GLOTTAL OPENING FOR JAPANESE VOICELESS CONSONANTS

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Use of a fiberscopic technique [1, 2] has provided a new scope in studying laryngeal adjustments in speech. [3 - 8] The results so far obtained in our observations on Japanese voiceless consonants, with a limited number of samples, can be summarized as follows:

1) There is an opening gesture of the glottis for voiceless consonants. The maximum width of the glottis varies with different phonemes and phonological environments.
2) In stops, there is a greater opening of the glottis for word initial position than for medial position. The glottal width for geminate stops is comparable to word medial non-geminates.
3) In fricatives, the glottal width for geminates is larger than for non-geminates.
4) There is a large opening of the glottis for a devoiced vowel.

This paper is a report of further studies on the variability of the glottal width for Japanese voiceless consonants with special reference to the time period during which the glottis is open.

Experimental Procedure

The fiberscopic laryngeal films analyzed in the present study are those prepared in our previous experiment of devoicing of vowels in 1971 which used an adult male speaker of Tokyo dialect as the subject. A detailed description of the speech materials and of the procedures of the filming was reported in the previous article. [7] On those films, the samples for

/seHseH/, /keHkeH/, /teHteH/, /seQseH/, /seQkeH/, /sekieH/, /sekikeH/, /sekiteH/, and /kieH/, each of which was repeated six times, were re-examined in the present study.

As a measure of glottal width, the distance between the tips of the vocal processes of the arytenoid cartilages on both sides was estimated, frame by frame, by a newly developed technique with use of a computer.[9)]

In the present technique of fiberscopic observation, there is no reference available for estimating absolute dimensions of the laryngeal structures. A major source of error involved in the measurement of glottal width on the film frame involves changes in the laryngeal image size caused by variations in the distance between the tip of the fiberscope and the larynx during the experimental run. Possible error rate in the present measurement was estimated as roughly in the range of 10%. This estimation was based on the measurement of the distance from the vocal process to the anterior commissure, i. e., the vocal fold length, at the onset of [s] in the frame sentence "sore o-------" for all utterances, and on visual examination of the laryngeal images.

Results and Remarks

Figure 1 shows graphic presentations of the glottal width measured on successive film frames for typical utterances of /seHseH/, /keHkeH/, and /teHteH/. Each word was embedded in a frame sentence "sore o-----to yuu" ("We call that----"). The interval of successive frames is 20 msec (50 frames/sec). The arrows under each graph indicate the timings of oral closure and release for the consonant, and the v's indicate the timings of voice onset of the following vowel.

In the sample of /seHseH/, the time span where the glottis is open for the initial [s] is 160 msec and that for the medial [s] is 180 msec, the glottal width being slightly larger for the initial position than for the medial. The maximum glottal width for the initial [k] in the figure is much greater than for the medial [k], while the duration of the glottal opening is 160 msec for the initial [k] and 140 msec for the medial. In the example of /teHteH/ the glottis abducts to a small extent with a duration of 140 msec for the initial [t] and no separation of the arytenoids is observable for the medial position.

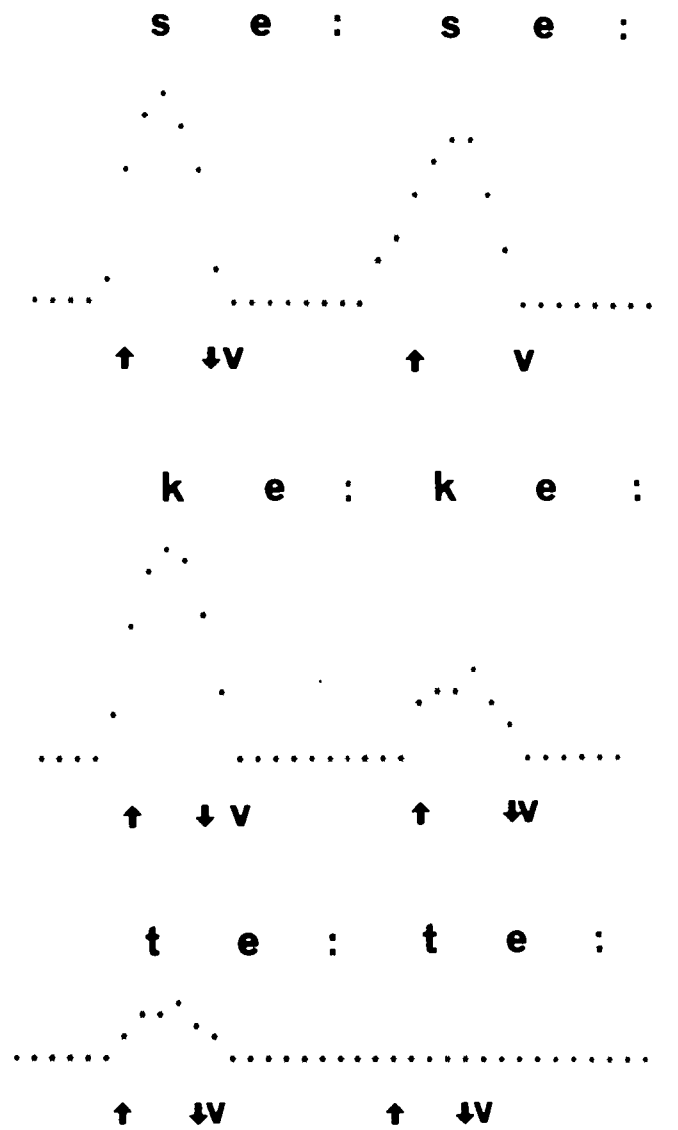

Fig. 1. Graphs of the glottal opening-closing processes in the utterances of /seHseH/, /keHkeH/, and /teHteH/ in a frame sentence "sore o--- to yuu." Upward arrows and downward arrows indicate oral closure and release respectively, and v's indicate voice onset of the following vowel.

We then examined the relationship between the peak value of the glottal width and the duration of the glottal opening for each of the voiceless segments. In Figure 2, the relationship between the maximum glottal width and the duration of the glottal opening for initial [s]'s is displayed. The ordinate indicates the peak value in an arbitrary scale, and the abscissa the duration in number of film frames (every 20 msec). The graph shows a considerable variability in the maximum glottal width, and also in the duration of the glottal opening, within the word initial [s]'s. The extent of the variation in the glottal width is far beyond the range of error. There seems to be no correlation between the peak value and the duration.

Figure 3 is the graph for the word initial [s], the medial [s] and the geminate one in repeated utterances of /seHseH/ and /seQseH/ where /Qs/, the geminate, is phonetically represented as [ss]. The glottal opening for the medial [s] also varies both in the peak value and the duration, and the range of the two dimensions almost coincides with the word initial position. Here also the peak value has little correlation with the duration. The glottal condition for the [ss] group, as plotted in the graph, is clearly distinguished from that for non-geminate [s]'s, showing greater peak value and duration.

Figure 4 is for the word initial and medial [k]'s and for geminate [kk]'s. Samples are repeated utterances of /kieH/, /keHkeH/, /sekieH/, and /seQkeH/. Within each of the three groups, there is little correlation between the peak value and the duration. The group of initial [k]'s shows greater glottal width, and longer duration as well, than that of medial [k]'s. On the other hand, the geminates having the longest duration among the three groups show the glottal width in the same range as the medial [k]'s.

Figure 5 compares geminate [kk]'s to [k̥ik]'s where the vowel [i] between the [k]'s is devoiced. Samples are repeated utterances of /seQkeH/ and /sekikeH/. Word initial [s]'s are also displayed in the graph. The duration for the group of [k̥ik]'s is comparable to that for the [kk] group, while the glottal width is much larger in the former.

Figure 6 shows glottal conditions for [s]'s, [k]'s and [t]'s in word initial position. The glottal width, as well as the duration, for [k]'s is in the same range as for [s]'s. The range of the glottal width for [t]'s, showing smaller values, is clearly separated from that for the [s], [k] group, while a

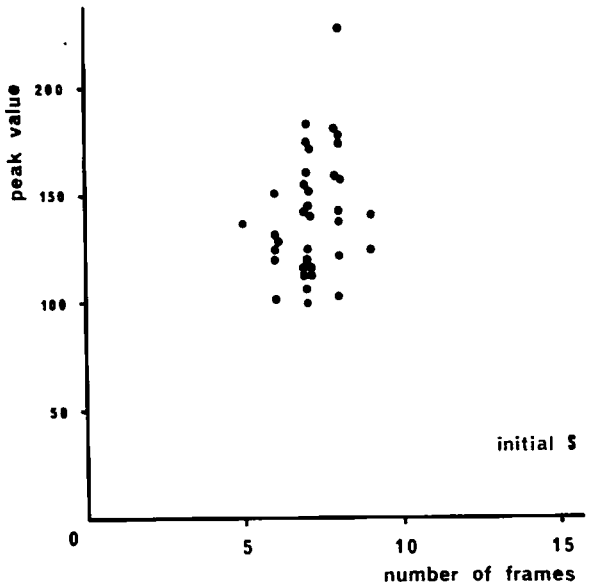

Fig. 2. Relationship between the glottal width and the duration of the glottal opening for the word initial [s].

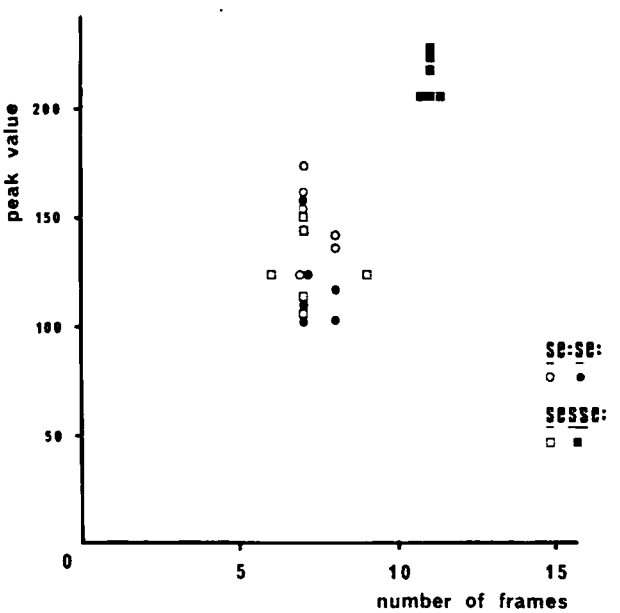

Fig. 3. Same as Fig. 2. for initial and medial [s], and the geminate [ss]. Samples are repeated utterances of /seHseH/ and /seQseH/. Open circles and squares indicate the word initial [s], filled circles the medial [s], and filled squares the geminate.

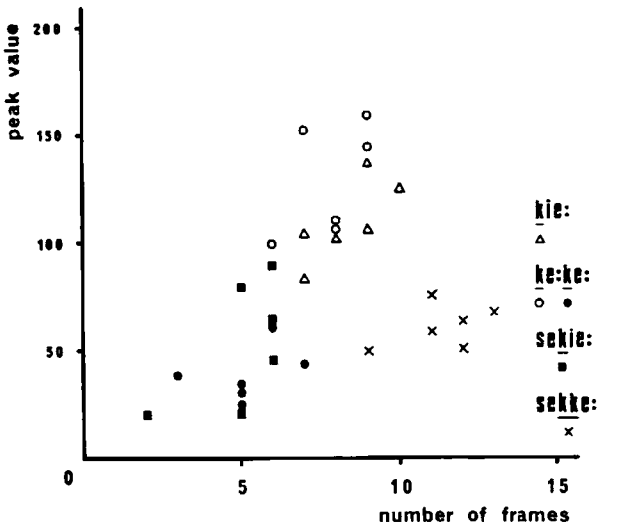

Fig. 4. Same display as Fig. 2. for the initial and medial [k], and the geminate [kk]. Samples are repeated utterances of /kieH/, /keHkeH/, /sekieH/, and /seQkeH/. Open triangles and circles indicate the initial [k], filled circles and squares the medial [k], and crosses the geminate.

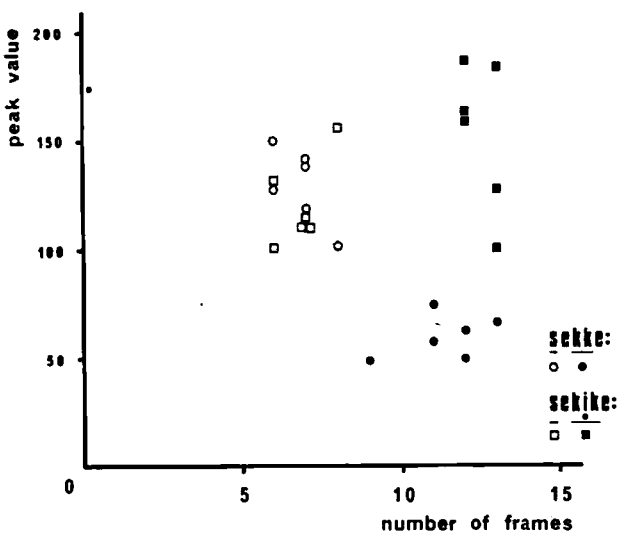

Fig. 5. Same as Fig. 2. for the initial [s], the geminate [kk], and the voiceless segment [k̥ik]. Samples are repeated utterances of /seQkeH/ and /sekikeH/. Open circles and squares indicate [s], filled circles the geminate, and filled squares [k̥ik].

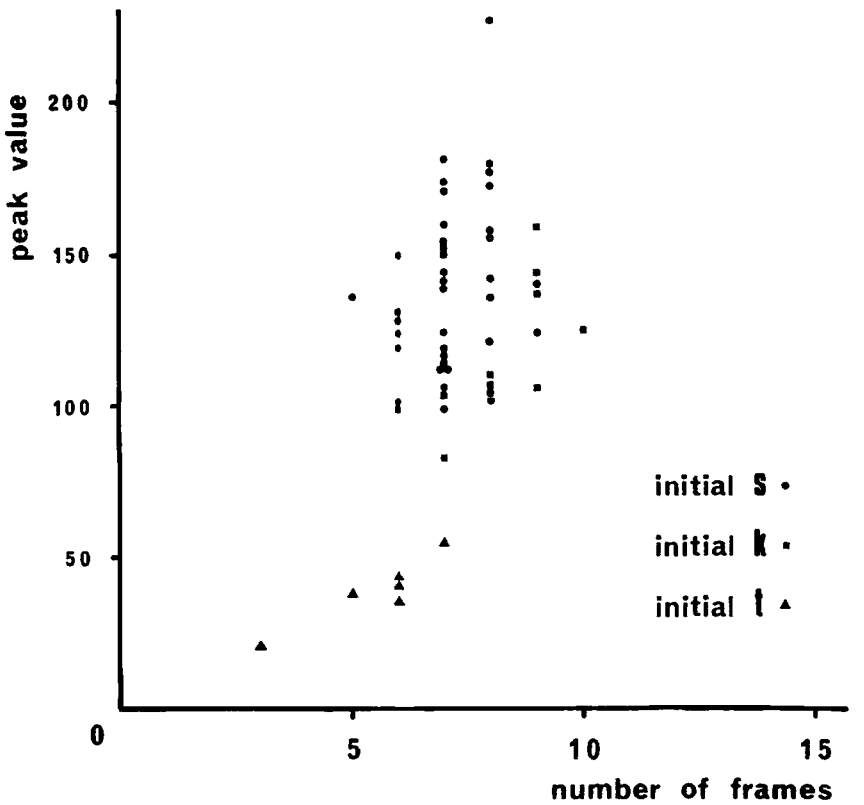

Fig. 6. Same as Fig. 2. for the initial [s], [k], and [t]. Circles indicate [s], squares [k], and triangles [t].

considerable overlapping on the axis of duration is observed between the [t] group and the group of [s] and [k].

The present results revealed a considerable variability in the glottal width, as well as in the duration of the glottal opening, for a given consonant in the same circumstance. The data further revealed little correlation between the glottal width and the time span where the glottis is open. Comparing the glottal condition between different phonemes, it was also revealed that the maximum glottal width was not necessarily correlated with the duration of the glottal opening.

It is interesting to note that Fujimura et al.,[10] in an experiment with dynamic palatography, observed little correlation between the size of the maximum tongue contact area and the closure period when a given stop consonant was repeated in the same context. They claimed that a dynamic model with a fixed pre-program for the articulatory actions could not account for their observation, and they hypothesized a contribution of some feedback in regulating the stop duration. Whether a similar effect of "some feedback" can be introduced to the opening and closing gestures of the glottis is still to be examined. But it seems to be true that our data, though limited to one subject, also suggest a contribution of some complex regulating mechanism to the articulatory laryngeal actions, where the glottal width may not be specified as a simple function of the duration of the glottal opening.

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