DEVOICING OF VOWELS *

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It is well known that high vowels between voiceless consonants are usually devoiced in many dialects of Japanese including the Tokyo dialect. [1), 2)] Our previous studies with a fiberscope revealed a wide opening of the glottis for the devoiced vowel segments. [3), 4)] In the present study, the apparent glottal width for the devoiced vowel was systematically examined in comparison with that for voiceless consonants.

Experimental Procedures

A male subject, a native speaker of the Tokyo dialect, repeated a set of sixteen sentences six times. Each sentence embedded a test word in a frame "soreo -- to yuu" (That we call --). The test words are:

/seisei/, /keikei/, /teitei/, /seikei/, /seitei/, /seki'ei/,
/seQsei/, /seQkei/, /seQtei/, /sekisei/, /sekitei/, /sekikei/,
/ki'ei/, /kikei/, /kitei/, /kisei/

No accent kernel is attached to those words. In the phonemic transcriptions, /QC/'s (where C stands for a voiceless consonant) represent tensified geminate consonants which occur only in the medial position of the word. Thus, for example, /Qs/ may be approximately represented phonetically as [ss] and /Qk/ as [kk]. Devoicing typically takes place for all of [i]'s between voiceless consonants, thus giving [kɨse:] for /kisei/, for example.

By repeating the set of the test sentences six times, we obtained at least six samples for each of voiceless consonants /t/, /k/, and /s/, for the phoneme sequences /kik/, /kit/, and /kis/, all in both word initial and medial positions, and for geminate consonants /Qt/, /Qk/, and /Qs/ in medial position.

A fiberscope was inserted through the nose of the subject and positioned in the hypopharynx so as to obtain a good view of the glottis during

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the utterances. The glottal view was photographed by a 16-mm cinecamera at a rate of 50 frames per sec. with simultaneous recording of the speech signal and synchronization time marks. Sound spectrograms and oscillograms of the speech signal with the time marks were made to obtain correspondence between film frames and speech sounds. The film frames corresponding to the speech segments under consideration were visually inspected by use of a motion picture analyzer and two measures of the glottal opening were estimated, viz, the distance between the tips of the vocal processes of the arytenoid cartilages and the maximum width in the membranous portion of the glottis.

Results and Remarks

A reasonably constant speed of utterance was confirmed by measuring durations of test words in the repeated utterances. Durations for the 4-mora words from /seisei/ through /sekikei/ as listed before were within the range of 550 to 650 msec, and those of the 3-mora words from /ki'ei/ through /kisei/ ranged from 400 to 500 msec.

Mean durations for each of /QC/'s and /kiC/'s were:

initial [k̟s]: 268 msec, medial [k̟s]: 258 msec, [ss]: 223 msec,
initial [k̟t]: 262 msec, medial [k̟t]: 253 msec, [tt]: 235 msec.
initial [k̟k]: 314 msec, Medial [k̟k]: 273 msec, [kk]: 260 msec.

In sound spectrograms, geminate consonants were manifested as a simple continuation of turbulent noise for the fricatives or of silence for the stop closures, while devoiced vowel segments showed turbulent noise with some characteristic formant patterns and were clearly distinguished from the adjacent stop closures, and less clearly but usually distinctly from the fricative segments.

The glottal width for the voiceless consonants varied considerably depending on the particular phoneme and the phonological environment. However, the temporal pattern of the glottal opening and closing was rather simple, showing a single peak of the glottal width during the consonant period, for both geminate and non-geminate consonants, as shown in Figures 1 to 4.

Figures 1 to 3 show selected frames of the glottal view for utterances

of /seisei/ (Fig. 1), /teitei/ (Fig. 2), and /keikei/ (Fig. 3) in the frame sentences. In each figure, from top to bottom, a broad phonetic transcription, a sound spectrogram, and selected frames are shown. Demarcations below the sound spectrogram indicate time segments corresponding to the selected film frames. In each figure, the leftmost frame shows the glottis for [o] preceding the initial consonant of the test word. The next three successive frames show the opening process, the fifth frame the maximum opening, and the next two the closing process of the glottis during the initial consonant. The rightmost frame shows the maximum opening of the glottis for the word medial consonant. In Fig. 4, we see glottal views for the geminate stops and [kɟt] in word medial position. The leftmost frames are for the vowels preceding the consonants, and the rightmost for the following vowels. The six successive frames in the middle show the glottis for the time stretch that include the maximum opening for the geminate consonants and [kɟt]. For the /kiC/-type sequences of phonemes, the glottal width continued to increase during the closure period of [k] and reached a maximum in the subsequent time segment that included the release noise and the devoiced vowel. The width then decreased during the following consonant segment and reached the phonatory position for the succeeding vowel segment; here also we see a single peak of the glottal width in the time course (Fig. 4).

Peak values of the glottal width at the two measure points of the glottis during the time course of geminate and non-geminate consonants and the /kiC/ sequences are compared in Fig. 5. In the figure, (I) indicates the word initial position, and (M) the word medial position, and numerals on the scale represent the apparent measures in millimeter on the magnified film frames. Horizontal bars for each item represent the entire ranges of sample variations and circles indicate the mean values. Solid lines represent the width in the membranous portion of the glottis, whereas broken lines that at the vocal process. The glottis for the fricative [s] showed a considerable opening in both initial and medial positions. The opening was still larger for the geminate [s]. The glottal width for stop consonants were smaller in the medial position than in the initial position. These results compare with those obtained in our previous studies.[5)]

Geminate stops showed a small glottal aperture that was comparable

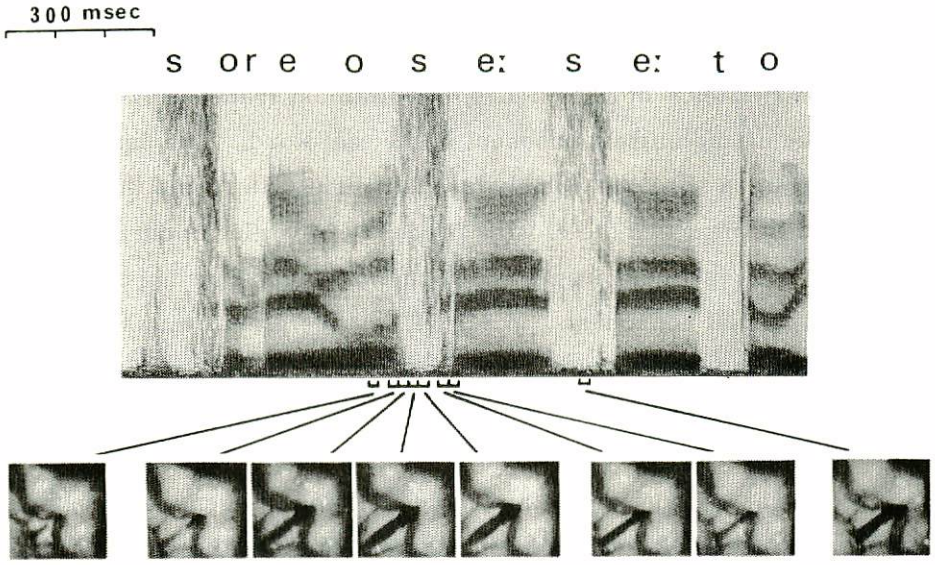

Fig. 1. Selected frames of the glottal view for /seisei/ in the frame sentence with the wideband spectrogram.

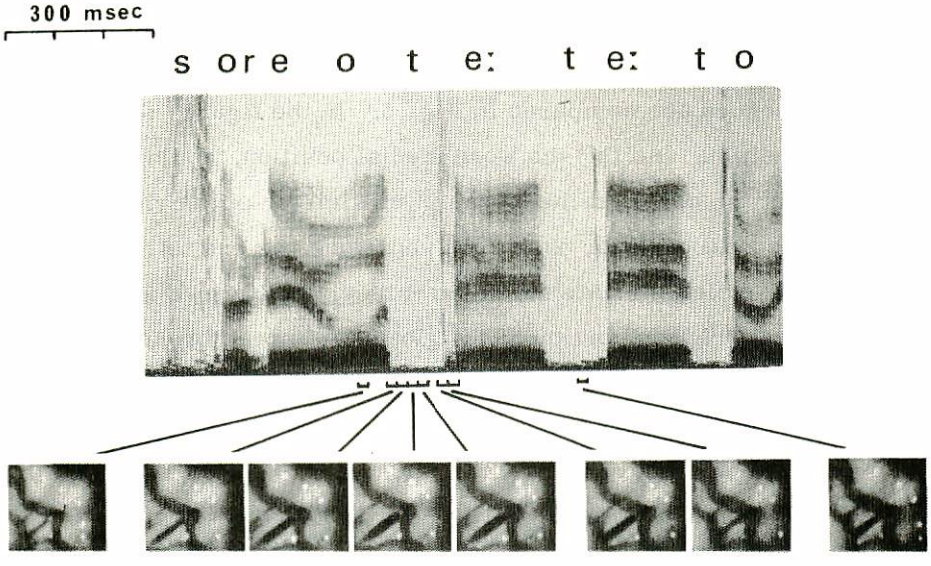

Fig. 2. Similar as in Fig. 2 for /teitei/.

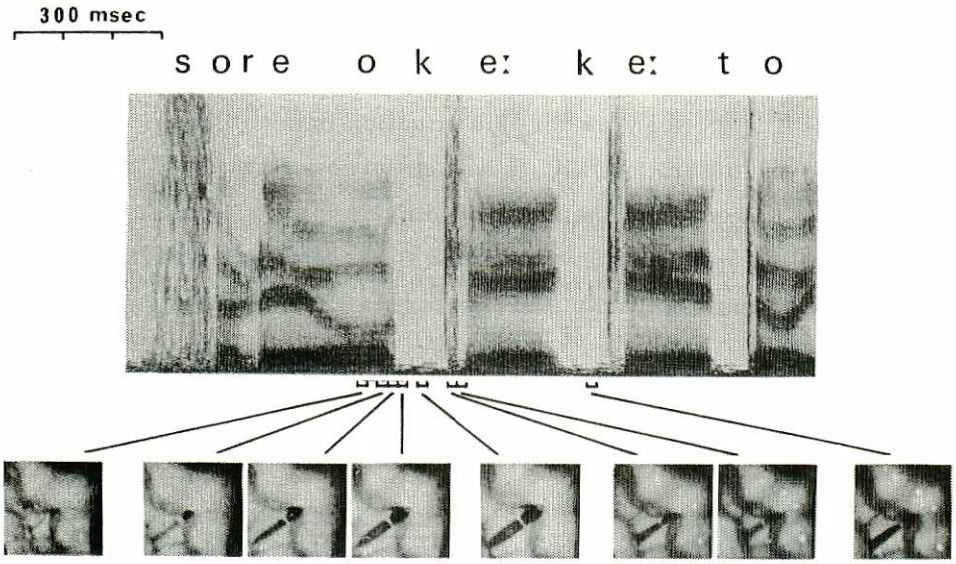

Fig. 3. Similar as in Fig. 1 for /keikei/.

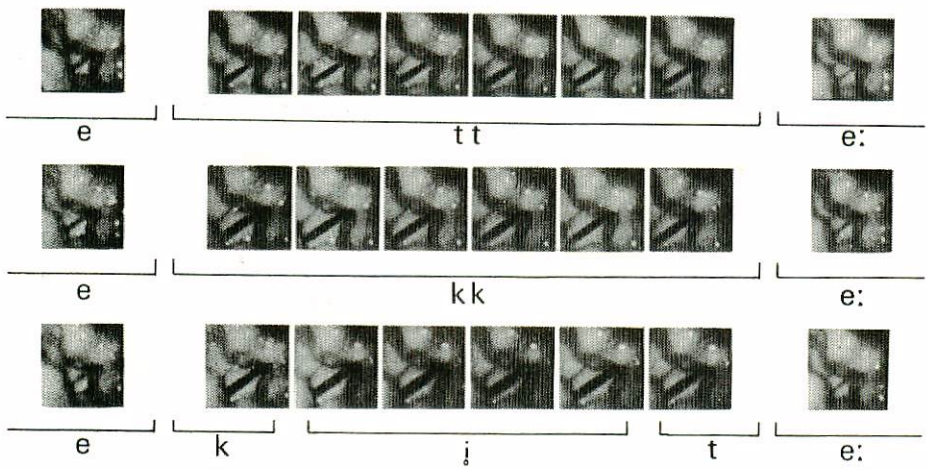

Fig. 4. Glottal views for the geminate stops and [ki̥t] in medial position.

to the medial non-geminate stops. The smallest opening among the voiceless consonants was observed for the word medial [t], where the arytenoids stayed apparently in the phonatory position with the vocal processes in contact, a spindle shaped gap being observed along the membranous portion of the glottis. The glottal view for this situation is seen in Fig. 2. The glottal opening for the initial /kiC/'s was as large as for /Qs/. In medial position, [k$_{\text{i}}$s] showed about the same opening as in initial position, while somewhat smaller openings were observed for medial [k$_{\text{i}}$t] and [k$_{\text{i}}$k], the values of which being comparable to that of [s].

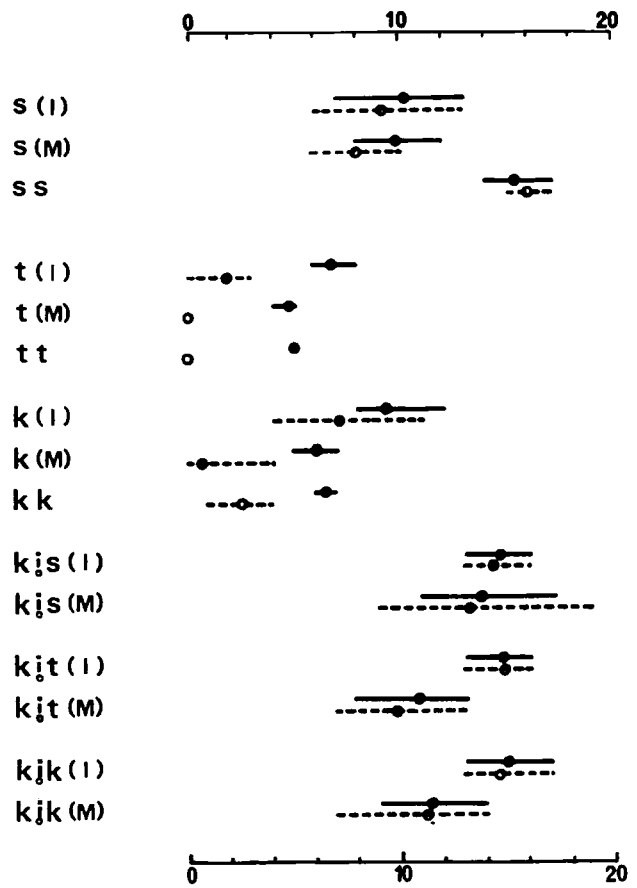

Fig. 5. Glottal width for voiceless segments. The number of measured sample is: 59 for s(I), 18 for k(M), 12 for t(M), and 6 for all the rest.

The opening of the glottis for the medial [kɟt] and [kɟk] were significantly larger than for [tt] and [kk] which lasted for approximately the same durations, and this fact shows that the glottal adjustments for devoicing of the vowel are not a mere skipping of the phonatory adjustments for the vowel but a positive effort of widening of the glottis for the devoiced vowel segment, even though there is no phonemic distinction between the voiced and devoiced vowels. This conclusion compares well with previous EMG findings.[3] The data, as shown in the difference in the glottal opening between the initial and medial positions, also suggests that the glottal width for the devoiced segment is influenced considerably by the adjacent consonants.

References

1) S. Kawakami, "Voiceless Morae and Accent Patterns" Hogen Kenkyu no Mondaiten [Issues in the Study of Dialects], Meiji Shoin Publ. Co. (1970 in Japanese).

2) M. S. Han, "Unvoicing of Vowels in Japanese, " The Study of Sounds, 10:81-100 (1962).

3) H. Hirose, Z. Simada, and O. Fujimura: "An Electromyographic Study of the Activity of the Laryngeal Muscles during Speech Utterances, " Annual Bulletin (Research Institute of Logopedics and Phoniatrics, University of Tokyo), No. 4, 9-25 (1970).

4) M. Sawashima, "Devoiced Syllables in Japanese - - A Preliminary Study of Photoelectric Glottography, " Annual Bulletin (Research Institute of Logopedics and Phoniatrics, University of Tokyo), No. 3, 35-41 (1969).

5) M. Sawashima, "Observation of the Glottal Movements, "Preprints: Speech Symposium, Kyoto, C-2-1 - C-2-7 (1968).