ELECTRO-PALATOGRAPHIC STUDIES ON JAPANESE INTERVOCALIC /r/ AND /d/

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ABSTRACT

Electro-palatographic studies on the tongue palate contact patterns have been conducted on Japanese /d/ and /r/ in /VCV/ sequences in a carrier sentence. Subjects were 3 adults of Tokyo dialect. Complete stop closure at the anterior palate was seen for /d/ while many /r/ samples showed incomplete closure. Some of /r/ samples showed the anterior contact separate from the contact at the lateral part of the palate. Time curves of the anterior contact for /r/ revealed smaller area and shorter time span than those for /d/.

INTRODUCTION

Japanese /d/ is a stop consonant with formation of closure at the back of teeth and/or the alveolar ridge, while it is generally said that Japanese /r/ in intervocalic position is realized as a tap or a flap, with the tip of the tongue making one tap against the alveolar ridge. This stop-flap opposition implies that the palato-lingual contact is shorter in duration and also smaller in area for /r/ than for /d/.

In the field of experimental phonetics, use of the electro-palatography is considered to be one of the most powerful approaches for elucidating articulatory characteristics of the two sounds. Electro-palatographic finding of shorter duration and smaller area in articulatory contact has already been reported[1]. However, the data were quite limited and a more systematic study was needed.

In the present paper, results of our electro-palatographic study of tongue-palate contact patterns of Japanese intervocalic /d/ and /r/ in varying vowel contexts are presented.

EXPERIMENTAL PROCEDURES

Three native Japanese speakers of the Tokyo dialect served as subjects. None of the subjects reported any speaking disabilities. Test words were meaningless sequences of the form /$V_1CV_2V_1CV_2$/ (V_1=i, e, a, o, u; V_1=e, a, o; C=d, r). The test words were embedded in the carrier sentence /Sorewa ____ desu/ (It is ____). Each of the test sentences was repeated ten times, with a flat accent for the test word, at a comfortable speaking rate for the subject. Thus, 20 utterance samples were recorded for a given /V_1CV_2/ sequence.

The artificial palates used in this study had 63 electrodes. Contact signals from the electrodes in the artificial palate were stored in a computer connected to a portable electro-palatograph unit at a rate of 64 frames/sec. When the subject read a test sentence and pushed the control button after each utterance, the data for a duration of one-second were stored in the computer. The speech signals were also sampled by the computer at a rate of 64 frames/sec after rectification and integration over a 16 msec time window. The stored data were reproduced and observed in slow motion on an oscilloscope. The plotting of the necessary contact patterns was printed out by a high-speed line printer.

RESULTS AND COMMENTS

1. Maximum contact patterns

For each of the utterance samples, successive palatographic frames indicating the time course of the articulatory tongue-palate contact for the pertinent consonant were obtained. The peak articulatory contact was identified as the frame showing the maximum contact (maximum contact pattern) in the frame series. Maximum contact patterns were collected for all the utterance samples. With these maximum contact patterns, we constructed a contact pattern which consisted of the electrodes showing contact in more than 10 (50%) of the 20 repetitions, for each test word of each subject. This pattern was considered to be the average contact pattern for each test word in a given subject. The results are shown in Fig. 1.

In the figure, the patterns for /d/ and /r/ in the same vowel context are superimposed on the scheme of the artificial palate. The area demarcated by the thick line indicates the contact area for /d/, while the shaded area indicates that for /r/.

The average patterns reveal that, for /d/ there is a complete stop closure at the anterior margin of the palate for all of the vowel contexts in all three subjects. Also, there is little variation in the contact pattern among the different vowel contexts at the anterior part of the palate within each subject, while there is some context-dependent variability at the posterior part.

The average patterns for /r/ generally show a smaller contact areas than those for /d/. At the anterior part of the palate, there are many /r/ patterns which do not show complete closure.

Table 1 summarizes the contact area as defined by the number of on-electrodes in the maximum pattern for selected /d/-/r/ pairs of the test words. It is seen that for all the subjects /d/ shows a greater contact area than /r/.

Frequency of the occurrence of complete closure for 20 tokens of selected /d/-/r/ pairs of the test words are summarized in Table 2. It is noted that for all the subjects, most or more than half of the /d/ patterns show complete closure while more than half of the /r/ patterns do not.

The characteristic feature for Subj. 1 is that the contact at the anterior part shifts backward for /r/ as compared to /d/. This appears to occur

Subject \ Utterance	ada/ara	ede/ere	odo/oro	Average
Subj. 1	25	28	22	25
	16	20	17	18
Subj. 2	22	28	21	24
	17	20	16	18
Subj. 3	24	27	26	26
	17	22	22	20
Average	24	28	23	25
	17	21	18	19

Table 1: The average number of on-electrodes in the maximum contact patterns for 20 tokens of selected test words.

Subject \ Utterance	ada/ara	ede/ere	odo/oro	Average
Subj. 1	20	20	20	20
	1	6	7	5
Subj. 2	13	13	13	13
	6	1	4	4
Subj. 3	19	14	20	18
	2	10	14	9
Average	17	16	18	17
	3	6	8	6

Table 2: The frequency of occurrence of complete closure for 20 tokens of selected dest words.

only in the context of the back vowels for Subj. 2, while no such shift in the place of contact is observable for Subj. 3. Thus, there is some individual variation in the contact patterns for /r/.

Another feature of /r/ is that some of the /r/-patterns show contact at the anterior part separate from the contact at the lateral part of the palate. Whether this represents a specific tongue gesture for /r/ or not is an open question at this moment.

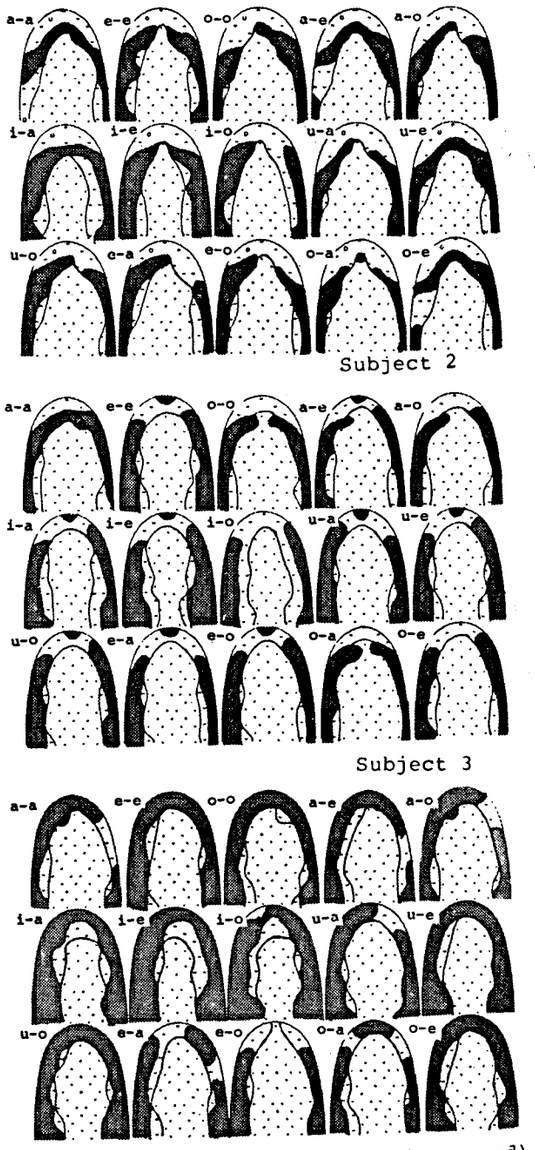

Fig. 1: Maximum contact pattern(averaged) for /d/ and /r/. The area demarcated by solid line is for /d/, the shaded area for /r/.

2. Time course of the tongue-palate contact

As described above, there was a complete stop closure at the anterior part of the palate for most of the /d/ patterns. The duration of the complete closure ranged from 2 to 4 frames out of 64 frames/sec. Some of the /r/ patterns also showed this stop closure. The duration of the closure in these cases ranged from 1 to 2 frames. This indicates that there is a difference in the time pattern, as well as the spatial pattern, of the tongue-palate contact between /d/ and /r/.

We then determined the average number of on-electrodes at the anterior part of the palate for 20 repetitions along the time course of each /V_1CV_2/ sequence, as shown in Fig. 2. In the figure, the ordinate of each graph indicates the number of on-electrodes and the abscissa the time axis. The time curve is demarcated by each frame of the palatogram, and the vertical line on the curve indicates the standard deviation. The dashed line indicates the contact for /d/ and the solid line that for /r/.

It should be noted that the area of the contact, i.e., the number of on-electrodes, is larger for /d/ than for /r/ throughout the time curse for all of the subjects and for all of the test samples. Also, it is apparent that /d/ shows a longer time span than /r/ both in peak contact and in the transition of the contact area. Thus, the /d/ and /r/ curves of Subj. 1 are clearly separated

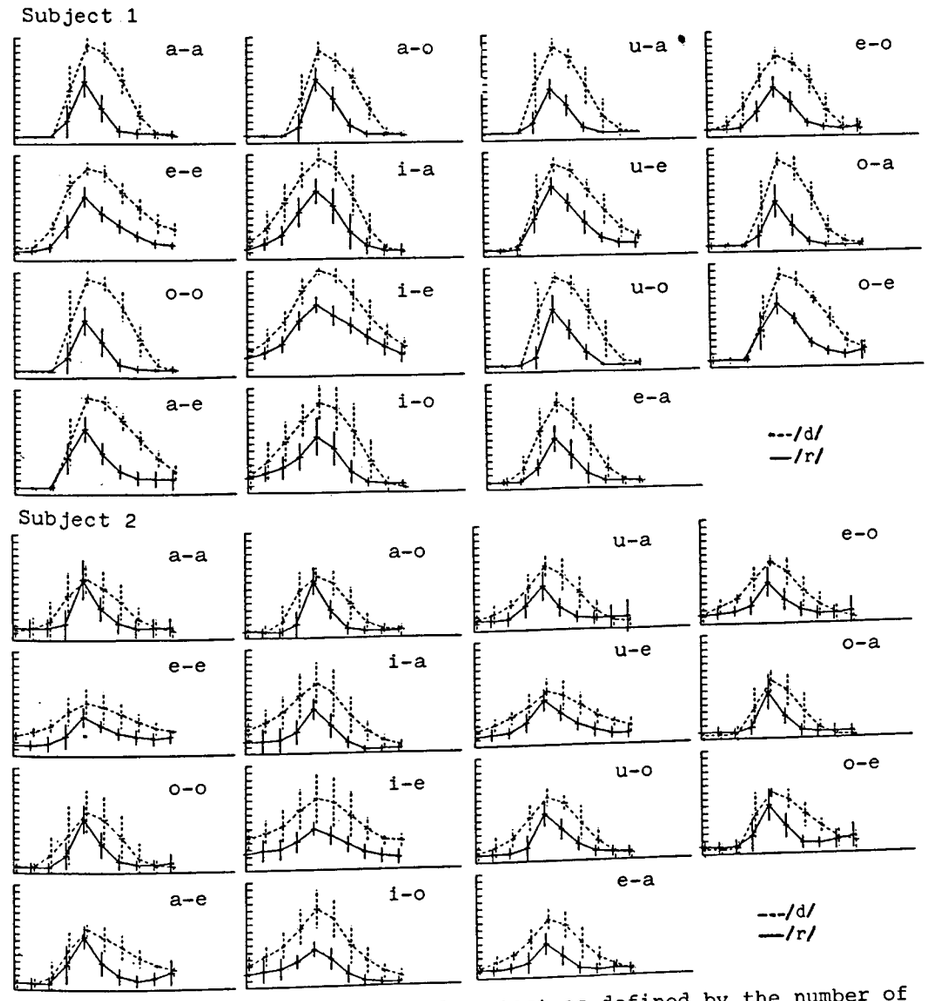

Fig. 2-1: Time curve of the area of contact as defined by the number of on-electrodes at the anterior palate for /d/ and /r/ for Subj.1 and Subj.2. Dashed line is for /d/, solid line for /r/.

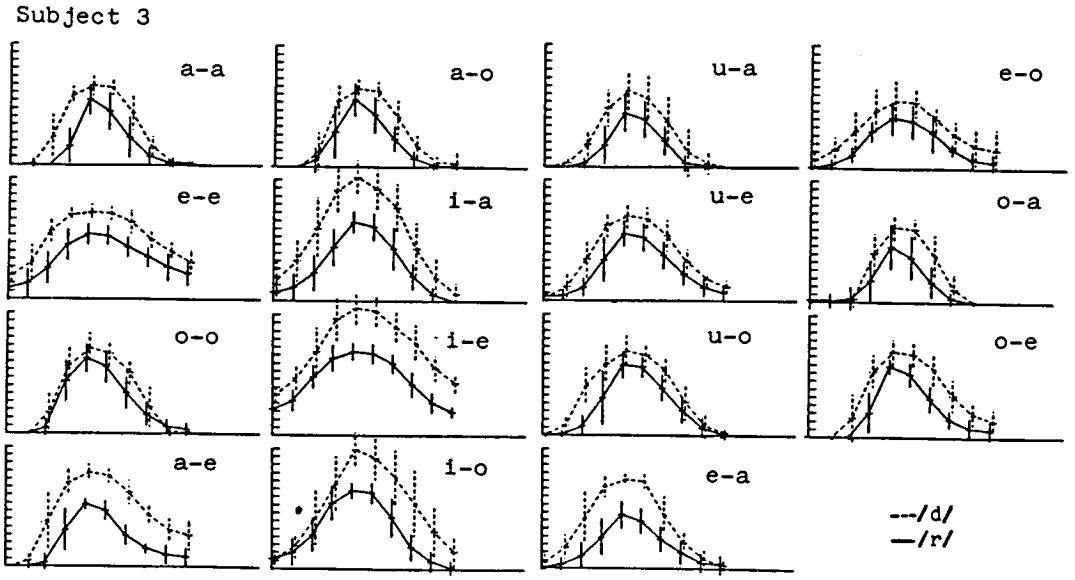

Fig. 2-2: Time curve of the area of contact as defined by the number of on-electrodes at the anterior palate for /d/ and /r/ for Subj.3. Dashed line for /d/, solid line for /r/.

from each other for all of the vowel contexts. Some of the curves of Subj. 2 show that the peak values of contact for /d/ and /r/ are comparable to each other. In these cases, however, the /r/ curves show a much steeper slope before and after the peaks than the /d/ curves, indicating a faster transition to and from the peak contact for /r/. The time curves of /r/ for Subj. 3 present rather similar contours to those for /d/, the contacts for /r/ showing smaller values than those for /d/. Thus, the distinction between /d/ and /r/ appears to be less evident in Subj. 3 than in Subjs. 1 and 2, as far as the tongue-palate contact pattern is concerned.

SUMMARIES

Electro-palatographic study was conducted on Japanese intervocalic /d/ and /r/. The results were summarized as follows:

1) Maximum contact pattern revealed that the contact area was greater for /d/ than for /r/. It was also noted that most of the /d/ patterns showed complete closure at the anterior palate while many of the /r/ patterns did not.
2) Some of the /r/ patterns showed the anterior contact separate from the lateral contact along the teeth ridge, which was never seen in the /d/ patterns.
3) Time course of the anterior contact revealed a shorter time span of articulatory contact for /r/ than for /d/.
4) There appeared to be greater individual variation in the articulatory contact for /r/ than for /d/, which resulted in some individual variation in the difference between /d/ and /r/.

REFERENCES

[1] Fujimura, O., Tatsumi, I. F. and Kagaya, R.: Computational processing of palatographic patterns. J. Phonetics, 1; 47-54, 1973.

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