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Cross Language Study of Perception of Dental Fricatives in Japanese and Russian

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Introduction

Japanese has two dental fricatives /s/ and /sj/ (which is, phonetically, generally transcribed as [ʃ]) and Russian has three dental fricatives /s/, /s'/ and / ʃ /. The characteristics of these fricatives were compared by spectrographic analysis and also through perception tests of the Japanese fricatives by Russian subjects and of the Russian fricatives by Japanese subjects.

Acoustic Analysis

1. Experimental procedure

1.1 Japanese speech samples

The speech samples were the following six mono-syllables

/sa/, /su/, /so/,
/sja/, /sju/, /sjo/.

These mono-syllables were produced by three male speakers. Each syllable was uttered three times. Thus, in total, 54 speech samples were analyzed.

1.2 Russian speech samples

The speech samples were the following nine syllables

/sa/, /su/, /so/,
/s'a/, /s'u/, /s'o/,
/ ʃ a/, / ʃ u/, / ʃ o/.

These mono-syllables were produced by four male speakers of the Moscow dialect. As in the case of the Japanese speech samples, each syllable was uttered three times. Thus, in total, 108 speech samples were analyzed.

1.3 Method of analysis

Two acoustic parameters were measured using a spectrograph analysis program on a personal computer. One parameter was the frequency of the peak power in the fricative noise spectrum (NF). The other parameter was the onset frequency of the second formant transition of the following vowel (OF2). For measuring the formant, the speech samples were sampled at 10kHz with an accuracy of 12 bits per sample, and FFT analyses were performed. OF2 were measured by visual inspection of the spectrogram. As for noise frequency, the speech samples were sampled at 20kHz and the central parts of the noise

periods were extracted using a 51.2-ms Hamming window. The noise spectrum was estimated by LPC analysis and NF were determined by visual inspection of the spectrum.

2. Results

The results of the acoustic analysis are shown in Fig. 1. In the case of Japanese, /sj/ is characterized by a higher OF2 and lower NF than /s/. In Russian, /s'/ has nearly the same NF as /s/ and is characterized by a higher OF2 than /s/. On the other hand, / ʃ / has nearly the same OF2 as /s/ and a lower NF than /s/. Thus, Japanese /sj/ is located between Russian /s'/ and / ʃ / on the OF2-NF plane and has intermediate characteristics between Russian /s'/ and / ʃ /. However, its position is closer to Russian /s'/ than to Russian / ʃ /. This result conforms with the fact that Russian usually transcribes Japanese /sj/ by Russian /s'/. Another point to be noticed is that while Japanese /s/ and /sj/ and Russian /s/ and / ʃ / all exhibit the coarticulatory effect of lowering in both the OF2 and NF when followed by the vowel /o/, Russian /s'/ does not show this coarticulatory effect. It appears that a palatalized consonant has a special characteristic of a lip-rounding coarticulation with following vowel.

Perception Tests

1. Perception test of Japanese sounds by Russian subjects

1.1 Speech samples

The Japanese speech samples for the perception test were following three types of words, including nonsense words.

(1) Target: word-initial syllables

$$\begin{Bmatrix} s \\ sj \end{Bmatrix} \begin{Bmatrix} a \\ u \\ o \end{Bmatrix} \begin{Bmatrix} s \\ sj \\ p \\ t \\ k \end{Bmatrix} \begin{Bmatrix} a \\ i \end{Bmatrix}$$

48 bi syllabic words

(2) Target: word-final syllables

$$\begin{Bmatrix} s \\ sj \\ p \\ t \\ k \end{Bmatrix} \begin{Bmatrix} a \\ i \end{Bmatrix} \begin{Bmatrix} s \\ sj \end{Bmatrix} \begin{Bmatrix} a \\ u \\ o \end{Bmatrix}$$

48 bi syllabic words

(3) Target: word-medial syllables

$$\begin{Bmatrix} s \\ sj \\ p \\ t \\ k \end{Bmatrix} \begin{Bmatrix} a \\ i \end{Bmatrix} \begin{Bmatrix} s \\ sj \end{Bmatrix} \begin{Bmatrix} a \\ u \\ o \end{Bmatrix} \begin{Bmatrix} s \\ sj \\ p \\ t \\ k \end{Bmatrix} \begin{Bmatrix} a \\ i \end{Bmatrix}$$

384 tri syllabic words

In the above list, the words containing the syllables /si/ or /ti/ were excluded because

these syllables are phonetically realized as [ʃ i] or [t͡ʃi]. These words were uttered by three male speakers. They were sampled at 20kHz and stored in a computer. They were presented to the subjects in random order at intervals of 2s.

1.2 Subjects

The subjects were 5 Russian students who had studied Japanese for 3 years in Russia and 10 months in Japan. They were instructed to identify the initial(1), the final(2) and the middle(3) consonant in each word as either /s/ or /sj/.

1.3 Results

Fig. 2 shows the confusion rates between /s/ and /sj/. The over-all error rate is not so large, but there was a tendency that some of the /sj/ sounds to be identified as /s/. If it is assumed that Russian subjects consider the Japanese /sj/ and Russian /s'/ the same sound (as mentioned before), Russian subjects will discriminate Japanese /s/ and /sj/ using the phonetic boundary between Russian /s/ and /s'/. As is suggested by the data in Fig. 1, this phonetic boundary is a vertical line on the OF2-NF plane. Namely, Russian subjects discriminate /s/ and /s'/ mainly by their OF2 value. As stated before, some of the Japanese /sj/ sounds tend to have a lower OF2 when followed by vowel /o/, in which case these /sj/ sounds will be perceived as /s/ by Russian subjects.

2. Perception test of Russian sounds by Japanese subjects

2.1 Speech samples

The Russian speech samples for the perception test were 45 meaningful words which have the syllable /sa/, /su/, /so/, /s'a/, /s'u/, /s'o/, / ʃ a/, / ʃ u/, / ʃ o/ in the word-initial position. These words were uttered two times each by three male speakers of the Moscow dialect. Thus, the stimuli sound totaled 270. They were sampled at 20kHz and presented to the subjects in random order at intervals of 2s.

2.2 Subjects

The subjects were 38 Japanese students who had studied Russian for 2 months in Japan. The subjects were instructed to identify the initial consonant in each word as either /s/, /s'/ or / ʃ /.

2.3 Results

The results are shown in Fig. 3. It can be seen in the Fig. 3 that the Japanese subjects showed a large confusion between /s'/ and / ʃ /, but the confusion between /s/ and / ʃ / and the confusion between /s/ and /s'/ were very small. Data in Fig. 1 suggests that on the OF2-NF plane the Japanese phonetic boundary is an oblique line. The upper left region is /s/, and the lower right region is /sj/. Both of the Russian fricatives, /s'/ and / ʃ /, are located in the region of Japanese /sj/. The above results can be considered as a natural consequence of this acoustic pattern.

Another point to be noted in Fig. 3 is that Japanese subjects identify some instances

of Russian /s'/ as /s/. The reason for this type of error is not clear at present and further acoustic analysis of these sounds is necessary.

Concluding Remarks

The above explanation of the results of the perception test are given based on the acoustic data shown in Fig. 1. The data shown in Fig. 1 were obtained for fricatives in the mono-syllabic speech samples different from the test stimuli used in the perception test. For a more detailed discussion of the results of the perception tests, information on the acoustic characteristics of the test stimuli is necessary. For this purpose, an acoustic analysis of the speech samples in the perception test is now being conducted.

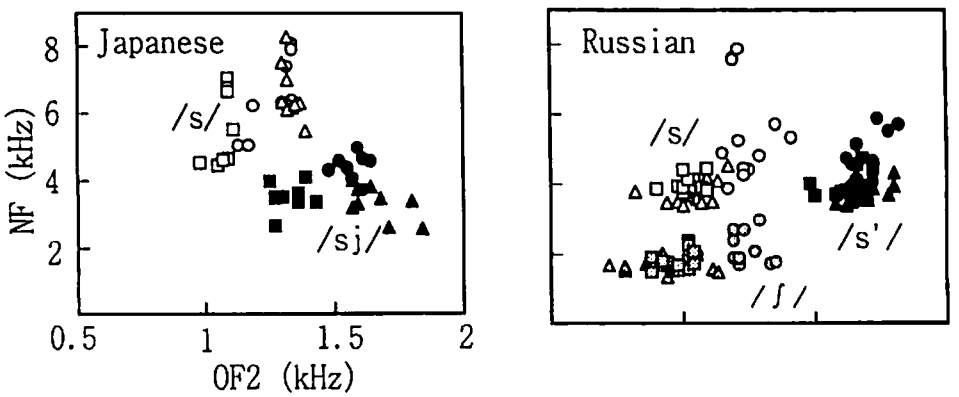

Fig. 1 Acoustic characteristics of Japanese and Russian Fricatives.
Ordinate: Frequency of the peak power in the fricative noise in the noise spectrum
Abscissa: Onset frequency of the second formant transition of the following vowel

Japanese:	○ sa	△ su	□ so
	● sja	▲ sju	■ sjo
Russian:	○ sa	△ su	□ so
	● s'a	▲ s'u	■ s'o
	○ ʃa	△ ʃu	□ ʃo

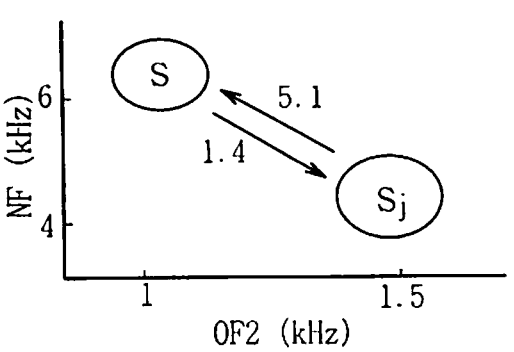

Fig. 2 Confusion rate for Japanese sounds by Russian subjects.

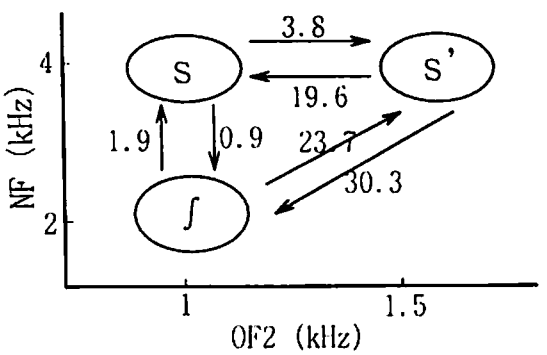

Fig. 3 Confusion rate for Russian sounds by Japanese subjects.