LARYNGEAL GESTURES IN KOREAN STOP CONSONANTS

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There are nine phonemes of stop consonants in Korean. They are classified in three places of articulation (labial, dental and velar), and also in three manners of articulation. In the manner-classification, the three types are often referred to as the "forced" or "tense-unaspirated", the "unaspirated" or "lax-slightly aspirated", and the "aspirated" or "tense-heavily aspirated", respectively.[1)2)] The "forced" and the "aspirated" stops are voiceless inspite of their environments and the "unaspirated" stop is voiceless in word initial position but voiced in word medial position when both the preceding and succeeding sounds are voiced.[1)]

In this study, we examined utterances by one male native speaker of Korean who speaks a dialect heard near Seoul. The subject uttered three types of stops in the three places of articulation in isolated nonsense syllables of the forms /Ce/ and /eCe/, where C stands for the pertinent stop consonant. The glottal images obtained through a fiberscope were recorded in the form of a 16-mm black and white movie, and the speech signal was simultaneously recorded on magnetic tape.* Each phonetic form as the utterance item was uttered four times in these recordings.

1. /Ce/ syllables

For representing the glottal width, the distance between the vocal processes (see Figure 1) was measured, frame by frame, from the glottal images of each representative utterance of each /Ce/ syllable. In Figure 2, the measured distance thus obtained is plotted against the frame number. The frame rate was 24 frames/sec. The following results have been obtained. In the "forced" type /P, T, K/, the glottis begins to close rapidly starting from the rest position (the state for expiration), and a complete

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* These data were obtained at the Research Institute of Logopedics and Phoniatrics, University of Tokyo in 1969 by O. Fujimura and H. Hirose, with Prof. S-J. Kim of Yonsei University, who served as the subject when he visited the laboratory.

contact of the vocal prosesses is found in the third frame before voice onset. In this state of adduction of the glottis, it is noteworthy that the membranous portion of the glottis still remains slightly open.

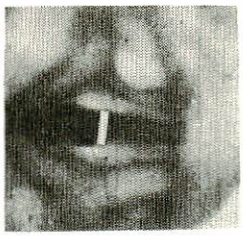

Figure 1. An example of the open glottis in the image recorded on the film. The short white line drawn in the picture indicates the vocal processes where the glottal width was measured.

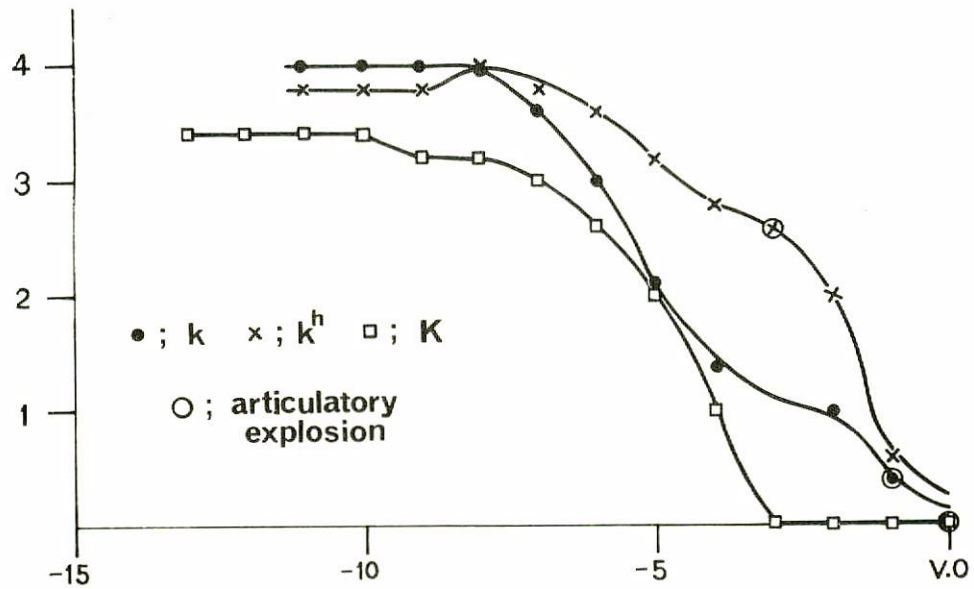

Figure 2. Time courses of the glottal width for representative utterance samples of the three types of velar stops. The open rectangles represent the "forced" type, the crosses the "aspirated", the filled circles the "unaspirated". The abscissa represents the frame number counted back from the time of voice onset (V. O), one frame corresponding to 1/24 sec. The ordinate gives an arbitrary scale for the glottal width.

Figure 3 illustrates an image of the glottis in this state, in comparison with other types. In the "unaspirated" type /p, t, k/, the glottis begins to close gradually and the vibration of the membranous portion starts while the glottis at the vocal process is still slightly open (see Figure 3). In the "aspirated" type /p^h, t^h, k^h/, the glottis closes rapidly, especially after the articulatory explosion, much in the same manner as in the case of the "forced" type, but when the vibration of the membranous portion starts, the vocal processes are still slightly separate, similarly to the cases of the "unaspirated" type (see Figure 3).

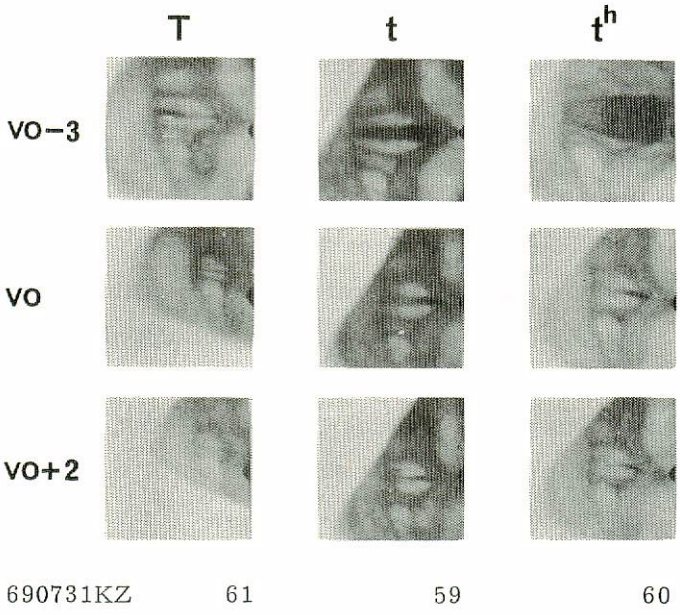

Figure 3. The glottal views of each type immediatly preceding and succeeding the voice onset after the pertinent stop. Note that, in the "forced" type T, the vocal processes are completely in contact in all the three instances, whereas, in the other type, they are slightly separate, except the frame before voice onset of the aspirated type, in which the glottis is wide open. (particularly for the aspirated)

The articulatory explosion occurred in the same frame as voice onset in both the "forced" and the "unaspirated" types, except for the "unaspirated" velar stops.* In the "aspirated" type, in contrast, it occurred in the second or third frame (about 80-120 msec) before voice onset, and at the instant of the articulatory explosion, the vocal processes were wide open.

By visually examining the gross change of the overall appearances of the vocal cords and parts of the arytenoids, particularly in terms of the apparent width of the vocal cords, the elevation and lowering of the glottal level can be detected (see Figure 4). In the "forced" type, a marked lowering of the glottis is seen near the voice onset frame. This effect was always observed for the twelve utterances of this type, but was never observed for the other two types. It must be mentioned that this lowering of the larynx for the "forced" stops is associated with a special kind of high-pitched voice in the immediately succeeding vocalic segment (see Section 3) in contrast to the usual correlation between a higher voice pitch and a higher laryngeal level.**

2. /eCe/ syllables

In /eCe/ syllables, the width of the glottis at the vocal processes was measured frame by frame for several frames preceding and following the voice onset. First, by the comparison of the glottal widths for the three types at the moment of articulatory explosion, it was found that the distance in the "aspirated" type was distinctly wider than the others, among which the glottis for the "unaspirated" tended to be somewhat open, even though the vocal cords were in vibration.

Furthermore, in the case of the "forced" type, the contact between the vocal processes was observed starting from about the third frame before voice onset, just as in the case of the /Ce/ syllables. In the case of the other two types, no complete contact was observed in the frames, neither in

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* The frame corresponding to the release was determined by a visual inspection of sound spectrograms.

** This common effect is demonstrated by Japanese and English utterances in the 16-mm films entitled "The Larynx in Speech Utterance," prepared by the Research Institute of Logopedics and Phoniatrics (1968 and 1970). Also see Y. Kakita and S. Hiki, "A Method for the Observation of Laryngeal Control in Speech," Reports of the 1971 Spring Meeting, Acoust. Soc. Japan.

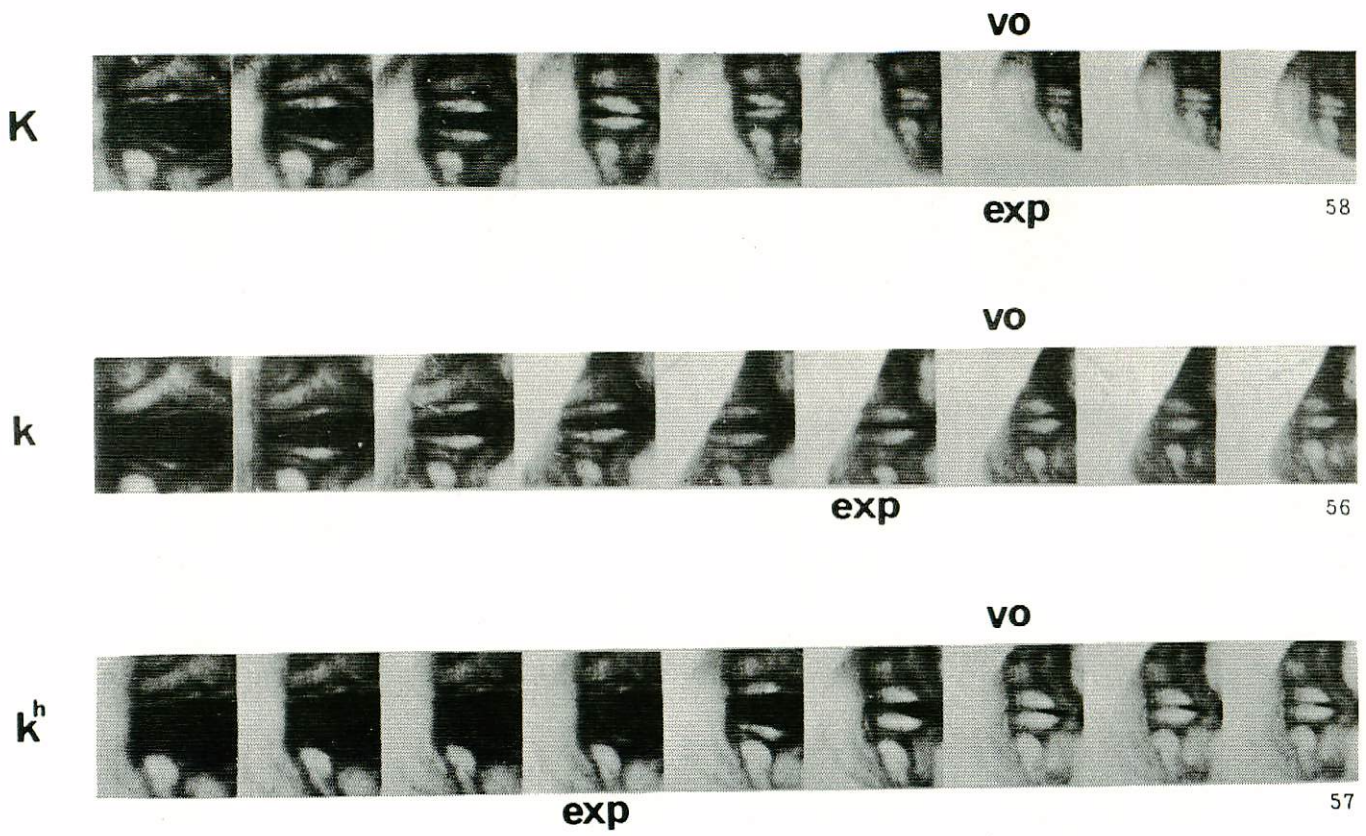

Figure 4. Successive frames for each type of the velar stops. Note the gross change of the overall appearance of the vocal cords.

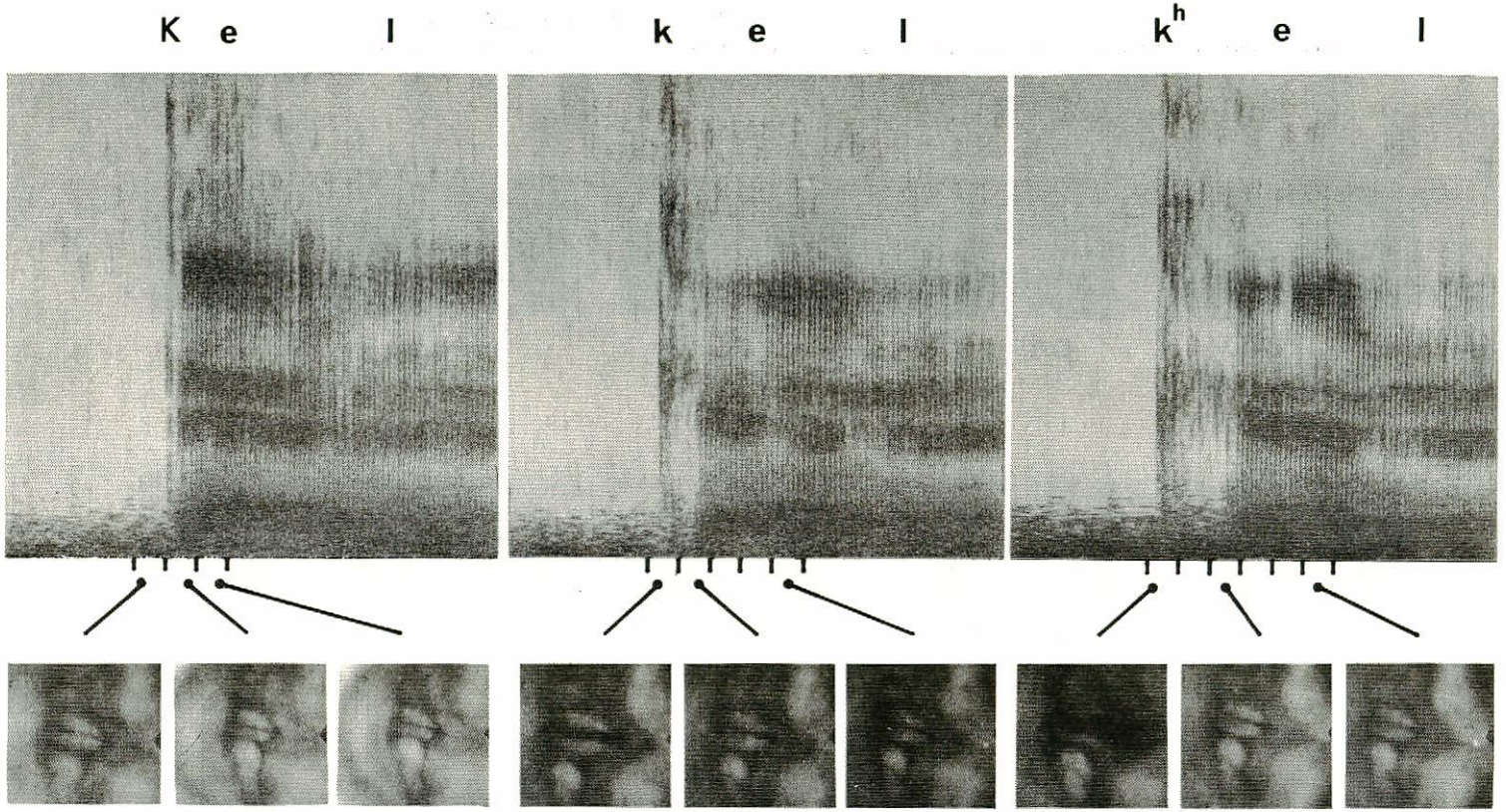

Figure 5. Sound spectrograms and sample frames from the fiberscopic movie: from left to right, "forced", "unaspirated", and "aspirated".

the closure period nor in about the three frames after voice onset, and the vocal cords vibration began while the vocal processes were still slightly separate.

3. The Sound Wave

Acoustic characteristics of the simultaneously recorded speech signal have been studied by sound spectrography, and the following results have been obtained.

In /Ce/ syllables, the F_3 and F_4 of the vowel segment following the "forced" type were constantly prominent (see for example Figure 5). In contrast, the same vowel following the "unaspirated" stops manifested weak higher resonances in the same frequency ranges, especially during the initial 50 msec. These were true also in /eCe/ syllables. Mrs. Mieko Han has also noted on occasional occurrences of this characteristic of "forced" type.[3)]

In addition to the acoustic characteristics of the "forced" type as stated above, there was another acoustic peculiarity of this type in terms of pitch contours. The speech waveforms were examined by an oscillograph, to measure the fundamental periods in the initial portion of the vowel segment immediately following the postconsonantal voice onset. The average value of the fundamental periods from the initial to the fifth pitch cycle showed a clear difference between the "forced" and the "unaspirated". Namely, in the case of /Ce/, the "forced" type showed the averaged pitch values in a range of 4.8 msec to 5.9 msec, the "unaspirated" from 5.9 msec to 6.6 msec. In the case of /eCe/, the values for the "forced" stops were from 5.1 msec to 5.9 msec, for the "unaspirated" from 5.9 msec to 6.7 msec.

4. Concluding Remarks

By the fiberscopic observation, it has been found that there are differences between types in both the time courses of the glottal width and the apparent glottal conditions in the succeeding vowel segment. Some causal relations may be assumed between these physiological features and the acoustic characteristics as described in this section.

The glottal conditions must have some influences on the glottal waveforms in the vocalic segments after a stop consonant. As one of them, hiss components caused by the air stream through the slightly open vocal

processes may be predicted for the "unaspirated" and the "aspirated" type. In the case of the presently discussed subject, this effect has not been observed clearly in the form of the narrow-band section patterns obtained by the sound spectrograph. In another Korean subject whose utterances were spectrographically studied, apparent hiss components were observed during the initial phase of the vocalic segment after explosion of the "aspirated" or "unaspirated" types. It may be said, therefore, that there is a tendency for the glottis to close imperfectly in these cases, and this effect from time to time is revealed in the form of aperiodicity or "breathiness" of the voice, whereas there are no such tendencies and the voice is rich in higher formant frequency regions in the vowel segments immediately following the "forced" type stops. The waveform of the volume velocity at the glottis in these cases where "tenseness" of the laryngeal gesture persists is probably characterized by a rapidly closing phase and a relatively long closed phase, which give rise to both less damped and also high level higher formant components.

This effect should be partly observed by the waveforms indicating the glottal area, which can be obtained by means of photo-electric glottography. Though, unfortunately, we have not taken the glottograms in the subject discussed in the main body of this paper, we have taken some glottographic data with the other subject, who was referred to above. In fact, in glottograms of this subject, whose acoustic characteristics were quite similar to those described in section 3 except in respect to the hissiness, we found clear differences between the "forced" type and the others, when the vocalic segments immediately following the postconsonantal voice onset were examined. Namely, for the "forced" type, the slope in the glottal waveform was quite steep, and the closed phase was apparently longer than for the other two types near the voice onset. Quantitative analysis in this respect are still to be performed with some more glottographic data.

These facts suggest, at any rate, that the adjustments of the vocal cords are substantially different for the "forced" type articulation when compared with the other two types, and this gross difference in the laryngeal gesture may persist for some period even well after the succeeding voice onset.

This conclusion about peculiarity of the "forced" types seems to compare qualitatively with the conclusion by Lisker and Abramson in their cross language studies of stop consonants in respect to the timing relation between the explosion and the voice onset time.[4)]

References

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2) C. W. Kim, "Cineradiographic Study of Korean Stops and a Note on Aspiration," Quarterly Progress Report (Research Lab. Electronics, M. I. T.), No. 86, 259-271 (1967).

3) M. S. Han and R. S. Weitzman, "Acoustic Features in the Manner-Differentiation of Korean Stop Consonants," Studies in the Phonology of Asian Languages V (Acoustic Phonetics Research Laboratory, Univ. of Southern California) (1967).

4) L. Lisker and S. Abramson, "A Cross-Language Study of Voicing in Initial Stops: Acoustical Measurements," Word, Vol. 20, No. 3 (1964).