the VOC muscle immediately preceding the articulatory release is marked for the aspirated consonant, followed by the lenis, but does not appear for the gottalized consonant, and then the reactivation of the VOC muscle before the vowel onset after each voiceless consonant is maked for the aspirated and the glottalized consonants, but least for the lenis consonant. The timing of the reactivation of the VOC muscle is earliest for the glottalized consonant, but the VOC muscle seems to be most steeply reactivated for the aspirated followed by the glottalized and the lenis consonants.

Figs. 2-A,B,C and D compare the activity of the PCA and VOC muscle for the test utterances containing the three types of palato-velar stops in syllable-initial position followed by vowel /u/. The test utterance type is /ikəsi "C"ulita/, where "C" stands for the aspirated /k^h / in Fig. 2-A, for the lenis /k/ in Fig. 2-B and for the glottalized /k`/ in Fig.2-C. The patterns of the activity of the PCA and VOC muscles are very similar for the dental stops with one exception, that is, the slight activation of the PCA muscle before the voice onset followed by a vowel for the glottalized palato-velar stop.

Figs. 3-A,B,C and D show the patterns of the activity of the PCA and VOC muscles for the affricates followed by the vowel /e/. Fig. 3-A shows the aspirated /c^h / affricate, Fig. 3-B the lenis /c/ and Fig. 3-C the glottalized /c`/. The activation of the PCA muscle before the voice onset followed by a vowel is marked for the aspirated and the lenis consonants, but slight for the glottalized one. The timing of the activation of the PCA muscle is earliest for the aspirated consonant followed by the lenis and the glottalized. The suppression and the reactivation of the VOC muscle before the voice onset are very similar to the pattern of this activity for the dental stops.

Figs. 4-A,B and C show the averaged EMG activities of the PCA and VOC muscles for the fricatives followed by the vowel /i/. Fig. 4-A shows for the lenis /s/ fricative, and Fig. 4-B the glottalized /s'/. The activation of the PCA muscle for the production of the fricatives is marked for the lenis consonant followed by the glottalized one. The timing of the activation is earlier for the glottalized than for the lenis consonant. The degree and timing of the reactivation of the VOC muscle is higher and earlier for the glottalized than for the lenis consonant.

Discussion

Although there are many physiological studies on the laryngeal articulatory adjustment in Korean consonant production, there has been no report on PCA muscle activity in the production of Korean consonants in the literature.

The present study revealed that EMG patterns for Korean stops, affricates and fricatives in syllable-initial position were characterized by the different activity patterns of the PCA muscle, the abductor and the VOC muscle, one of the adductors, for the test

Fig. 1-A

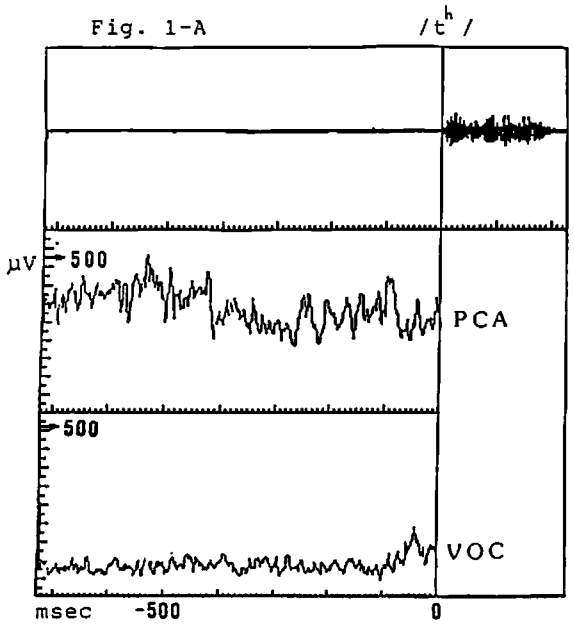
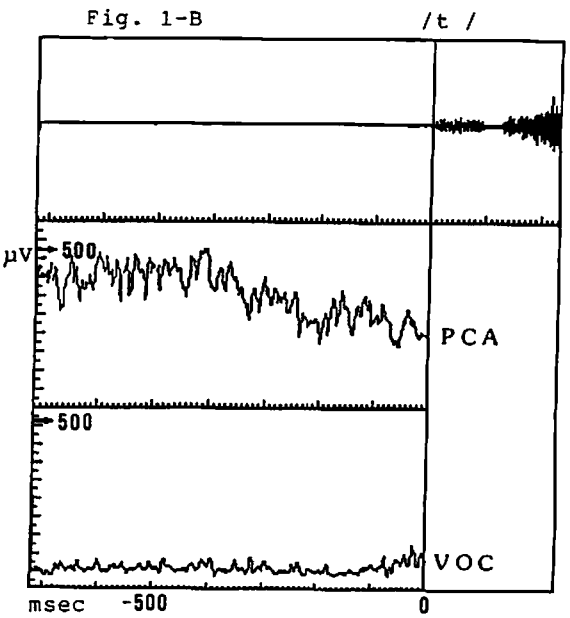
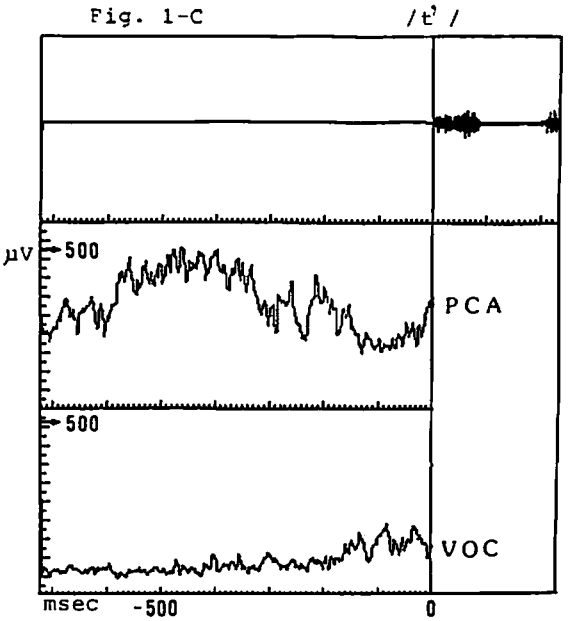
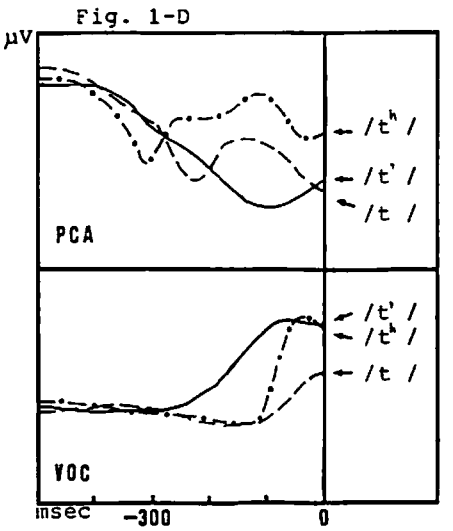


Fig. 1-B







Figs. 1-A,B,C and D

Averaged EMG signals(A,B,C) and schematic presentation(D) of the PCA and VOC for the three dental stops in syllable-initial position. The line-up point for the averaging was the onset of the vowel after the consonant. The postconsonantal vowel was /e/ for all cases. Fig. 1-A shows the aspirated /t^h/ stop, Fig. 1-B the lenis /t/ stop and Fig. 1-C the glottalized /t'/.

Fig. 2-A

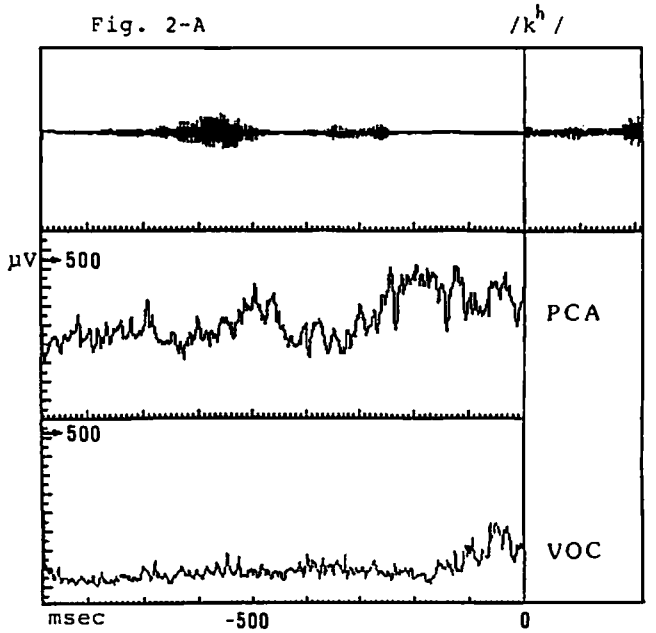
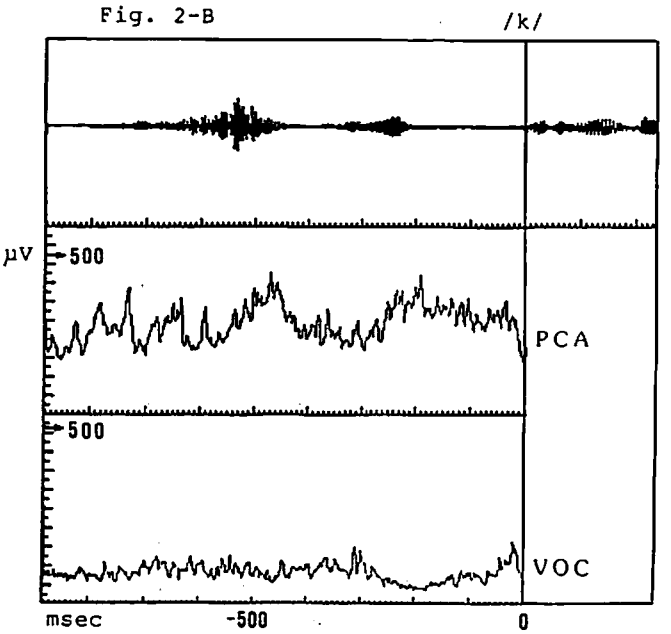
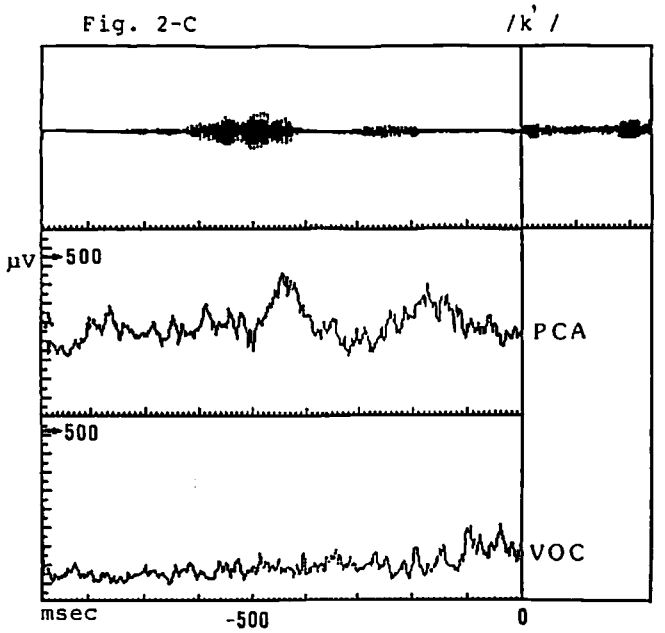


Fig. 2-B





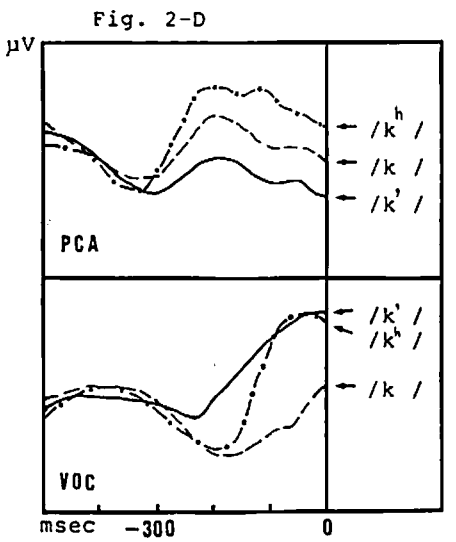


Fig. 2-A,B,C and D

Averaged EMG signals(A,B,C) and schematic presentation(D) of the PCA and VOC for the three palato-velar stops in syllable-initial position. The postconsonantal vowel was /u/ for all cases. These words were uttered in the frame sentence /ikəsi --- "C"ul ita/ (This is ---), where "C" stands for the three different palato-velar stops. Fig. 2-A shows the aspirated /k^h/ stop. Fig. 2-B the lenis /k/ and Fig. 2-C the glottalized /k'/.

Fig. 3-A

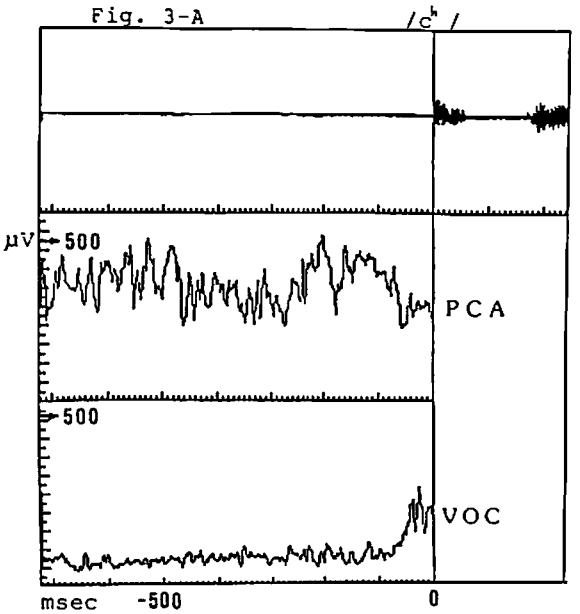
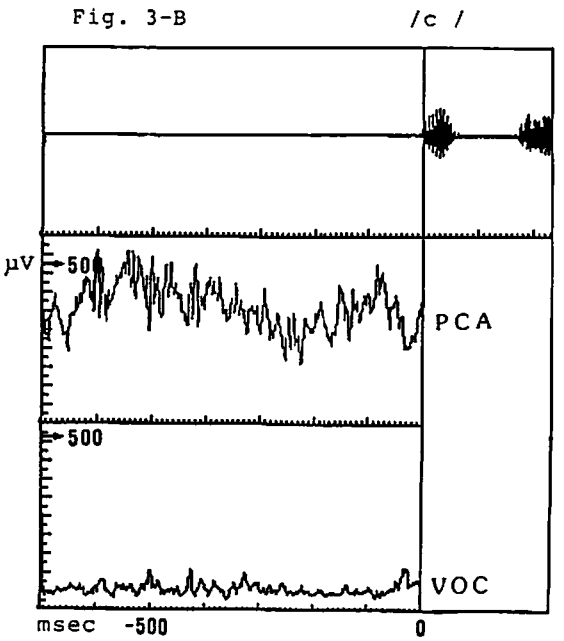
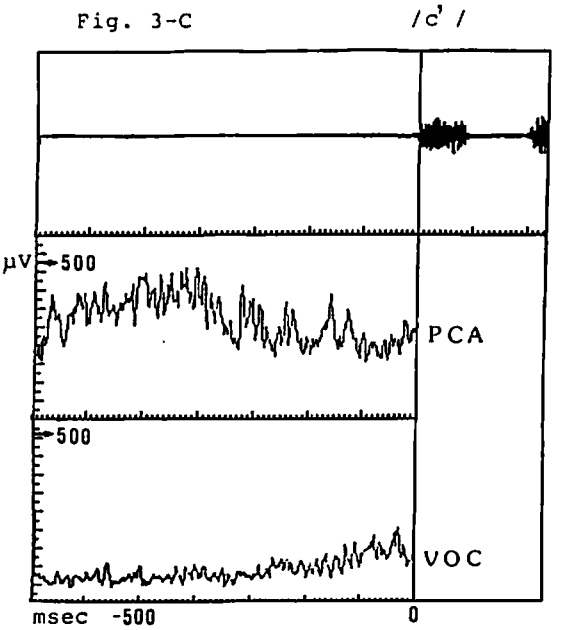
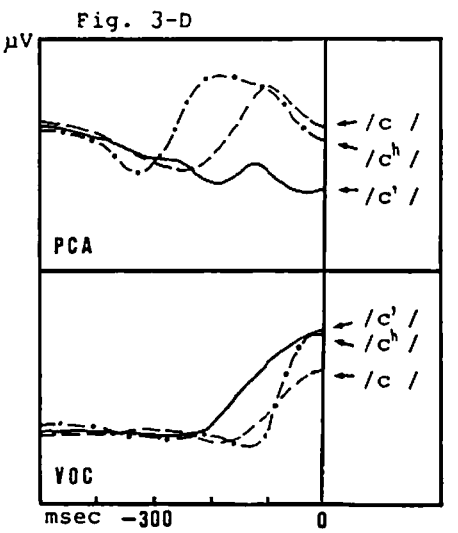


Fig. 3-B







Figs. 3-A,B,C and D

Averaged EMG signals(A,B,C) and schematic presentation(D) of the PCA and VOC for the three affricates in syllable-initial position. The line-up point for averaging was the onset of the vowel after the consonant. The postconsonantal vowel was /e/ for all cases. Fig. 3-A shows the aspirated /c^h/ affricate, Fig. 3-B the lenis /c/ and Fig. 3-C the glottalized /c'/ affricate.

Fig. 4-A

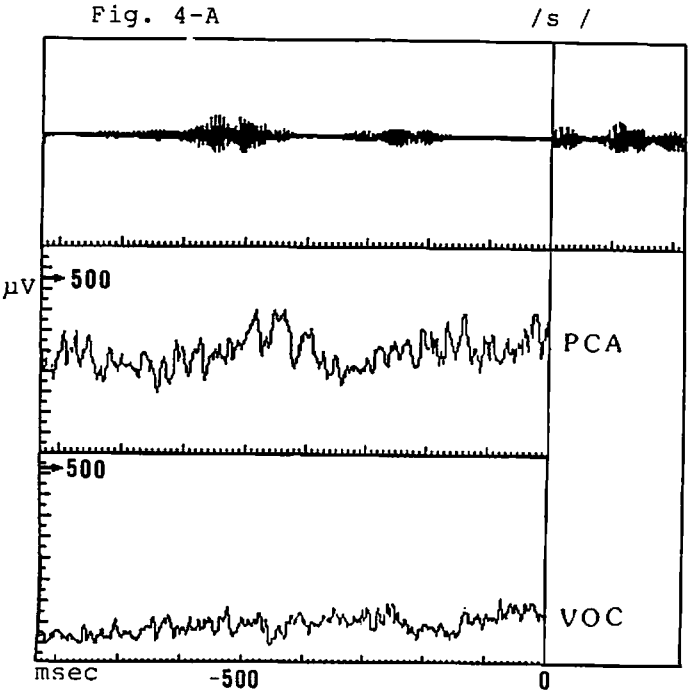


Fig. 4-B

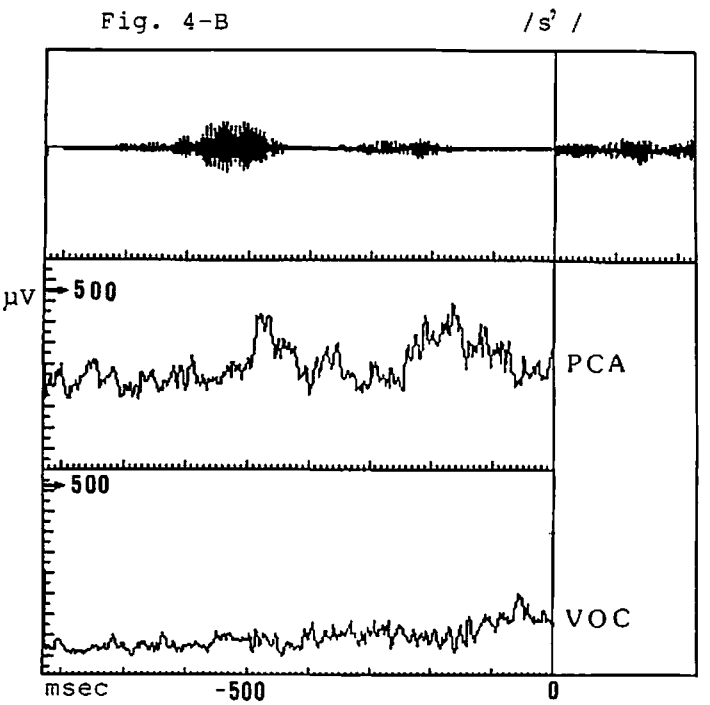
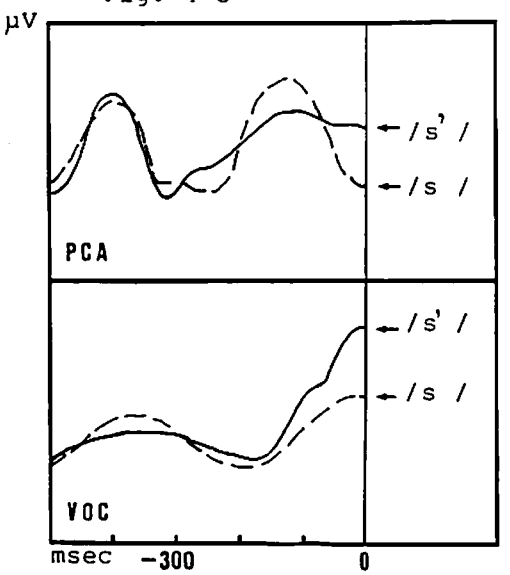


Fig. 4-C



Figs. 4-A,B and C

Averaged EMG signals(A,B) and schematic presentation(C) of the PCA and VOC for the two types of fricatives in syllable-initial position. The postconsonantal vowel was /i/ for all cases. These words were uttered in a frame sentence /ikasi --- "C"ul ita/ (This is ---), where "C" stands for the two types of fricatives.

words produced by a native speaker of the Chonbuk dialect. The earliest and largest activation of the PCA was found for the aspirated stops and the affricate, and the latest and least activation of the PCA was found for the glottalized stops and the affricate (Figs. 1, 2. 3).

On the other hand, there was an early and marked reactivation of the VOC immediately following the initial consonant for the glottalized stops and the affricate, and a late and steep reactivation for the aspirated stops and the affricate before the voice onset, while a middle-range degree and timing for PCA activation and a mild reactivation of the VOC before the voice onset were found for the lenis consonants.

A similar reciprocal pattern between the PCA and the adductor muscle is often obfor utterances in American English as well as Japanese and Danish. In Korean stops, however, laryngeal control does not appear to operate in a simple binary fashion. As already noted, Hirose, Lee and Ushijima[5] claimed that the relatively steep increase in VOC activity for the glottalized consonants must be taken as a characteristic feature of this type of korean stop, and that this activity pattern may correspond to the acoustic feature of "laryngealization" or "glottalization" described by Abramson and Lisker[7] and Ladefoged[8]. In the present study, the steepest increase in VOC activity was revealed for the aspirated consonant. On the basis of the activity patterns observed in the present study, we suggest that the laryngealization for the glottalized consonant in Korean is mainly due to the none-activation of the PCA and the early reactivation of the VOC before the voice onset, and that the characteristics of the aspirated consonant are a marked activition of the PCA and a steep reactivation of the VOC.

Hirose et al.[6] observed an apparent difference in the degree and timing of the increase in VOC activity for forced (glottalized) stops between the two Korean subjects who served in their two sessions, and they suggested that the apparent difference in the EMG pattern was due to dialectal differences between Seoul and Taegu. In the present study, it was observed that the VOC reactivation for the glottalized consonant in the Chonbuk dialect was earlier but less steep than in the Seoul and Taegu dialects.

The present study suggests that there is a very important physiological correlate between the PCA and the VOC for the production of the three types of Korean consonants. In particular, VOC activity probably results in a constriction of the glottis and an increase in the inner tension of the vocal folds and can be taken as a physiological correction". As for the main mechanism of the production of aspirated consonants, the marked increase in PCA activity must be associated with the steep reactivation of the VOC before voice onset.

Summary

1. For the production of the Korean aspirated consonants in syllable-initial position, the

most marked and earliest activation of the PCA muscle associated with a steep reactivation of the VOC before the voice onset were most characteristic.

2. For the production of the Korean glottalized consonants, little or no activation of the PCA muscle associated with the earliest and most marked reactivation of the VOC muscle was characteristic.

3. For the Korean lenis consonants, there was a more moderate activation of the PCA muscle than for the glottalized consonant, and the least and the latest reactivation of the VOC among the three types of Korean consonants.

References

1. Umeda, H. and N. Umeda (1985) : Acoustical features of Korean "forced" consonants. Gengo Kenkyu (Journal of the Linguistics Society of Japan) 48, 23-33.

2. Han, M.S. and R.S. Weitzman (1970) : Acoustic features of Korean /P,T,K/, /p,t,k/ and /ph,th,kh/. Phonetica 22, 112-128.

3. Lee, C.Y. and T.S. Smith, (1971): A study of subglottal air pressure in Korean stop consonants. Paper presented at the 82nd meeting of Acoustical Society of America.

4. Kagaya, R. (1974) : A Fiberscopic and Acoustic Study of the Korean Stops, Affricates and Fricates, J. Phonetics 2, 161-180.

5. Hirose, H., C.Y. Lee and T. Ushijima (1974) ; Laryngeal control in Korean Stop Production. J. Phonetics 2, 145-152.

6. Hirose, H., H.S. Park, H. Yoshioka, M. Sawashima and H. Umeda (1981) ; An Electromyographic Study of Laryngeal Adjustment for the Korean Stops, Ann. Bull. RILP, No. 15, 31-43

7. Abramson, A.S. and L. Lisker (1972) ; Voice timing in Korean Stops. Proceedings of the Seventh International Congress of Phonetic Science, Montreal, 1971. The Hague: Mouton. 439-446.

8. Ladefoged, P. (1973) : The features of the larynx. J. Phonetics 1, 73-83.