PATTERNS OF LINGUOPALATAL CONTACT DURING JAPANESE VOWEL DEVOICING

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ABSTRACT

It is widely claimed that close vowels in Japanese are devoiced when they occur between voiceless consonants. In this paper, voiceless vowels are represented symbolically as [V-] and voiced vowels as [V+]. The patterns of linguopalatal contact during C[V-]C units and the corresponding C[V+]C units are examined using the method of electropalatography (EPG). Our results show that C[V-]C units and the corresponding C[V+]C units often differ with respect to: (1) the amount (patterns) of tongue-palate contact from C1 (the preceding consonant) to C2 (the following consonant) and (2) the articulatory time interval from C1 to C2. Generally, the amount of linguopalatal contact is significantly greater at the front part of the palate in C[V-]C units compared to the corresponding C[V+]C units. The articulatory time interval from C1 to C2 is generally shorter in C[V-]C units compared to the corresponding C[V+]C units, though this is not always the case for all consonantal types. However, the articulatory gesture of the vowel appears to exist between voiceless consonants regardless of whether they are voiced or devoiced. Devoiced vowels have often been examined from the aspect of the opening gesture of the glottis since a turbulent noise during devoiced vowels is expected to be made at the glottis. However, our study seems to suggest that a turbulent noise can also be produced in the oral cavity - as well as at the glottis - by increasing the degree of tongue-palate contact. In principle, it is expected that the larger the tongue-palate contact is, the greater the turbulent noise will become due to the increased rate of airflow. This kind of linguopalatal contact appears to be a positive effort of a speaker rather than simply a matter of a shorter articulatory time interval in C[V-]C units: both factors seem to be related to the production of vowel devoicing, which seems to suggest that aerodynamic effects are involved.

1. INTRODUCTION

In Japanese, close vowels are frequently devoiced in the context below.

$$\begin{bmatrix} \text{V} \\ +\ \text{close} \end{bmatrix} \rightarrow \begin{bmatrix} \text{V} \\ -\ \text{voice} \end{bmatrix} \Big/ \begin{bmatrix} \text{C} \\ -\ \text{voice} \end{bmatrix} \_\_ \left\{ \begin{matrix} \begin{bmatrix} \text{C} \\ -\ \text{voice} \end{bmatrix} \\ \# \end{matrix} \right\}$$

(# word boundary)

The physiological process of vowel devoicing in Japanese has been examined using fiberoptics, EMG and photoelectric glottography etc [1]. Devoiced vowels between voiceless consonants are produced with one glottal opening gesture so that there is no vibration of the vocal folds during the transition from C1 to C2. The source of excitation during a devoiced vowel is made with an opening gesture of the glottis so the resonant frequencies would be expected to be generally similar to that of the voiced counterpart, differing only in the absence of voicing. However, the spectral patterns of devoiced vowels can be categorised into two different types, some showing a formant-like structure while others have spectra more similar to fricative consonants [2]. This seems to suggest that voiced and the corresponding devoiced vowels may also be different in the patterns of linguopalatal contact. In a similar vein, Farnetani [3] shows that the patterns of linguopalatal contact differ depending on the type (e.g. plosive, fricative) and the voicing of the consonants in Italian. She suggests that this is due to aerodynamic effects. It is probable that the difference between voiced and the corresponding devoiced vowels might not simply be a matter of the opening/closing gesture of the glottis. The distinction for voiced and the corresponding devoiced vowels also seems to involve aerodynamic effects.

The duration of a devoiced mora (C[V-]) is shorter than the corresponding voiced mora (C[V+]) [4], [5]. Shorter duration is typical of fast speech, which often leads to articulatory "undershoot" [6]. Yet this does not appear to be an explanation for the

Japanese devoicing, since the process of vowel devoicing seems to be influenced more by the type of the adjacent consonants than by the tempo of speech [10], [11]. These studies seem to suggest that the vowel devoicing effect is different from fast speech.

In this paper, we examine the patterns of linguopalatal contact during voiced and the corresponding devoiced vowels, specifically in the context between voiceless consonants (we will refer to these as C[V+]C units and
C[V-]C units). If devoiced vowels are simply voiceless allophones of the corresponding voiced vowels, little difference would be expected in the patterns of linguopalatal contact.

2. METHOD

21 words (out of a possible 23 words) which are phonologically liable to vowel devoicing were selected from the list in the Oxford Acoustic Database [7]. Each word was said in voiced and devoiced ways 3 times in a normal and relaxed style, without a carrier sentence (phonologically devoiceable vowels can often be voiced by Japanese speakers [2]). The words were said without pitch-accent.
The subject (the experimenter) wore the EPG palate for approximately 30 minutes before the recording. Recording was carried out in the recording studio at the University of Reading. EPG data and its corresponding acoustic signals were captured simultaneously and analysed using a Unix workstation. The sample rate for the acoustic signals is 10 KHz and 100 frames per second for the EPG data [8].

CVC units were examined from the release of C1 until the maximum contact of C2. The average amount of tongue-palate contact of each electrode of three tokens were taken. The patterns of linguopalatal contact for C[V-]C units and the corresponding C[V+]C units are examined from 3 aspects:

1) The articulatory time interval from C1 to C2
2) Total amount of linguopalatal contact
3) The patterns of linguopalatal contact at the corresponding equal measurement time points

3. RESULTS AND DISCUSSION

3:1 The articulatory time interval

Our results show that the articulatory time interval from C1 to C2 is usually shorter in C[V-]C units compared to the corresponding C[V+]C units, though this is not always the case for all the consonantal types [4]. In principle, the articulatory time interval tends to be longer in C[V-]C units compared to the corresponding C[V+]C units when either of the adjacent consonants is:

- C1 is /k/ and C2 is /t/
- Either of the consonants (C1 or C2) is /h/

3:2 The amount of linguopalatal contact

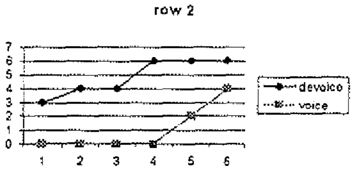
The results show that the difference in the amount of linguopalatal contact is generally statistically significant for C[V-]C units and the corresponding C[V+]C units. General Linear Model (GLM) comparing all rows of the palate for voiced and devoiced vowels generally gave a p-value of <.001. t-tests were used to compare counts for individual rows, and for rows at the alveolar region (generally at the 2nd and 3rd rows) normally showed p-values of < .001.

3:2:1 Typical patterns of linguopalatal contact of voiced and devoiced close vowels

Typical patterns of tongue-palate contact of voiced and devoiced close vowels are identified in the word /kyakisen/, and /kyakusen/. EPG pictures represent the view looking down from above. The top of the picture represents the front part and the bottom represents the back of the palate. There is more tongue-palate contact at the front part (the alveolar region) in devoiced vowels compared to the corresponding voiced vowels (reference Fig.1-4)

3:3 The patterns of linguopalatal contact at the corresponding points in time

The patterns of linguopalatal contact for C[V-]C units and the corresponding C[V+]C units at the corresponding 6 equally-spaced measurement points are often different at the front part of the palate. In general, activity of tongue-palate contact shows earlier onset in C[V-]C units compared to the corresponding C[V+]C units. In this particular example of the word (/chakushoku/), the difference in the amount of tongue-palate contact is significantly greater in C[V-]C units compared to the corresponding C[V+]C units at the 2nd and the 3rd rows.



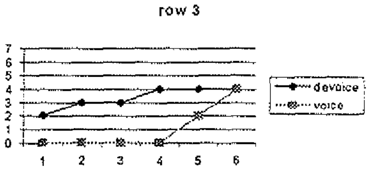


Fig 5. The amount of linguopalatal contact at 2nd & 3rd row in the word /chakushoku/. X corresponds to the successive measurement points in C[V-]C units and the corresponding C[V+]C units. Y corresponds to the total amount of tongue-palate contact at each measurement point.

In principle, therefore, C[V-]C units show a greater amount of tongue-palate contact compared to the corresponding C[V+]C units, specifically at the front part of the palate. The difference in the amount of linguopalatal contact at the mid-back part of the palate is not significant, regardless of whether the vowel is voiced or devoiced.

4. DISCUSSION AND CONCLUSIONS

The patterns of linguopalatal contact for C[V-]C units and the corresponding C[V+]C units are often different. A comparatively larger amount of tongue-palate contact is often obtained in C[V-]C units than the corresponding C[V+]C units, specifically at the front part of the palate. The patterns of tongue-palate contact show significantly earlier onset in C[V-]C units compared to the corresponding C[V+]C units. This appears to be similar to the production of fricatives such as /s/ and /ʃ/: a turbulent noise is generally made by forcing the air through the narrow gap between the tongue and the palate at the front part of the palate. By increasing the constriction of the tongue against the palate, the rate of airflow will be increased during a devoiced vowel.

The goal of speech production is not independent from its perception [9]. It has been suggested that Japanese vowel devoicing is also influenced by the environment and the type of the listeners [10], [11].Devoiced vowels are realised as fricative-like noise, and are relatively weak in terms of their acoustic energy compared to the corresponding voiced vowels. Thus, devoiced vowels may present problems of perception for listeners.

5. SUMMARY

It seems from our data that voiced and the corresponding devoiced vowels are different not only in terms of the state of the glottis. Tongue-palate contact has been shown to differ between voiced and devoiced vowels, and this in turn implies aerodynamic differences.

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APPENDICES

A typical pattern of voiced /i/, devoiced /i/ and voiced /u/ and devoiced /u/

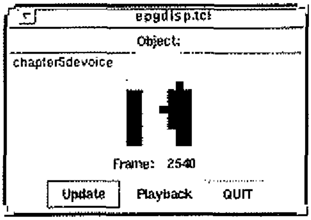

Fig 1. Devoiced /i/

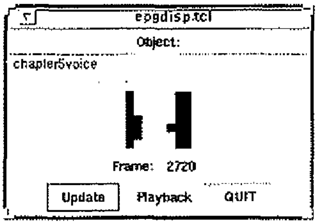

Fig 2. Voiced /i/

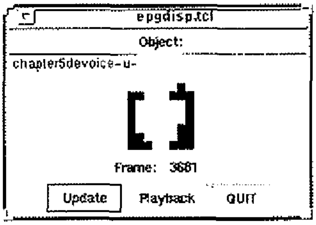

Fig 3. Devoiced /u/

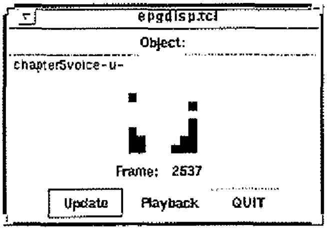

Fig 4. Voiced /i/