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A PRELIMINARY REPORT ON THE INTERACTION BETWEEN MOVEMENTS OF THE VELUM AND TONGUE DURING THE PRODUCTION OF /CVV(V)N/ SEQUENCES IN JAPANESE

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Introduction

There have been many investigations on the movement of lips, tongue and jaw during speech production. However, because of technical difficulties, little is known about the velum itself and the interaction between the velum and the other articulators. Since the velum is located deep in the nasopharynx, it can hardly be investigated without invasive techniques like X-ray cine-radiography[1]. A nasopharyngeal fiberoptic endoscope makes the observation of the velum easy; however, to obtain the movement trajectory of the velum requires tedious frame-by-frame measurements of the recorded film for the investigator[2]. Recently, a device for monitoring velar position and its movement pattern, the Velotrace, has been developed which makes it possible to monitor velar movements simultaneously with those of the other articulators. Until now, since this kind of multidimensional observation was very difficult, little has been reported about the relationship between the movements of velum and the other articulators.

In this paper, preliminary results on the interaction between the movements of the velum and tongue are reported. The movements of the velum and tongue were monitored simultaneously using the Velotrace and the ultrasound-imaging technique.

Method

An experiment was conducted to investigate the relationship between the movements of the velum and tongue during production of words containing a nasal consonant following various vowels. Test words consisted of /CVVN/ and /CVVVN/ sequences, where C was /k/, V was /a/, /i/ and /u/, and N was the Japanese nasal syllabic /N/. Each test word was pronounced in a carrier sentence /korewa ___ mae desu/ (This is in front of ___. or This is before ___.). Test words are shown in table 1.

Table 1

/kaVN/ series;	/kaaN/	/kaiN/	/kauN/
/kaiVN/ series;	/kaiaN/	/kaiiN/	/kaiuN/

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The movement of the velum was monitored using the Velotrace. This device has already been reported in the literature[3), however, a minor modification was made to it. A magnet-angle sensor replaced the LED-position sensing detector system, which rendered the velotrace a free-standing device free from the LED-position sensing camera. The Velotrace signal and the acoustic signals were digitized at a 5 kHz-sampling rate under 12-bit resolution and stored in a microcomputer. The acoustic signal was also recorded on a DAT.

Soundspectrograms were made for each test word using a Sonagraph. Then the points where /k/ was released and the nasalization for /N/ occurred were determined by inspection of the soundspectrograms[4)]. The intervals between the /k/ release and the onset of nasalization were measured from the soundspectrograms. In order to relate the physiological data (velar movement) with the acoustic events, the point of the /k/ release was also determined on the acoustic waveform recorded simultaneously with the Velotrace signal on the computer. Using the timing of the /k/ release as a reference point, the height of the velum was measured where the nasalization began. The onset of the decrease in the velar height from the reference was also measured. A series of timing codes was generate at the rate of 60 pulses per second which corresponded with each field of the video signal. The time code was used to align the trajectories of the velar movements. The shape of the tongue was monitored using an ultrasound imaging system and recorded using a video tape recorder[5)]. A 90-degree 3.5 MHz sector probe was located under the subject's jaw with a 5 cm thick piece of ultrasonic conductive material, so that the probe itself did not interfere the movement of the jaw. B-mode data was recorded on a videotape with the acoustic signal and time codes. The recorded data was the dubbed onto a VCR disk for further analysis. Selected frames were selected by searching the time codes and displayed on a CRT monitor and printed using a video printer. The tongue shape was traced on the video prints by hand.

Results

A part of the results is presented in figure 1 and 2. The upper portion of figure 1 displays the trajectory of the velar movement against time during the production of /kaaN/, /kaiN/ and /kauN/ in a carrier sentence. The ordinate indicates the elevation of the velum, and the abscissa indicates the reference point at which nasalization was observed on the soundspectrogram. The lower portion of figure 1 displays the tongue shape for each test word at the reference point. Although nasalization occurred at that moment, it is probable that the shape of the tongue was relatively maintained for the vowel preceding the nasal in each test word. On the other hand, the velum was kept in a relatively higher position for /i/ and /u/ as compared with the case of /a/.

The arrangement of the display in figure 2 is the same as in figure 1. The test words were /kaiaN/, /kaiiN/ and /kaiuN/. The trajectories of the velar movements for /i/ and /u/ were different from those for /a/, although the tongue shapes were very similar, unlike the case of /kaVN/ as shown in figure 1.

Discussion

The result from figure 1 suggests that the opening of the velopharyngeal port for nasalization may depend upon the quality or the tongue height of the preceding vowel. It is said that an open velar port is reflected in the position of the velum, although velar position may also vary when the port is completely closed[6]. So, this result may be understood if the critical size of the velopharyngeal opening for nasalization depends upon the ratio between the impedance of the oral cavity and of the nasal cavity. In other words, when a vowel is followed by nasals, high vowels like /i/ or /u/ are more likely to be nasalized than the low vowel /a/, because high vowels produce a higher impedance in the oral cavity than low vowels like /a/. However, a systematic difference in velar movements was also found in the /kaiVN/ series as well as in the /kaVN/ series. This might not be a case which can be understood by the impedance difference between oral and nasal cavities. To understand this discrepancy, not only the physical properties of the velopharyngeal port, but other factors like phonetic environments must taken into account for further investigation.

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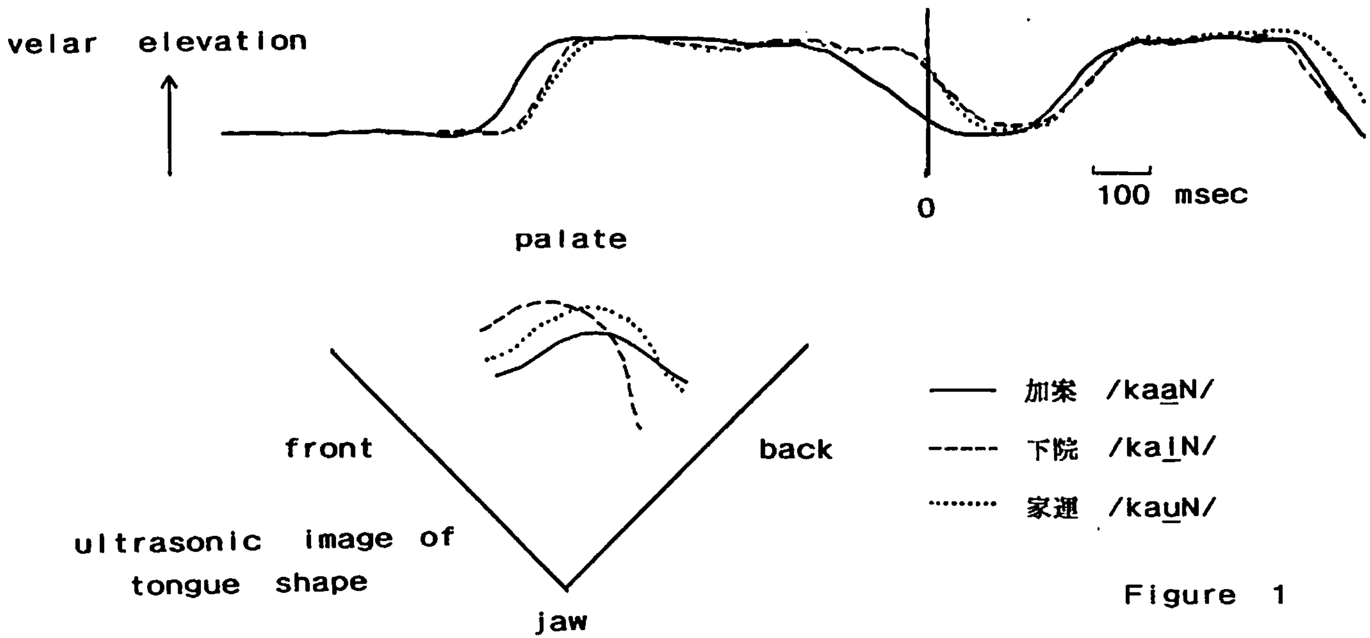
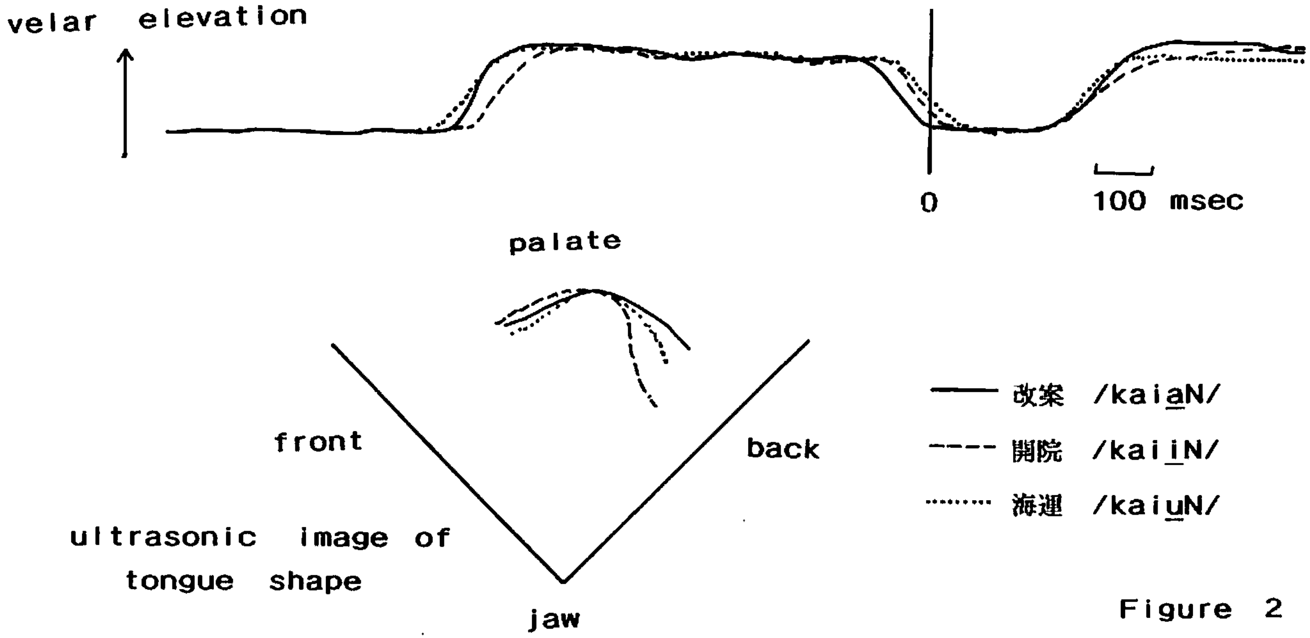

velar elevation
0
100 msec
palate
front
back
jaw
ultrasonic image of
tongue shape
加案 /kaaN/
下院 /kaiN/
家運 /kauN/

Figure 1


velar elevation
0
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jaw
改案 /kaiaN/
開院 /kaiiN/
海運 /kaiuN/

Figure 2