

# PERCEPTUAL PROPERTIES OF RUSSIANS WITH JAPANESE FRICATIVES

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## ABSTRACT

This study investigated the perceptual properties of second language learners in acquiring second language phonemes. The case where the relation between two phonemes of a second language and those of a native language changes according to following vowels was studied. The perceptual properties of Russians with regards to Japanese fricatives were examined. In the perception test, the confusion of [ɕo] with [so] was very large. This phenomenon could be caused by the difference between the transition onset time from [s'] to vowels and that from the other consonants to vowels. It is considered that, in the case of following vowel [a] and [o], Russians equated Japanese [s] and [ɕ] with Russian [s] and [s'] respectively. However, in the case of [u], they did not equate them in such a manner. This is probably because the acoustic properties of Japanese [ɰ] are very different from those of Russian [u].

## 1. INTRODUCTION

It is well known that second language learners have difficulties with non-native phonemes because of the interference of the previously acquired phonemes in their native language. In order to clarify the factors behind these difficulties, there have been many studies on the features of the interference caused by the native language. For example, the perceptual properties of Japanese learners of English with regards to American English /r/ and /l/ have been extensively investigated. In the Japanese language, the American English phonemes /r/ and /l/ are not used distinctively. Therefore, Japanese speakers have difficulties with learning these phonemes. In contrast to the above case, there are cases where the second language has two phonemes which approximately correspond to two phonemes of a native language, and each phoneme of the second language is identified with the nearest native phoneme. In this case, the error rate of discrimination between two phonemes of the second language depends on the relation between the phonemic boundaries in the native language and the second language. There will be cases where the relation between the phonemic boundaries of a second language and those of a native language change according to following vowels. The present paper aims at studying what kind of perceptual difficulties emerge in such situations. From this point of view, the perceptual properties of Russians with regards to Japanese fricatives were investigated. In Japanese, there are two dental fricatives, [s] and [ɕ]. In Russian, on the other hand, there are three dental fricatives, [s], [s'] and [ʃ]. In general, it is said that Russians identify Japanese [s] and [ɕ] with Russian [s] and [s'], respectively. However, it is known that the relations between these Japanese and Russian fricatives depend upon following vowels. In this study, acoustic

analyses of Japanese and Russian fricatives were performed and also a perception test using the Japanese fricatives was given to Russians, and the characteristics of Japanese fricative perception by Russians are discussed.

## 2. ACOUSTIC ANALYSIS

### 2.1. Experimental Procedure

#### 2.1.1. Speech samples

*Japanese*--- The Japanese speech samples were bi-syllabic nonsense words which had fricatives in word-initial position. The word-initial syllables were constructed with a dental fricative [s] or [ɕ], followed by a vowel [a], [o] or [ɰ]. The vowels [i] and [e] were excluded because they could only combine with [s] or [ɕ], but not both, except in nonnative words. The second syllables consisted of [s], [ɕ], [p], [t] or [k], followed by the vowel [a] or [i]. In the case of a following vowel [i], however, there were no phones [si] and [ti]; these combinations were pronounced as [çi] and [tçi] respectively. Therefore, these combinations were also excluded from the speech samples. Thus, 48 words were used for the analysis. These words were uttered by 3 Japanese male speakers.

*Russian*--- The Russian speech samples were meaningful words which had the dental fricative [s], [s'] or [ʃ] in word-initial position. The vowels following the fricatives were the same as Japanese [a], [o] or [u]. However, there are few Russian words which have [s'o] or [s'u] in word-initial position. Therefore, the nonsense words constructed by the replacement of word initial [s] in the meaningful word by [s'] were used. In total, 45 "words" were used for the analysis. These words were uttered by 3 Russian male speakers.

#### 2.1.2. Methods of analysis

A spectrum analysis of the fricatives and a formant analysis were performed.

*Spectrum analysis of fricatives*--- The speech samples were sampled at 20kHz. The central parts of the noise periods were extracted using a 51.2ms Hamming window and FFT analyses were performed. The spectrum curves were approximated by adding two single resonance curves with different resonant frequencies. To simplify the analysis, the higher resonant frequency was determined by visual inspection and fixed to constant values according to each individual fricative and each individual vowel. Bandwidths of lower and higher peaks were fixed to 300Hz. The resonant frequency of a lower peak and the component of the D.C. were changed to obtain the optimal approximation of the spectrum. The "noise frequency (NF)" was defined as the frequency which provided the least sum of square errors.

*Formant analysis*--- The speech samples were sampled at 10kHz, and wide-band spectrograms were displayed. The onset frequency of the second formant ( $F_2O$ ) was measured by a visual inspection of the spectrogram. In the Japanese speech samples, the samples in which the devoicing of the vowel [u] occurred were eliminated.

## 2.2. Results of Analysis

### 2.2.1. Japanese

The results for Japanese are shown in Figure 1. In this figure, the ellipses represent a 90% confidence region on the data values, assuming a Gaussian distribution for the data; [s] and [ç] are well separated by two parameters, i.e. NF and  $F_2O$ .

In the case of the following vowel [a], [ç] is characterized by a lower NF and higher  $F_2O$  than that of [s]. Likewise, in the case of [o], [ç] is characterized by a lower NF and higher  $F_2O$  than that of [s], as in the case of the vowel [a]. When the case of [o] is compared with that of [a], [so] and [ço] featured a lower NF and  $F_2O$  than those of [sa] and [ça], respectively. As can be seen in Table I., the  $F_2O$  of [ço] is 0.33kHz lower than that of [ça], and the NF of [ço] is 0.22kHz lower than that of [ça]. In addition, the NF of [so] is 0.24kHz lower than that of [sa], and the  $F_2O$  of [so] is 0.31kHz lower than that of [sa]. It was observed that the vowel [o] affects the acoustic properties of [s] and [ç] nearly equally, compared to the same consonants followed by [a].

In the case of [u], as with [a] and [o], [ç] featured a lower NF and higher  $F_2O$  than that of [s]. The NF of [stu] and [çtu] are 0.27 and 0.31 kHz lower than those of [sa] and [ça], respectively, but by nearly the same  $F_2O$  as those of [sa] and [ça], respectively. Like the case of [o], it was observed that the vowel [u] affects the acoustic properties of [s] and [ç] nearly equally, compared to the same consonants followed by [a].

### 2.2.2. Russian

The results for Russian are shown in Figure 2. In Russian, as in Japanese, [s], [s'] and [ʃ] are well separated by two parameters, i.e. NF and  $F_2O$ .

In the case of [a], [ʃ] is characterized by a lower NF than that of [s], and by nearly the same  $F_2O$  as that of [s]. On the other hand, [s'] is characterized by a higher  $F_2O$  than that of [s], and by nearly the same NF as that of [s]. That is, the difference between [ʃ] and [s] is mainly in NF, and the difference between [s'] and [s] is mainly in  $F_2O$ . In the case of [o], as with the case of [a], [ʃ] featured a lower NF than that of [s], and nearly the same  $F_2O$  as that of [s]. In addition, [s'] featured a higher  $F_2O$  than that of [s], and nearly the same NF as that of [s]. When the case of [o] is compared with [a], as can be seen in Table I., the NF of [so], [s'o] and [ʃo] are 0.62, 0.71 and 0.44 kHz lower than that of [sa], [s'a] and [ʃa] respectively and the  $F_2O$  of [so], [s'o] and [ʃo] are 0.25, 0.16 and 0.27 kHz lower than that of [sa], [s'a] and [ʃa] respectively. Namely, in the case of [o], the NF and the  $F_2O$  decreased in all consonants. The tendency of the decrease in Russian is as same as that in Japanese.

In the case of [u], as with [a] and [o], [s'] has a higher  $F_2O$  than that of [s], and nearly the same NF as that of [s]. [ʃ] has a lower

NF than that of [s], and nearly the same  $F_2O$  as that of [s]. The NF of [su], [s'u] and [ʃu] are 1.02, 0.78 and 0.46 kHz lower than that of [sa], [s'a] and [ʃa] respectively and the  $F_2O$  of [su], [s'u] and [ʃu] are 0.38, 0.14 and 0.46 kHz lower than that of [sa], [s'a] and [ʃa] respectively. Namely, in the case of [u], like the case of [o], the NF and the  $F_2O$  decreased in all consonants. The tendency in [u] is different from in [u]. The difference between the tendency in Japanese and in Russian corresponds to the difference between the articulation of Japanese [u] and of Russian [u]: Japanese [u] is an unrounded central vowel, whereas Russian [u] is a rounded back vowel.

Furthermore, in the case of both [o] and [u], it is a remarkable phenomenon that the decrease of  $F_2O$  in [s'] is smaller than that in [s] and [ʃ]. As explained below, it is argued that this phenomenon is caused by the difference of the transition onset time from the consonant to the vowel. Moreover, this phenomenon could affect the results of the perception test mentioned below.

## 3. PERCEPTION TEST

A perception test using Japanese words as stimuli and Russian subjects was also performed.

### 3.1. Stimuli

The Japanese speech samples for the perception test were the words which were used in the acoustic analysis described above. These words were sampled at 20kHz and stored in a computer. They were randomized with each speaker and recorded on three tapes by each speaker. They were presented to the subjects at intervals of 2s, and a beep sound was presented every 10 stimuli.

### 3.2. Subjects

The subjects were 27 Russian students who had studied Japanese for 1 month in the Japanese Department of the Institute of Asian and African Countries at Moscow State University. The subjects were instructed to identify the initial consonant in each word as either [s] or [ç] and mark either "s" or "sj" on answer sheets. Japanese [ç] was represented by "sj", so that the Russian subjects would not confuse Japanese [ç] with Russian [ʃ].

### 3.3. Results

The results of the perception test using Japanese words and Russian subjects are shown in Table II. In the case of [a], the confusion between [s] and [ç] is very low; the error rate was only a few percent. In the case of [u], as with [a], confusion between [s] and [ç] was very small. In the case of the vowel [o], however, confusion of [so] with [ço] was small, but confusion of [ço] with [so] was very large; the error rate was 24 %.

## 4. Discussion

The results of the perception test using Japanese fricatives and Russian subjects were characterized by a larger confusion of [ço] with [so] compared with a smaller confusion of [so] with [ço] and less confusion between [sa] and [ça]. This result

corresponds well with the results of the acoustic analysis presented in Figure 3. In Figure 3, in the cases of following vowel [a] and [o], Japanese [s] overlaps with Russian [s], and Japanese [ɕ] is located closer to Russian [s'] than Russian [ʃ]. Therefore, there is a possibility that Russian speakers would distinguish Japanese [s] from [ɕ] on the basis of the relation between Russian [s] and [s']. Incidentally, this conforms to the fact that Russians generally transcribe Japanese [ɕa], [ɕo] and [ɕu] as cя, cэ and cю, respectively, which stand for [s'a], [s'o] and [s'u], when they transcribe Japanese sounds with Russian letters. According to Figure 3, Japanese [sa] and [ɕa] almost overlap with Russian [sa] and [s'a], respectively. Therefore, if Russians distinguish [sa] and [ɕa] in such a manner, the confusion between [sa] and [ɕa] should be small. However, in the case of [o], Japanese [ɕo] is located midway between Russian [s'o] and [so]; therefore [ɕo] should be confused with [so]. This corresponds well with the results of the perception test.

The reason why the relation of Japanese [ɕ] to Russian [s] and [s'] followed by [o] is different from that followed by [a] is that, as mentioned in the results of the analysis, lowering of F<sub>2</sub>O in [s'o] is smaller than that in [so]. The cause of lowering of F<sub>2</sub>O in [s'o] is inferred as below. Visual inspection showed that there was a spectral peak in the fricative portion of the stimuli which was connected to F<sub>2</sub> in the vowel portion. We called this spectral peak the F<sub>2</sub> of the fricatives. In Japanese [s], [ɕ], and Russian [s] and [ʃ], the onset of the transition from this F<sub>2</sub> to vowel F<sub>2</sub> is in the fricative portion. That is, the voice onset follows the onset of the formant transition in these cases. On the other hand, in Russian [s'], the onset of the formant transition nearly coincides with the voice onset. In other words, in Japanese [s], [ɕ], and Russian [s] and [ʃ], the tongue starts to move from the middle of the fricative portion to the vowel articulation. In Russian [s'], however, the tongue holds its configuration until the end of the fricative portion and does not start to articulate the following vowel until the end of the

fricative portion.

Due to the above facts, with Russian [s'], the F<sub>2</sub>O of [a] is relatively close to that of [o], while, in Japanese [ɕ], the F<sub>2</sub>O is different from that of [a]. This is because the F<sub>2</sub>O decreases to the F<sub>2</sub> frequency of the following vowel. However its decrease is larger for [o] and smaller for [a], due to the variation of the F<sub>2</sub> frequency of the following vowels. Therefore, the F<sub>2</sub>O of Japanese [ɕa] is relatively close to that of Russian [s'a]; the F<sub>2</sub>O of Japanese [ɕo], however, is much lower than that of Russian [s'o]. Consequently, on the NF-F<sub>2</sub>O plane [ɕo] is located midway between Russian [so] and [s'o].

The results of the perception test showed that, in the case of [u], the confusion between [su] and [ɕu] was small. Russian [u] is the closest Russian vowel to Japanese [u]. In Figure 3, Japanese [su] is located midway between Russian [su] and [s'u]. Therefore, if Russians equated, as in the case of [a] and [o], Japanese [su] and [ɕu] with Russian [su] and [s'u], the confusion should be large. In fact, however, the confusion was small, so it appeared that they did not equate in such a manner. This is probably because the acoustic properties of Japanese [u] are very different from those of Russian [u]: Japanese [u] is an unrounded central vowel, whereas Russian [u] is a rounded back vowel. It is an interesting question what criteria they apply in discriminating between Japanese [su] and [ɕu].

In conclusion, this paper reveals that the relations between the acoustic properties of Japanese and Russian fricatives vary according to their following vowels. Therefore, the difficulties experienced in learning Japanese fricatives by Russians depend upon the properties of the following vowels. Furthermore, it was found that there is the case where the equating of [ɕ] with [s'] does not occur when the difference in acoustic properties between following vowels is sufficiently large. It is an interesting question for future investigation what kind of criteria second language learners use in such a case in the perception of the second language consonant.

|      | Japanese           |                 |       | Russian            |                 |
|------|--------------------|-----------------|-------|--------------------|-----------------|
|      | F2 onset frequency | Noise frequency |       | F2 onset frequency | Noise frequency |
| [sa] | 1.32               | 4.71            | [sa]  | 1.29               | 4.93            |
| [so] | 1.01               | 4.47            | [so]  | 1.04               | 4.31            |
| [su] | 1.25               | 4.44            | [su]  | 0.91               | 3.91            |
| [ɕa] | 1.63               | 3.99            | [s'a] | 1.76               | 4.83            |
| [ɕo] | 1.30               | 3.77            | [s'o] | 1.60               | 4.12            |
| [ɕu] | 1.75               | 3.68            | [s'u] | 1.62               | 4.05            |
|      |                    |                 | [ʃa]  | 1.30               | 2.65            |
|      |                    |                 | [ʃo]  | 1.03               | 2.21            |
|      |                    |                 | [ʃu]  | 0.86               | 2.09            |

Table I. The mean value of the F2 onset frequency and the Noise frequency, in kHz.

| Following vowel [a] |          |     | Following vowel [o] |          |     | Following vowel [u] |          |     |
|---------------------|----------|-----|---------------------|----------|-----|---------------------|----------|-----|
| Stimuli             | Response |     | Stimuli             | Response |     | Stimuli             | Response |     |
|                     | [s]      | [ɕ] |                     | [s]      | [ɕ] |                     | [s]      | [ɕ] |
| [s]                 | 98       | 2   | [s]                 | 99       | 1   | [s]                 | 96       | 4   |
| [ɕ]                 | 6        | 94  | [ɕ]                 | 24       | 76  | [ɕ]                 | 3        | 97  |

Table II. Confusion matrices for the perception test with Russian subjects in percentages.

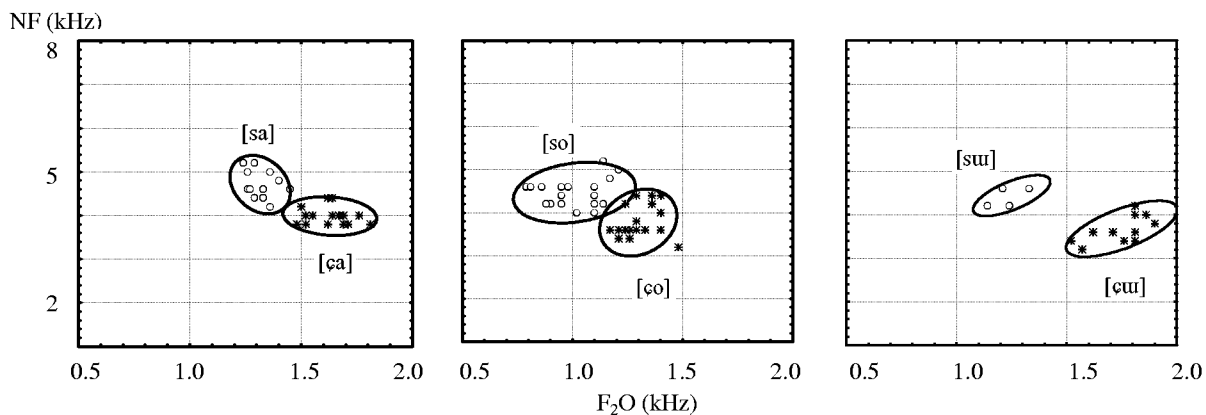


Figure 1. Results of the acoustic analysis of Japanese fricatives. The ellipses represent a 90% confidence region for the data values.

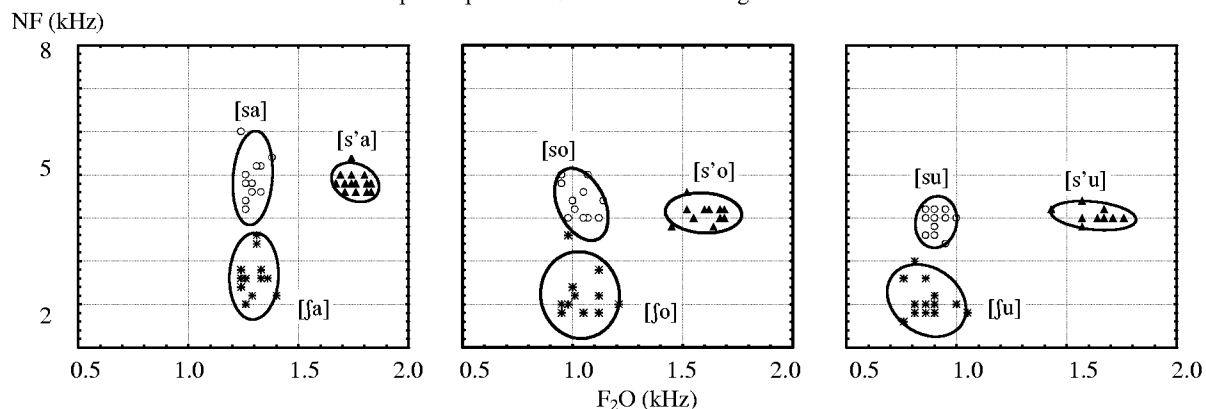


Figure 2. Results of the acoustic analysis of Russian fricatives. The ellipses represent a 90% confidence region for the data values.

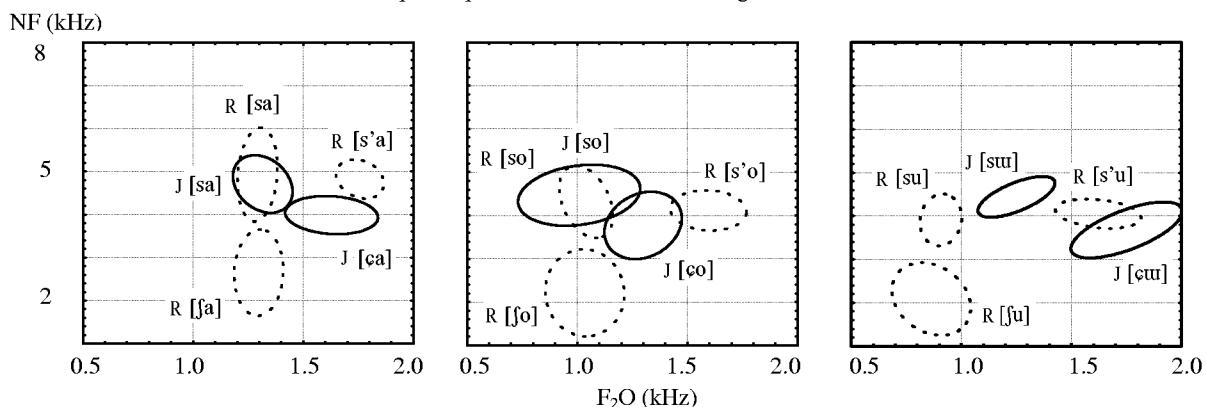


Figure 3. Relative relations between the acoustic features of Japanese and Russian fricatives. Solid line ---- Japanese; dotted line ---- Russian