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GLOTTAL AREA VARIATION AND SUPRAGLOTTAL PRESSURE CHANGE IN VOICING CONTROL*

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Introduction

An appropriate glottal closure and a sufficient pressure drop across the glottis are crucial conditions for vocal fold vibrations to occur. In running speech, we produce not only such voiced sounds but also voiceless sounds which are not accompanied by vocal fold vibrations. In other words, spoken speech sound sequences may be regarded as various sound trains composed of these two different categories of sounds--voiced and voiceless. Therefore, it is conceivable that we adjust and accommodate in space and time the glottal physical conditions for successive voiced and voiceless segments in the speech chain. The present paper aims at clarifying the temporal patterns of glottal area variation and supraglottal pressure change, particularly in the control of voicing during running speech.

Method and Procedure

The techniques used in the present experiment were simultaneous photo-electric glottography, fiberoptic video taping and recording of supraglottal pressure change and the audio signal.

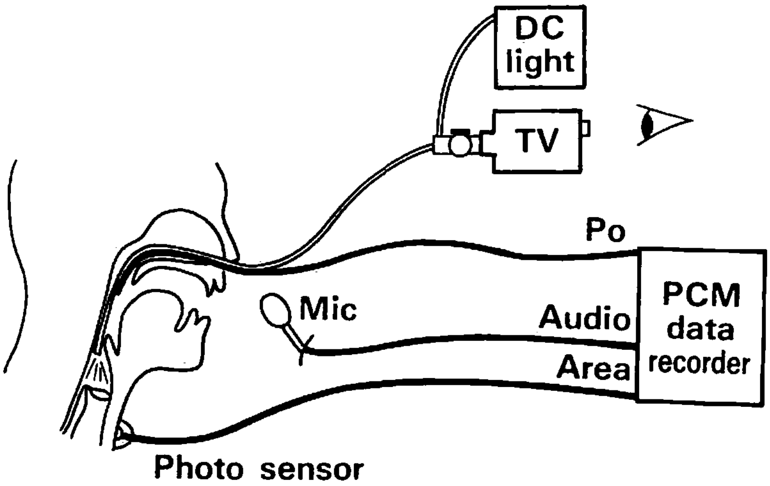

Fig. 1 Diagram of experimental procedure.

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Fig. 1 presents a diagram of the experimental procedure. For the recording of the glottal area variation, a flexible laryngeal fiberscope (Olympus VF-O) was inserted through the nostril. The image of the glottis was video-taped for monitoring. A cold DC light source, providing illumination of the upper glottal area, also served as the light source for the photo-electric glottography. The amount of light passing through the glottis was sensed by a photo-transistor placed on the neck below the lower edge of the cricoid cartilage. The electrical output registered on a channel of a PCM tape was used to estimate the glottal area after calibration using stereoendoscopy.

The supraglottal pressure change was registered using a miniature pressure transducer (Toyoda TCP 2), which was introduced through the other nostril and placed in the oropharynx above the glottis. In addition, the audio signal was also recorded on the third channel of the PCM tape.

Three native adult speakers of the Japanese served as the subjects. Of all the possible phoneme sequences composed of /iCi/ (C=single or geminate voiceless obstruents), those that are meaningful words were selected as test utterances. In particular, the author paid special attention to voicing control during the production of intervocalic voiceless obstruents.

Results

Sample recordings of transilluminatin and oral pressure are given in Fig. 2. The upper row represents the photo-electric glottograms which served as an index of glottal area variation. The middle row shows the temporal patterns of the supraglottal

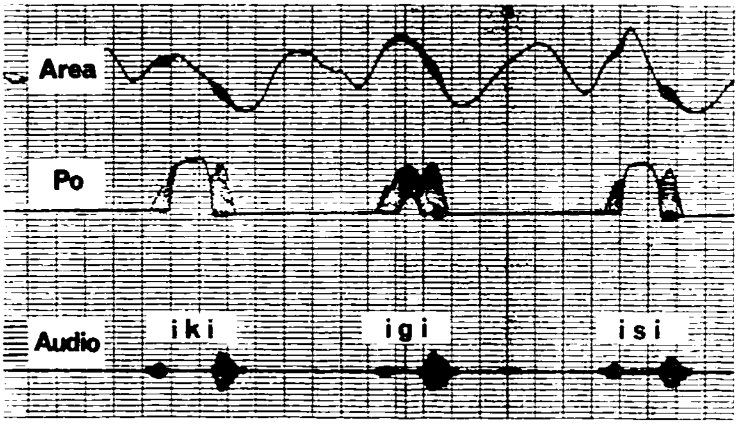

Fig. 2 Examples of glottal area change and supraglottal pressure change for representative utterance tokens.

pressure change. The bottom shows the corresponding audio signal. The initial portion corresponds to the utterance of /iki/, which is a meaningful word containing an intervocalic voiceless /k/ sound. At first, the glottogram as well as the pressure curve contain AC components due to the glottal vibration for the production of the initial vowel /i/. Then, the glottal area becomes wider, and the intraoral pressure goes up. Finally, the vocal fold vibrations are terminated for the implosion of /k/. The unvoiced period is maintained for a while and then the glottal area again becomes small, and the supraglottal pressure is suddenly reduced by the oral release for the explosion of /k/. The vocal folds immediately resume vibration for the following voiced vowel /i/.

The following Figs. show the temporal patterns of these two parameters more clearly. The signals after low-pass digital filtering at 80 Hz were plotted on an X-Y plane. The abscissa corresponds to the glottal area variation (AREA). The Y coordinate represents the intraoral pressure change (Po).

The left portion of Fig. 3 contains a representative token of the production of /iki/. Initially, the vocal folds vibrate while the glottal area widens together with the inflation of the intraoral pressure. Then, the vocal fold vibrations cease at the open triangular point in the graph. The trajectory continues to move counter-clockwise during the unvoiced period. When the glottal area becomes rather small and the pressure goes below a certain level (indicated by the filled triangle), the vocal folds resume vibration. It must be pointed out that the values of these two parameters are different for the cessation and restoration of voicing. At the termination of vocal fold vibration before the production of a voiceless obstruent, the glottal area is larger and the intraoral pressure is higher than when the vocal folds resume vibration immediately after a voiceless sound.

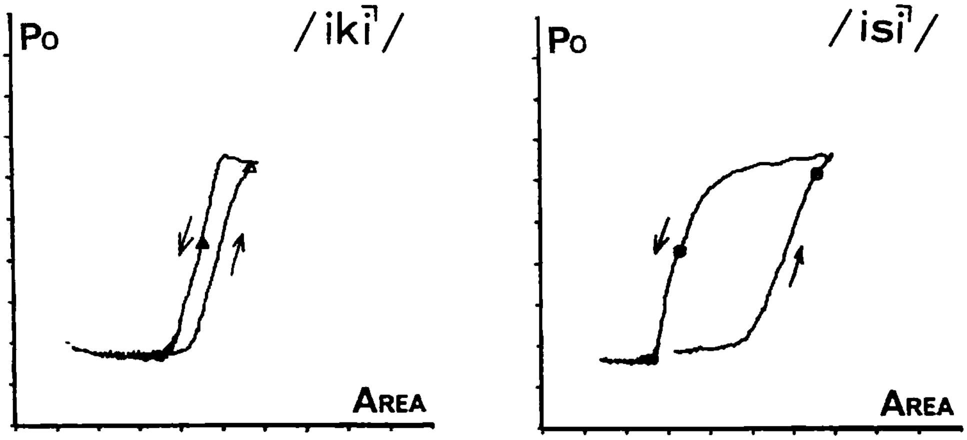

Fig. 3 Trajectories of the temporal patterns of glottal area change (AREA) and supraglottal pressure change (Po).

The right portion of Fig. 3 includes an example of an intervocalic /s/ production. Although the trajectory is oval in shape, which is a little different from the utterance containing an intervocalic /k/, the overall characteristics are similar. The curve runs counter-clockwise. In addition, the glottal conditions for cessation (open circle) and restoration (filled circle) are different.

Fig. 4 contains the trajectories of utterances containing the intervocalic geminates [kk] and [ss]. The curves cross themselves, yielding a figure 8 shape. Again, both the parameters for voicing offset and onset are apparently different.

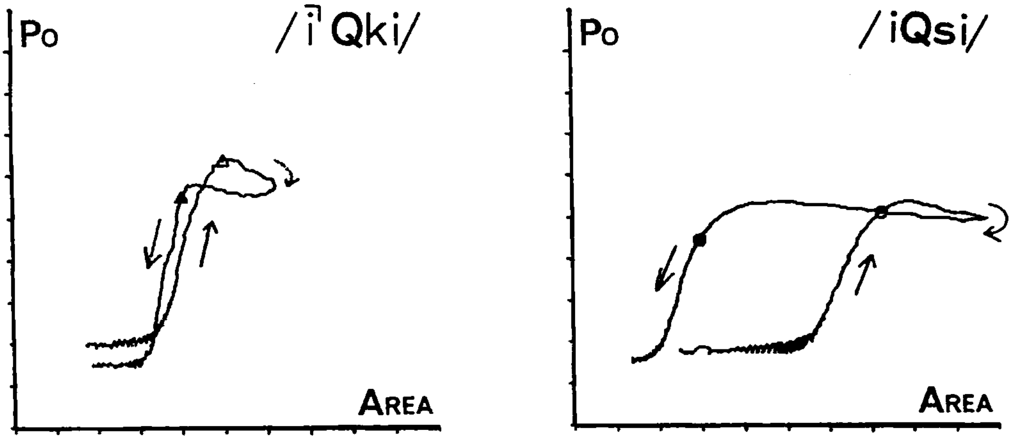

Fig. 4 Trajectories of utterances containing intervocalic voiceless geminate obstruents.

In order to show the difference between the glottal conditions more clearly, Fig. 5 contains 12 repetitions of single intervocalic obstruent productions. Only the values of the voicing offset and onset are plotted, corresponding to the timings of the implosion and explosion of the voiceless obstruents. The open circles (triangles) correspond to the voicing offset before the intervocalic /s/ (/k/) production, while the filled circles (triangles) represents the voicing onset after the intervocalic obstruent production. Although there are certain variations, these two groups of plots are clearly separable on this plane. This also implies that, when these values fall between the two groups, the glottal condition for voicing is uncertain. If the voicing precedes, the vocal fold may continue to vibrate. On the other hand, if the vocal fold vibrations do not precede, the glottal vibrations may not be excited for a while.

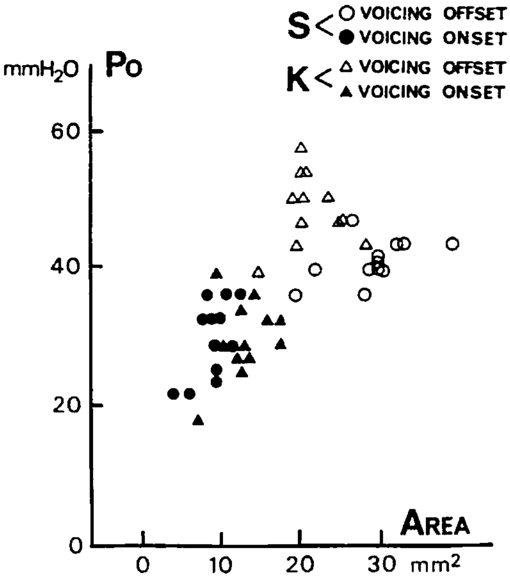

Fig. 5 Plots of voicing offset and onset conditions during the production of single intervocalic voiceless obstruents.

In summary, it can be concluded that voicing control is clearly accomplished mainly by the fine adjustments of these two parameters. In other words, the control can not be described well enough by each temporal change alone. In addition, it is demonstrated that the glottal conditions for the termination and restoration of vibrations are clearly different. In this connection, other parameters such as intrinsic laryngeal muscle activities, which may have some effect on the so-called "tension of the vocal folds" should be taken into account in order to clarify voicing control further. These simultaneous recordings are being planned for the near future.