WHY IS SLAVIC <č> NOT ALWAYS /t͡ʃ/?

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ABSTRACT

The Slavic affricate represented by <č> is tacitly or explicitly assumed to be /t͡ʃ/ for all Slavic languages. In this paper I revise the affricate inventories of Polish and Czech, showing that the symbol <č> stands for two different sounds: the postalveolar /t͡ʃ/ in Czech and the retroflex /t͡ʂ/ in Polish. This conclusion is supported by the results of an acoustic study of Polish and Czech affricates.

Keywords: affricates, Polish, Czech, retroflex sounds

1. INTRODUCTION

What is Slavic <č> in IPA terms? How is it realized in the individual Slavic languages? The answer to these questions should not be controversial, as several, if not all studies, tacitly or explicitly assume that the Slavic affricate <č> stands for /t͡ʃ/ in *all* Slavic languages [2], [3].

However, <č> makes a different perceptual impression depending on the language. Thus, for example, replacing the Czech <č> with the Polish <č> and vice versa would lead to a striking non-native pronunciation in both languages. A similar conclusion can be drawn with respect to other Slavic 'cross-splicing' effects such as the Lower Sorbian <č> and the Russian <č>.

The aim of this paper is to show that the affricate under question is a different sound in the two selected Slavic languages: Polish and Czech. It will be shown that, in fact, the two sounds considerably differ from each other with respect to selected parameters.

2. ACOUSTIC EXPERIMENT

The primary goal of the experiment is to prove that the Slavic affricate <č> is acoustically a different sound in Polish and Czech. It is hypothesized that the Czech <č> is the postalveolar /t͡ʃ/ and Polish <č> is the retroflex /t͡ʂ/. In addition, the affricate <č> will be occasionally compared with other coronal sounds of the same inventory.

2.1. Experimental design

In order to test the hypothesis eight speakers took part in the experiment: four native speakers of Standard Czech (two females, LS, MK, and two males, NN and KC aging from 22 to 28) and four native speakers of Standard Polish (two females, MN, MZ, and two males, JK, PW aged from 23 to 43). All speakers were monolingual and spoke a standard version of their native language.

The material consisted of words containing coronal voiceless consonants listed in (1).

(1) Phonemic systems

Czech /t, c, t͡s, <č>/

Polish /t , t͡ɕ, t͡s, <č>/

The consonants appeared in two positions: (i) word-initial before _/a/ and (ii) word-medial in the /a/_/a/ context. The vowel /a/ was chosen in order to avoid palatalization (the case of /i/) or rounding effects (the case of /u/). With one exception due to lexicon restrictions, i.e. the Czech word <*t'at*>, all the words were bi-syllabic with the stress falling on the first syllable. The words were embedded in carrier sentences. 10 repetitions of each sentence were randomized and presented in an orthographical form to the informants. The informants read the sentences at a normal speech rate. All recordings were conducted in a sound-proof laboratory at Centre for General Linguistics in Berlin.

The recordings were made at a sample rate of 22.05 kHz and were re-sampled to 11 kHz for formant analysis. The items were further analyzed with PRAAT [1].

In order to test the hypothesis the following acoustic parameters were investigated:

(2) Parameters:
- (i) the duration of the closure, the burst and the frication phase;
- (ii) the formants F1, F2 and F3 of the vowels preceding and following the consonant;
- (iii) the ranges of F1, F2, and F3 transitions of the vowels preceding and following the consonant.

In the present study there were also other parameters investigated such as (iv) the absolute and relative highest peak amplitude of the burst, (v) the frequency of the highest amplitude of the burst, and (vi) the spectral moments of the frication part: centre of gravity, skewness, and curtosis. However, due to space limitations it is only possible to discuss the selected parameters cf. (2).

For the calculations of the parameters in (2), six places in the spectrogram of the signal were determined by placing the cursor at the following points:

(3) Marking points:

(1) the beginning of the vowel preceding the consonant (V1),
(2) the end of the vowel preceding the consonant (V1),
(3) the beginning of the burst,
(4) the end of the burst,
(5) the beginning of the vowel (V2),
(6) the end of the vowel (V2)

The points were relevant to the measurements in the following way:

Ad (2i): the closure was measured from point 2 to 3, the burst from 3 to 4 and the frication from 4 to 5 (the burst and frication duration will be added and presented as frication in 2.2.)

Ad (2ii): the vowel formants F1, F2, and F3 were measured at the ending points of vowels, i.e. at 1, 2, 5 and 6. The vowel formants were obtained semi-automatically by means of Linear Predictive Coding (LPC). Prior to formant analysis the sounds were down-sampled to 11 kHz to strengthen the spectral structure of the first five formants by guiding the formant picking algorithm. The LPC was calculated by using the following parameters: 50 Hz pre-emphasis frequency, 25.6 ms analysis window duration, 1 ms time step and a 13 prediction order. Maximally five peaks from the LPC spectrum derived by peak picking were temporarily considered as formants. As in some cases a certain formant value could not be detected by the peak-picking algorithm, the three temporary formant values were checked for every spectrum and manually corrected if necessary, in order to determine the correct formant values.

Ad (2iii): the frequency ranges of the F1, F2, and F3 were computed by subtracting the frequency values at the endpoint of the formant transitions from those obtained at the midpoint of the vowel. (The midpoint of the vowel was calculated from the endpoints of the vowel as the equal temporal distance between the beginning and end of the vowel).

The statistical analyses were conducted in R environment (R Development Core Team 2010). Linear mixed effects models were employed for the variables studied as effect of language (Czech/Polish) considered a fixed effect, with nesting within a person (a random effect) [6]. Owing to the problems with heterogeneity of residuals for some of the models, the variance structure was fitted with various variances per person, which in all these cases strongly improved the fit. For Transition_Range_V2, the two-way model (with fixed effects language, Transition_Range_V2 and their interaction, and nesting within a person) was employed (cf. Fig.5&6). A similar model was applied for Formants_V2 (with fixed effects language, Formants_V2 and their interaction, and nesting within a person), (cf. Fig.3&4).

2.2. Results

The results presented in Fig.1 and Fig.2 show the average duration of closure and frication of the consonants in Czech and Polish, respectively. Note: the results for <č>, are displayed as /t͡ʃ/ in Czech and /t͡ʂ/ in Polish, according to the assumptions of the present study.

The results show a clear difference between the Czech and Polish <č>. Whereas the frication in the Czech <č> is longer than its closure (89.4 vs. 63.2 ms), an opposite scenario is found in the corresponding Polish sound: the closure is longer than the frication (79 vs. 55.6 ms). The difference between closure and duration is highly significant in both languages Polish ($p<.001$).

Furthermore, the difference between the Czech and Polish <č> with respect to frication is significant ($p<.05$) but not with respect to closure.

Potentially, it could be argued that the Polish <č> behaves more similarly to a stop where the closure is typically longer than the frication and it resembles less an affricate, cf. /t͡s/ and /t͡ʃ/ in Fig.1. However, it has been shown that such a characteristic is also typical of retroflex sounds occurring in other languages, cf. ([4],[5]).

Figure 1: Average duration of closure and frication phases in Czech consonants.

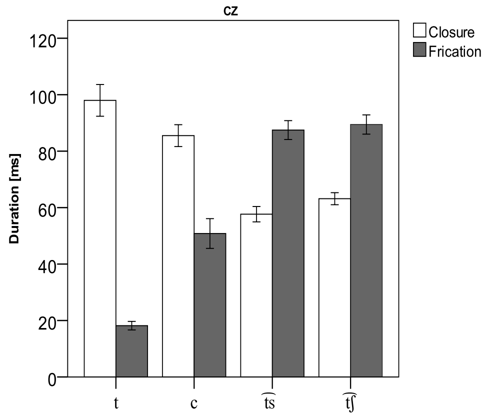
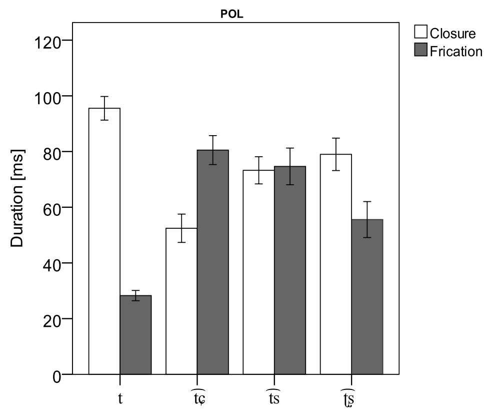


Figure 2: Average duration of closure and frication phases in Polish.



The results presented in Fig. 1 & 2. point to another difference between the Czech and Polish affricate inventory which is probably crucial for explaining the differences between languages. The Czech coronal inventory includes two affricates /t͡s/ and /t͡ʃ/ which (i) both show longer frication than closure and (ii) do not differ with respect to closure and frication duration when comparing to each other: 57.7 vs. 63.2ms for closure of /t͡s/ vs. /t͡ʃ/ and 87.5 ms vs. 89.4 ms for frication of /t͡s/ vs. /t͡ʃ/. (Both sounds do differ with respect to the spectral properties of frication, a point which will not be discussed in this paper). Yet, the Polish inventory is more complex as it consists of three affricates /t͡ɕ/, /t͡s/ and /t͡ʂ/. In contrast to Czech affricates, (i) the relation between closure and frication differs depending on the sound: whereas in /t͡ɕ/ the closure is shorter than frication (52.4 vs. 80.5 ms), in /t͡s/ both closure and frication are of almost the same length (73.3 vs. 74.7 ms) and in /t͡ʂ/ the closure is longer than frication (79 vs. 55.6 ms). Furthermore, (ii) a comparison of the closure and frication duration between the affricates reveals that the closure is shorter in /t͡ɕ/ than in /t͡s/ and /t͡ʂ/ and the frication is shorter in /t͡ʂ/ than in /t͡s/ and /t͡ɕ/. Such differences lead presumably to maintaining a better perceptual contrast between affricates of a complex system, cf. [9] for a perceptually-based hypothesis on Polish sibilants.

A considerable difference between the Czech and Polish <č> has been also found in formants of the following vowel.

Fig. 3 and 4 present the results of F1, F2, F3 of a vowel following a given consonant (measured at point 5) for Czech and Polish, respectively.

Figure 3: F1, F2 and F3 of the following vowel in Czech.

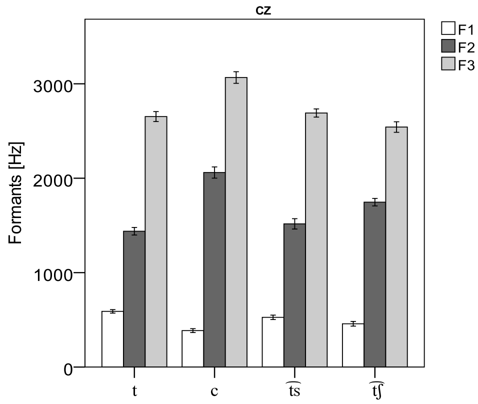
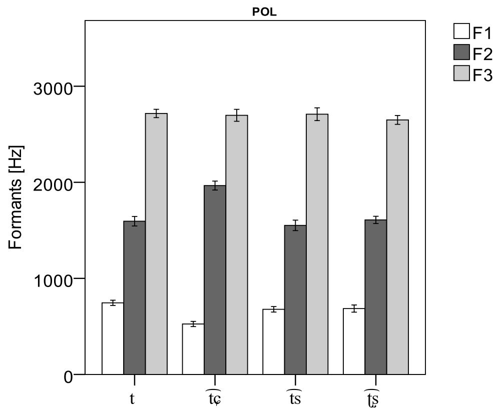


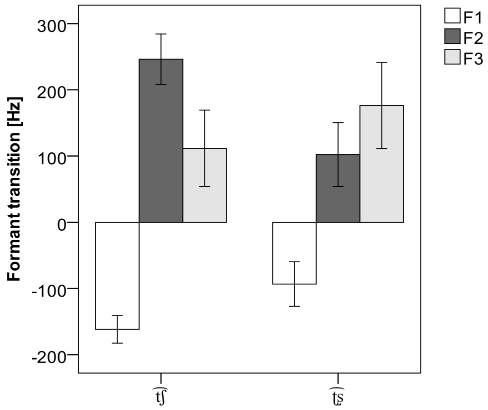
Figure 4: F1, F2 and F3 of the following vowel in Polish.



As far as <č> is concerned, a comparison of the formants of the following vowel points to differences especially in F1 and F2: F1 of the following vowel is higher in Polish (647 Hz) than in Czech (446 Hz) but a reverse scenario is found with respect to F2 which is higher in Czech (1776 Hz) than in Polish (1550 Hz). Statistically, only the difference with respect to F1 is significant ($p<.01$); $p=.0874$ for a comparison of F2 in Polish and Czech.

Finally, F1, F2, and F3 frequency ranges of [a] following <č> are presented in Fig. 5 for both languages. Again, the results refer to a word-medial position only.

Figure 5: F1, F2 and F3 transition ranges in Czech and Polish.



The statistical results reveal that the only significant difference between the Czech and Polish <č> in the frequency ranges of the vowel formant transition is found in F2 which is falling in Czech but not so in Polish ($p<.05$.).

3. DISCUSSION AND CONCLUSIONS

The present study points to significant acoustic differences between the Czech and Polish <č> which is permanently transcribed as /t͡ʃ/ in both languages. First, it was shown that the closure phase in Czech <č> is significantly shorter than the frication phase, a reverse pattern is observable in the corresponding Polish sound. Both languages also differ significantly in the frication duration, being shorter in Polish than in Czech. This latter result presumably points to an important articulatory difference, namely, the frication phase in Czech /t͡ʃ/ is articulated with the tongue blade, whereas the frication phase in the corresponding Polish sound is articulated with the tongue tip, a point confirmed by articulatory evidence available in the literature [8].

Second, the difference between the sounds is reflected in the lower F1 of the following vowel in Czech than in Polish suggesting a more raised tongue for the Czech sound.

Furthermore, the falling F2 of the following vowel in Czech strongly suggests a raised and fronted tongue blade in Czech <č>, which is typically found in inherently palatalized sounds such as /t͡ʃ/.

In summary, the acoustic differences between Czech and Polish <č> call for a revision of the symbol /t͡ʃ/ commonly used for transcribing the Polish affricate.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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