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AN ELECTRO-PALATOGRAPHIC STUDY OF JAPANESE INTERVOCALIC /r/

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Introduction

It is generally said that Japanese /r/ in initial position is a sort of weak stop, while intervocalic /r/ is realized as a tap or flap. In addition to this flap-like quality, it has been pointed out that vowel environments exert a great influence on the phonetic quality of this consonant. These observations have been mainly based on subjective introspection. In the field of experimental phonetics, however, there have been a few studies on the articulation of /r/, such as Shibata (1968) and Miyawaki (1972), which employ electro-palatography. These experimental studies are one step toward the investigation of the articulation of /r/, though they only study some /r/s in limited vowel environments.

Therefore, we decided to investigate the dynamics of the palato-lingual contact during the articulation of Japanese intervocalic /r/ using electro-palatography.

Method

The linguistic materials used in this study consisted of intervocalic /r/ in all the twenty-five possible vowel environments of Japanese. Meaningless words of the form /$V_1 rV_2 V_1 rV_2$/ (V_1, V_2 = i, e, a, o, u) were embedded in a carrier sentence of the form /Sorewa _____ desu/, or "It is _____".

Two native Japanese speakers of Tokyo dialect served as subjects. Subject 1 was a 26-year-old female; Subject 2 was a 54-year-old male. Neither of them reported any speaking disabilities.

The subjects were told to produce the sentences at a comfortable speaking rate and the key words with a flat accent. They repeated the text ten times. For each subject, twenty tokens of /r/ in each vowel environment were selected and analyzed.

The artificial palates used in this study had sixty-three electrodes. The data was stored in a computer connected to a portable palatograph unit (Tatsumi, 1972; Shibata et al., 1978). When the subjects read a text and pushed the control button after each utterance, data of a one-second duration was stored in the computer. The speech signals were sampled by the computer system at a rate of 64 frames/sec, after rectification and integration over a 16 msec time window. These signals were also recorded on an audio tape for the purpose of further acoustic analysis. The data stored in the computer could be reproduced and observed in slow motion on an oscilloscope. In addition, the plotting of the patterns of the necessary components was possible. The palato-lingual contact patterns were printed out by a high-speed line printer for the processing of the vast volume of data.

Results

In most articulations of /r/, the contact proceeds posterio-anteriorly along the teeth ridge. Fig. 1 shows examples of the contact pattern sequences obtained during the articulation of /ere/ and /ara/ for Subject 1. In this figure, the upper part of each pattern corresponds to the anterior portion of the palate, and the lower part to the posterior portion. The small dots show the positions of the sixty-three electrodes, and the blackened dots represent on-contact electrodes. The number beside the upper right-hand corner of each pattern gives the frame number. In the example of /ere/ shown in the upper half of Fig. 1, the contact proceeds posterio-anteriorly and reaches the maximum contact pattern in frame 12, which shows the largest number of on-electrodes during the articulation of /r/. This type of contact can be seen in the case of stop consonants.

In addition to the type of contact pattern of /r/ described above, there is another type in which the contact first occurs at the anterior portion of the palate. The lower half of Fig. 1 shows an example of the contact pattern obtained during the articulation of /ara/ for the same subject. In this example, the contact occurs at the anterior portion as shown in the pattern of frame 15, and frame 16 shows the appearance of the contact at the lateral edge. This second type of contact pattern was observed especially in an /a/ or /o/ environment. There were fourteen /ara/s of this type out of twenty repetitions and thirteen /aro/s. Also, /are/, /ora/, /oro/ and /aru/ showed more than 25% occurrences of this type of contact pattern.

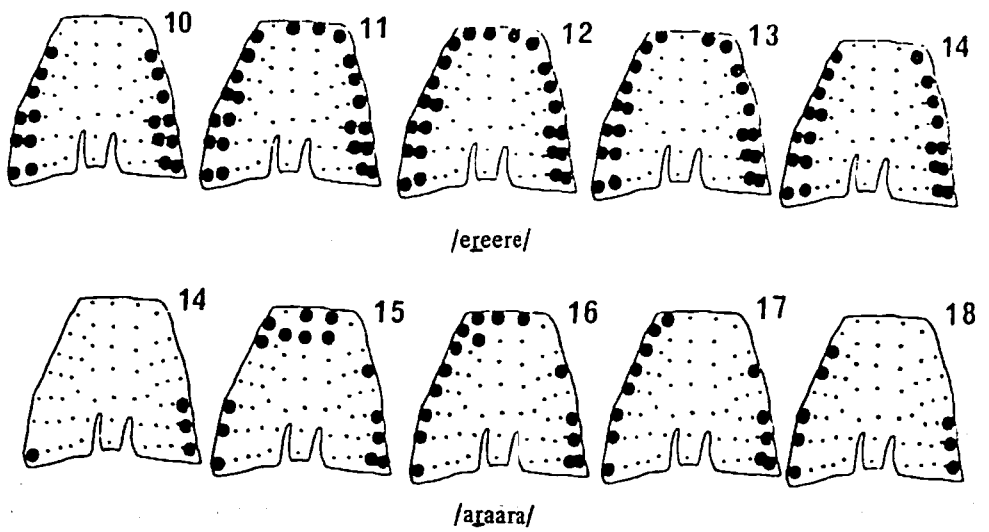

Fig. 1 *Examples of contact pattern sequences obtained during the articulation of /ere/ and /ara/ (Subject 1).*

The utterances of Subject 2 also show both types of contact pattern explained above. The upper half of Fig. 2 shows an example of the pattern during the articulation of /ere/, in which the contact proceeds posterio-anteriorly and reaches the maximum contact pattern in frame 26. In the utterances of Subject 2, the second

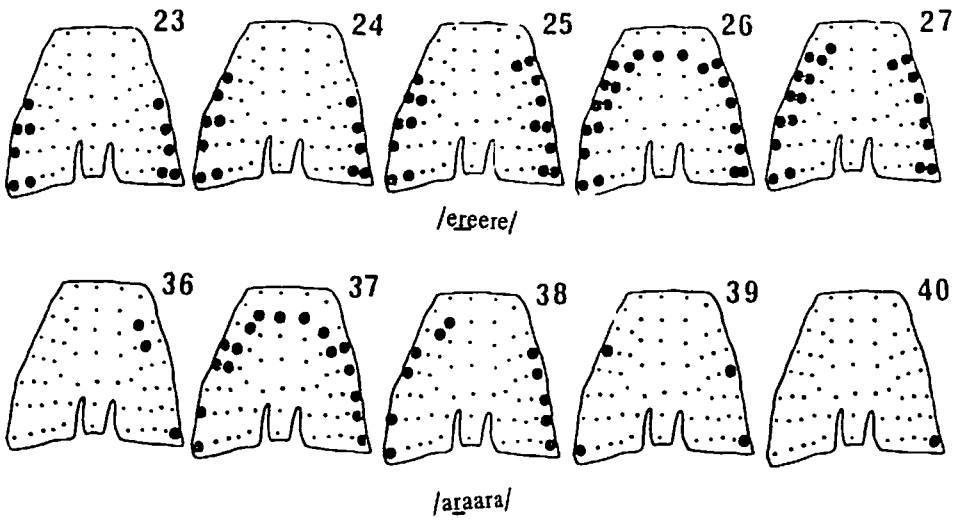

Fig. 2 *Examples of contact pattern sequences obtained during the articulation of /ere/ and /ara/ (Subject 2).*

type of contact pattern was observed especially in an /a/ or /o/ environment as in the case of Subject 1. In Subject 2's utterances, however, the frequency of the occurrence of this contact pattern showing a kind of lateral articulation was lower than in those of Subject 1. The lower half of Fig. 2 shows an example of this type of contact pattern, /ara/, in which the contact appears at the anterior portion of the palate in frame 36. /ara/, /ari/, /ori/, /uri/ and /oro/ showed more than 25% occurrences of this type of contact pattern for Subject 2.

Thus, there are two types of contact pattern in the production of /r/. In both cases, however, the contact first disappears from the central region in the anterior portion of the palate, and continues to disappear in a backward direction.

Figs. 3 and 4 show the average maximum contact pattern for /iri/, /uru/, /ere/, /ara/ and /oro/, respectively. In these figures, the blackened dots represent 100% on-contact electrodes i.e., electrodes showing on-contact for all the twenty tokens. Circles with small dots show the frequency of the contact given by a subscribed number (the number 4, for example, represents a frequency of 40%). As can be seen in these two figures, vowel environments have a great influence on the contact area. The /r/ of /iri/ is produced with a number of on-contact electrodes; while in the case of the /r/ of /ara/, the number of on-contact electrodes is small. During the articulation of /r/ in the utterance /ara/ for both subjects, and /oro/ for Subject 2, the electrodes with other than a 100% frequency of contact are observed in the anterior portion of the palate and at the lateral edge. Examination of the contact pattern of individual tokens revealed that in some cases the electrodes at the lateral edge showed off-contact, while those in the anterior portion of the palate showed on-contact. The pattern with on-contact electrodes in the anterior portion and an absence of those at the lateral ridge was observed in the second type of contact pattern.

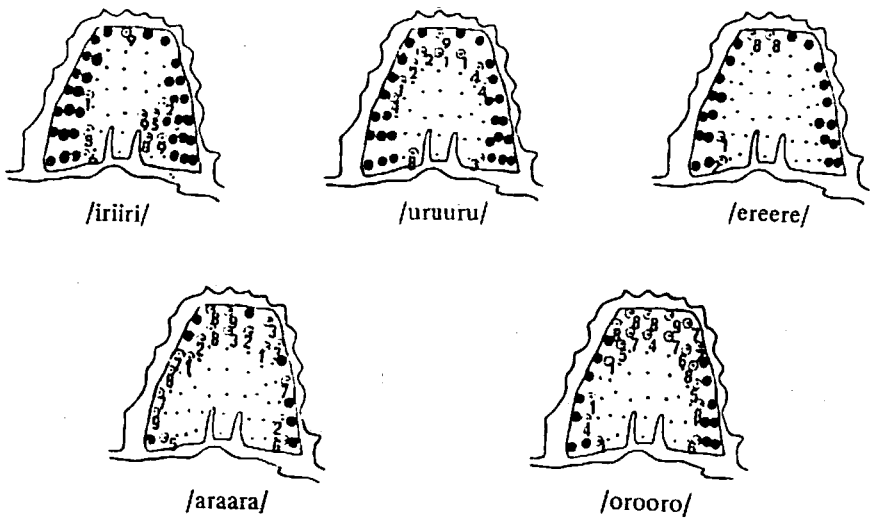

Fig. 3 *The average contact patterns for 20 tokens of /iri/, /uru/, /ere/, /ara/ and /oro/, respectively (Subject 1).*

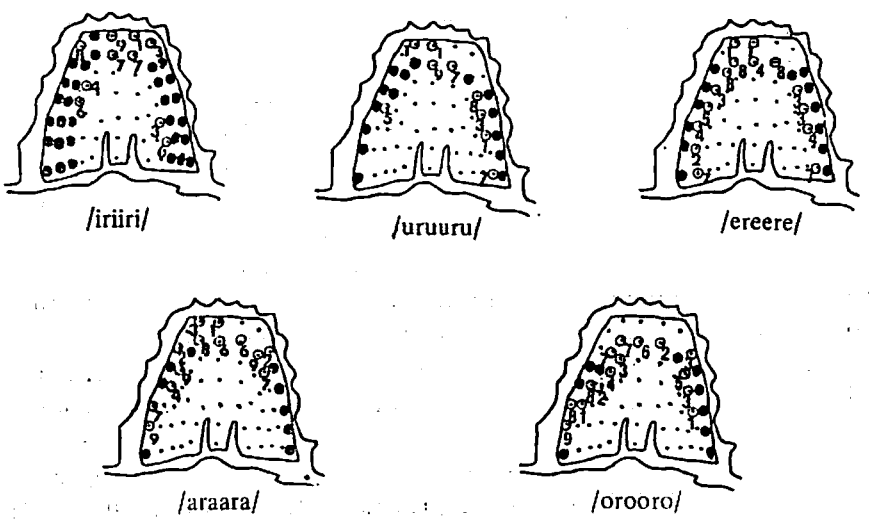

Fig. 4 *The average contact patterns for 20 tokens of /iri/, /uru/, /ere/, /ara/ and /oro/, respectively (Subject 2).*

Table 1 shows the average number of on-electrodes in the maximum contact patterns of twenty tokens for all the vowel environments. The /r/s which were preceded and/or followed by a high-front vowel /i/ took the widest area, while the environment of the low-back vowel /a/ resulted in a narrowing of the area.

So far we have seen a significant difference in the contact patterns resulting from different vowel environments. Table 2 shows the frequency of the occurrence of complete closure during the articulation of /r/ in all the vowel environments. The presence of complete closure is defined as either when all the electrodes of

Table 1 *The average number of on-electrodes in the maximum contact patterns of 20 tokens for each vowel environment. In the table, V1 is the preceding vowel and V2 the following vowel.*

V1 \ V2	i	e	a	o	u	Total
i	39	35	33	33	37	177
e	31	24	23	24	24	126
a	29	22	17	19	22	109
o	31	27	21	25	28	132
u	35	30	25	27	31	148
Total	165	138	119	128	142	692

(Subj. 1)

V1 \ V2	i	e	a	o	u	Total
i	35	29	22	21	27	134
e	27	20	14	15	20	96
a	25	18	16	17	19	95
o	25	19	14	17	19	94
u	27	21	14	18	20	100
Total	139	107	80	88	105	519

(Subj. 2)

Table 2 *The frequency of the occurrence of complete closure for 20 tokens.*

V1 \ V2	i	e	a	o	u	Total
i	18	17	20	19	16	90
e	15	14	16	12	15	72
a	19	19	2	6	19	65
o	19	20	9	15	20	83
u	12	16	12	14	16	70
Total	83	86	59	66	86	380

(Subj. 1)

V1 \ V2	i	e	a	o	u	Total
i	15	13	14	8	12	62
e	11	8	0	0	9	28
a	6	4	6	5	10	31
o	5	8	0	3	7	23
u	9	10	0	10	14	43
Total	46	43	20	26	52	187

(Subj. 2)

any one line along the teeth ridge show contact or when the corresponding electrode of a neighboring line shows contact in spite of the presence of an off-contact electrode in a certain line. As shown in the table, closure is not always attained during the articulation of /r/. Especially in the /a/ and /o/ environments, the frequency of the occurrence of closure is low; while /r/s preceded or followed by /i/ attain closure most frequently.

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