DEVOICING OF JAPANESE /u/: AN ELECTROMYOGRAPHIC STUDY

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ABSTRACT

Both cricothyroid and sternohyoid muscle activity was examined in a speaker of Tokyo Japanese with respect to devoicing of the vowel /u/. Sternohyoid activity, always with the cricothyroid activity suppressed, was related to implementation of a syllable of "stop consonant + u". However, this peculiar pattern of activity disappeared for the devoiced /u/ after an affricate or fricative. These results suggest that /u/ tends to be reduced or deleted in the nonplosive environment.

1. INTRODUCTION

Japanese has often been cited as an example of a language having voiceless or devoiced vowels [3]. They would sound unnatural if they were pronounced as voiced. For example, in two-mora words, the close vowel /i/ or /u/ must be devoiced when it is unaccented and occurs between voiceless obstruents. But the vowel devoicing in these cases is said to result from distinct articulatory processes. The difference between devoicing processes was first pointed out by Sakuma [4], and clarified in part by Han spectrographically [1]. Kawakami [2] summarizes as follows: the /pi, pu, ki, ku, cyu, syu/ followed by a voiceless consonant are simply devoiced, but the /ci, cu, si, su, hi, hu/ syllables usually do not manifest any voiceless vowels. Accordingly, the event as called "vowel devoicing" collectively is assumed to fall into two classes: (1) a devoiceable vowel is weakened or becomes voiceless when it appears after a stop consonant, whereas (2) the vowel usually is deleted and reduced to a mere consonantal lengthening after an affricate or fricative consonant (the /h/ in /hi/ or /hu/ is generally pronounced as fricative).

It seems difficult to distinguish acoustically between the simple devoicing and the entire deletion. We have tried to look into the physiological mechanism underlying this difference and report in this paper on a speaker who had a different control over the cricothyroid (CTh) and sternohyoid (SH) muscles between the classes 1 and 2.

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2. METHOD

2.1. Subject

A male speaker of Tokyo Japanese, who has lived from the teens in a city on the outskirts of Tokyo, served as subject. The subject was one of the authors.

2.2. Speech Material

The electromyographic (EMG) experiment was carried out twice on different days, but here we will discuss only the data concerning the vowel /u/ obtained from Experment 1. The words tested were of a form of /Cuki/ where C was /k, c, s, or zero consonant/ (/c/ stands for [ts]). Thus the following words

*kuki^* 'stalk'
*cuki^* 'moon'
suki 'plow'
uki 'float'

were tested in the frame sentence *ii ... no yo^o desu* '(it) looks like a nice ...'. These words are all ordinary, and the /u/ after a consonant is devoiceable. The words *kuki* and *cuki* are accented on the second syllable, but we asked the subject to utter them with no accent (The syllable immediately preceding the particle *no* can be unaccented; the symbol ^ indicates that the syllable marked with it has an accent. For detailed Japanese phonology, see Vance [6].). Moreover, the voiced counterparts

kugi 'nail'
cugi 'patch'
sugi 'Japanese cedar'
ugi (nonsense word)

were included as a control in the sentence list.

2.3. Data Recording and Analysis

EMG activity was derived from the CTh and SH muscles by using bipolar hooked-wire electrodes. The subject was asked to produce a total of 13 to 14 repetitions of each sentence, and recorded on a PCM tape recorder together with the EMG signals. All signals were digitized with 12-bit resolution and stored on an NEC desktop computer. On digitization, the EMG signals, after being full-wave rectified, integrated over a period of 5 ms, and finally low-pass filtered, were sampled at a rate of 1 kHz. The audio signal was sampled at a rate of 5 kHz.

The data files of interest were transferred to a Hewlett-Packard computer to calculate an ensemble average of the integrated EMG signals and to determine the line-up point necessary for averaging.

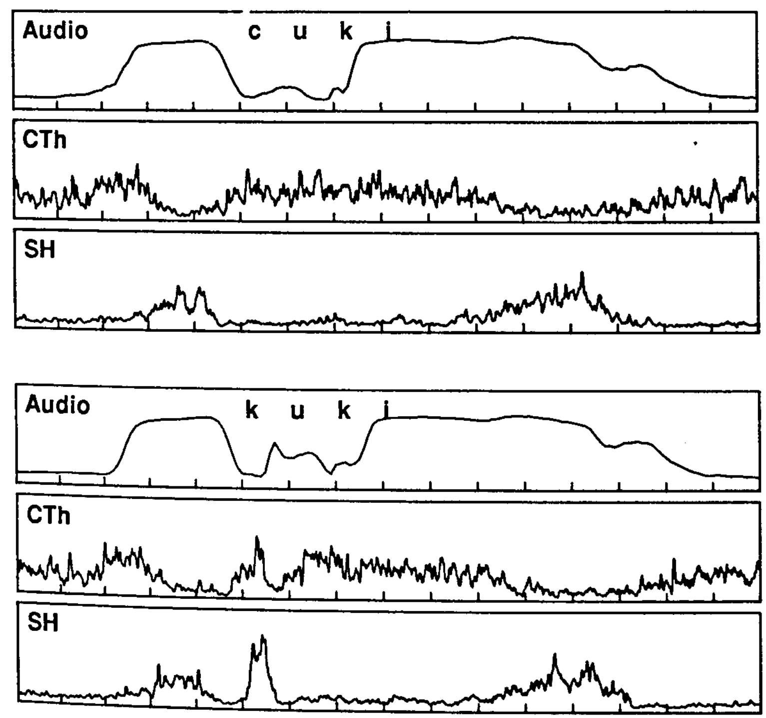

Figure1. Cricothyroid (CTh) and sternohyoid (SH) activity for the test words *cuki* (upper panel) and *kuki* (lower panel). The time axis is marked off at every 100-ms interval.

3. RESULTS

3.1. CTh and SH Activity

We were able to classify the CTh activity into two patterns depending on whether or not a short suppression was present in its activity. One was a pattern for the words *uki*, *ugi*, *cuki*, and *suki* which showed no apparent CTh suppression; the other pattern was seen for the words *kuki*, *kugi*, *cugi*, and *sugi* which showed a clear suppression in the CTh activation. Figure 1 illustrates an example of the results. It compares the CTh and SH EMG curves for the class 2 word *cuki* (upper panel) and the class 1 word *kuki* (lower panel), respectively. The EMG curves are shown here in a form of ensemble average of twelve tokens obtained from the same utterance type. Each curve is aligned with reference to the line-up point which indicates the instant of release of the second-mora [k] of the words.

For the affricate *cuki*, the CTh begins to increase its activity before the first-mora /cu/, and it remains rather active during the voiceless period of /cu/ and until the occurrence of an accent in *yo^o*. This activity is typical of Tokyo Japanese and has been viewed as contributing to manifestation of the fundamental tone of a phrase with no unaccented syllables [5]. In contrast to *cuki*, we can see a short suppression of CTh activity for the plosive *kuki*. The suppression occurs immediately after the release of articulatory closure of the first-mora /k/.

It is noteworthy here that this CTh suppression is concurrent with a burst of SH activity which continues for some 90 ms. The SH activity is overlapped with that of the CTh. But a closer inspection reveals that there is a gap of timing between their activity; the SH is activated about 20 ms later than the CTh, and does not cease its activity sooner after the CTh becomes rapidly inactive. The same pattern of activity in both muscles was observed regularly for the tokens of *kugi*, *cugi*, and *sugi*.

However, we could not see the SH activity in question at all for the other three words *uki*, *ugi*, and *suki*, and neither could we identify any CTh activity accompanied by an evident suppressive phase.

3.2. Acoustic Findings

The /u/ of *kuki* was not entirely devoiced in all the tokens; there were observable minute oscillations of the vocal folds with the exception of two tokens. On the other hand, we could not recognize any vocal oscillations for the words *cuki* and *suki* from their acoustic waveforms.

4. DISCUSSION

The characteristic pattern of activity observed from both CTh and SH shares a common syllabic structure of "obstruent + u". This was not exceptional to the word *kuki*, either. Consequently, we assume that an accentual phrase calls for SH activity when it begins with this type of syllable, and this SH activity is linked with a short suppression of CTh activity. Our assumption can be supplemented by other findings: the words *uki* and *ugi*, which do not begin with an obstruent consonant, never showed any such SH activity, and in addition, the SH basically behaved reciprocally against the CTh in the present speaker. In any case we cannot account for the devoicing process of class 1 by the peculiar EMG pattern we observed.

On the other hand, the SH activity under discussion disappeared for the words *cuki* and *suki*, which correspond to the class 2 devoicing. This was in sharp contrast to the voiced counterparts *cugi* and *sugi* where the vowel /u/ was not devoiced. Following our assumption above, this contrast is due to a kind of neural mechanism as follows: the vowel /u/ does not manifest itself entirely and the resultant sequence of consonants, such as [ck] or [sk], does not require any more SH contraction; this vanishment of the SH burst in turn releases the CTh from a suppressive phase.

5. SUMMARY

Our EMG findings from the cricothyroid and sternohyoid muscles suggest that the devoiceable /u/ after an affricate or fricative consonant is not merely devoiced, but rather tends to be reduced or deleted. This tendency is quite consistent with Han's observation [1]. Finally, we feel that we should make an additional measurement of laryngeal or tongue movements to clarify the difference between the processes of vowel devoicing.

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6. REFERENCES

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