View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Hochschulschriftenserver - Universität Frankfurt am Main

Perceptual and acoustic cues of Polish coronal fricatives

Marzena Zygis [Rochoń] and Silke Hamann

Zentrum für Allgemeine Sprachwissenschaft, Berlin

E-mail: marzena@zas.gwz-berlin.de, silke@zas.gwz-berlin.de

ABSTRACT

In this paper we revise the claim made by Halle & Stevens [1] and Maddieson & Ladefoged [2] that the Polish alveolo-palatal fricatives [ɕ, ʑ] are palatalized post-alveolars [ʃʲ, ʒʲ]. On the basis of perceptual experiments we show that alveolo-palatal fricatives and palatalized post-alveolars are two separate sounds which are distinguished not only by Polish native speakers but also by German ones. This claim is partly attested by centre of gravity measurements of the two sibilants.

1. INTRODUCTION

The present study is concerned with the Polish sibilant system as given in Table 1.

dental/ alveolar	retroflex	palatalized post-alveolar	alveolo-palatal
s, z	ʂ, ʐ	ʃʲ, ʒʲ	ɕ, ʑ

Table 1: Polish sibilant system.

In contrast to traditional descriptions [3, 4], we assume that the Polish non-palatalized post-alveolar phonemes are retroflexes and not laminal palato-alveolars, see [5]. Their palatalized counterparts [ʃʲ, ʒʲ]are post-alveolars, since retroflexes generally reject secondary palatalization [5, 6].

While [ɕ] and [ʑ] are phonemes in Polish, the status of [ʃʲ] and [ʒʲ] is not clear. The palatalized post-alveolars do not occur in native vocabulary, and in loan words they are found overwhelmingly before /i/, e.g. To[ʃʲ]iba 'Toshiba'. Marginal evidence for a possible phonemic status comes from a few proper names such as [ʃʲ]aak 'Sjaak'.

The Polish alveolo-palatals [ɕ] and [ʑ] are often considered to be the palatalized counterparts of /ʂ/ and /ʐ/, i.e. [ɕ, ʑ] = [ʃʲ, ʒʲ], since both sound classes are represented by the same phonological features [–anterior, +distributed, –back], see [1, 7]. The phonetic non-discriminability of these two Polish sounds is implied in [2], where it is said that 'it is […] appropriate to refer to [ɕ] as a palatalized post-alveolar, with the IPA term alveolo-palatal being a possible alternative' (p. 154).

In the present paper we argue that [ɕ, ʑ] and [ʃʲ, ʒʲ] constitute two separate phonetic categories. Evidence for this claim stems from two perceptual experiments; one with Polish native speakers only, the second comparing the task of Polish and German native speakers in distinguishing the segments under question. The results of these experiments are partly attested by acoustic measurements. Both perception experiments and the acoustic measurements are restricted to the voiceless segments [ɕ] and [ʃʲ]. We included the sibilants [ʂ] and [s] as control items in our perception experiments to give a complete picture of the acoustics of the Polish sibilant system.

Our study differs from the one conducted by Liskier (2001), cf. [8], who investigated perceptive judgements of full syllables, isolated fricative noises, and onsets of post-fricative residues with respect to [s], [ʂ], and [ɕ]. The palatalized post-alveolar is not investigated in [8].

2. PERCEPTION EXPERIMENTS

We recorded 10 tokens of the Polish sibilants [s], [ɕ], [ʂ], and [ʃʲ] in 9 contexts, namely in prevocalic, postvocalic, and intervocalic position, with the three vowels [a i u], cf. (1).

Prevocalic context	(i, u, a) _	(1)
Postvocalic context	_ (i, u, a)	
Intervocalic context	i_ i, u_u, a_a	

These stimuli were read from a list by two native speakers of Polish, one female (MZ) and one male (KZ). The recordings were made at a 22.05 kHz sample rate on DAT tape in a sound-proof room, digitalized and analyzed with the PRAAT programme.

2.1. EXPERIMENT 1

For the first experiment, we used the four sibilants in the prevocalic context with the vowel [a] of speaker MZ only. The 10 tokens of [sa, ɕa, ʂa, ʃʲa] were repeated 5 times, and the resulting set was randomized. The 200 stimuli were presented to 20 Polish native speakers who had to listen to one stimuli at the time and classify it as either [s], [ɕ], [ʂ], or [ʃʲ] by clicking at buttons with the Polish orthographical equivalents of "sa", "sia", "sza", and "szia", respectively. The resulting classification is given in Table 2.

s	ɕ	ʃʲ	ʂ
99.9	98.5	96.3	99.8

Table 2: Correct classification (in percent) of the four Polish sibilants by 20 Polish native speakers.

Table 2 shows that the listeners performed worst in identifying the palatalized post-alveolar [ʃʲ]. The high number of correct identifications for this class (96.3 %), however, shows that the Polish listeners have no problem distinguishing this class from the alveolo-palatal class. Interestingly, misclassification occurred mostly between the alveolo-palatal and the palatalized post-alveolar, in both directions, see Table 3.

		Response		
		ɕ	ʃʲ	ʂ
Stimulus	ʃʲ	3.1	96.3	0.6
	ɕ	98.5	1.4	0.1

Table 3: Classification (in percent) of [ʃʲ] and [ɕ] by 20 Polish native speakers.

Some listeners reported independently that they found it difficult to distinguish between the [ʃʲ] and [ɕ] items, and thus confirmed the results of the perception experiment.

2.2. EXPERIMENT 2

In the second experiment, we tested the influence of the vowel context and of the native language background (Polish vs. German). We restricted our stimulus set to one token of all four sibilants in each of the nine contexts as described under (1) (again by speaker MZ). The tokens within the same context were paired. Examples of these pairs are given in (2).

ʂi	ɕi	(2)
uɕ	uɕ	
aʃʲa	asa	
iɕ	is	

Each pair was repeated three times. The set of 270 pairs was presented in a randomized order to 25 Polish and 25 German native speakers in an AX test, i.e. the listeners had to decide whether the items in the pairs (A and X) were identical or not.

We posed the hypothesis that [ʃʲ] and [ɕ] are not distinguished equally well by Polish and German native speakers. Furthermore, we tested whether the German speakers were able to distinguish [ɕ] and [ʃʲ] or [ʂ] and [ʃʲ]. We expected them not to perceive a difference between these pairs as both consist of categories that are very close to the /ʃ/ category in German.

A subset of the results is presented in Table 4. The figures indicate the numbers of correctly discriminated [ʃʲ] vs. [ɕ] pairs by Polish and German listeners in different vocalic contexts, with percentages in brackets.

In order to test our hypothesis on the discriminability of [ʃʲ] and [ɕ] we calculated a χ^2 test. Table 5 summarizes the results of the test in all three contexts showing that Polish listeners discriminated the [ʃʲ] and [ɕ] pair better than German ones. However, the difference was not as large as we expected.

ʃʲ - ɕ		Polish listeners			German listeners		
V_	i_	75	212 (94.2)	610 (90.3)	74	155 (68.9)	488 (72.3)
	u_	66			33		
	a_	71			48		
_V	_i	74	189 (84)		69	163 (72.4)	
	_u	67			60		
	_a	48			34		
V_V	i_i	73	209 (92.9)		61	170 (75.6)	
	u_u	68			50		
	a_a	68			59		

Table 4: Correct discrimination of [ʃʲ] and [ɕ] by Polish and German listeners in postvocalic (V_), prevocalic (_V) and intervocalic (V_V) contexts, with a total number of 675 answers (percentages in brackets).

	Polish listeners	German listeners	Sum
Discriminated	610	488	1098
Not discriminated	65	187	252
Sum	675	675	1350

Table 5: Summary of the results in all three contexts.

The calculation of the χ^2 test reveals that [ʃʲ] and [ɕ] are not distinguished equally well by both groups of speakers. The empirical critical χ^2 amounts to 72.62 which is highly significant ($\chi^2_{0.01} = 6.63$). Thus, our hypothesis that the two groups of speakers differ in their performance was confirmed.

Table 6 shows the results of the experiment with respect to the discrimination of [ʃʲ] and [ʂ].

ʃʲ - ʂ		Polish listeners			German listeners		
V_	i_	38	175 (77.8)	459 (68.0)	38	139 (61.8)	383 (56.7)
	u_	67			50		
	a_	70			51		
_V	_i	23	155 (68.1)		31	106 (47.1)	
	_u	73			26		
	_a	59			49		
V_V	i_i	10	129 (57.3)		27	138 (61.3)	
	u_u	49			48		
	a_a	70			63		

Table 6: Discrimination of [ʃʲ] and [ɕ] by Polish and German listeners in postvocalic (V_), prevocalic (_V) and intervocalic (V_V) contexts (percentages in brackets).

Comparing Table 6 to Table 4 we see that [ʃʲ] and [ʂ] were more difficult to discriminate than [ʃʲ] and [ɕ]. Again, German listeners performed worse than Polish listeners (383 vs. 459 correct answers), with one exception: in an intervocalic context the Polish listeners obtained slightly worse results than the German listeners (138 vs. 129). Furthermore, the Polish listeners had problems with

discriminating [ʃʲ] and [ʂ] in _i context. We interpret this difficulty as the influence of the phonological knowledge that the retroflex cannot occur before a front vowel in Polish (but changes into the palatalized post-alveolar).

In sum, the results of the second perception experiment confirm that [ɕ] and [ʃʲ] are distinct phonetic categories for Polish listeners. German listeners could also distinguish these two categories, though slightly worse, showing that there must be some influence by the native perceptual background. Furthermore, both groups of listeners had problems distinguishing between [ʂ] and [ʃʲ], which we assume to be due to the very similar place of articulation of the two segments. Finally, the Polish listeners seemed to be influenced by their phonological knowledge in distinguishing [ʂ] and [ʃʲ] in _i context.

3. ACOUSTIC MEASUREMENTS

In contrast to previous studies on the acoustics of the Polish sibilants where the intensities and frequencies of sibilant spectral peaks (F_1, F_2, F_3, F_4) were investigated [3], we measured the centre of gravity (or spectral mean, henceforth COG) of all four Polish sibilants, including the palatalized post-alveolar [ʃʲ]. The COG was calculated for the whole duration of the fricative excluding the first and last 5% of the signal. According to Gordon et al.'s cross-linguistic study [9], COG correlates with the size of the front cavity and is higher for front tongue articulations and descends for back articulations. Therefore we expected the palatalized post-alveolar tokens to have COG values that differ from those of the alveolo-palatals.

Since secondary palatalization is often acoustically realized only in the second half of the palatalized segment, we also divided the sibilant tokens into three equal intervals and calculated COG values for each interval.

The results for the two speakers differ not only gender-specifically (cf. [9] for similar differences in centre of gravity measurements), therefore we represent and discuss them separately. The COG values for speaker MZ (female) for all four sibilants in _a context are depicted in figure 1.

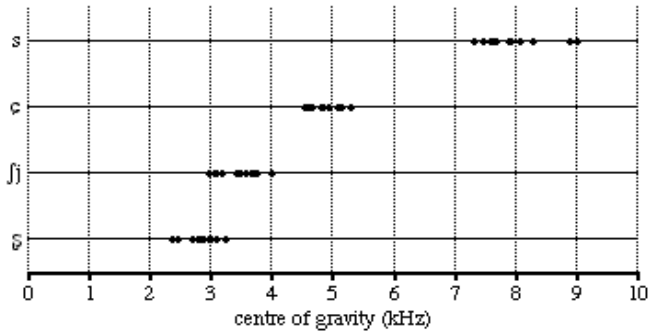

Figure 1: COG values for the Polish sibilants [s, ɕ, ʂ, ʃʲ] in _a context for speaker MZ (female).

Figure 1 shows that the values for the [ʃʲ] tokens of MZ lie between those of the [ɕ] and the [ʂ] tokens, and cluster as one class. [ɕ] and [ʃʲ] are clearly distinct; no overlap occurs. However, some overlap between [ʂ] and [ʃʲ] values can be observed. The values for the tokens [ɕ], [ʂ], and [s] cluster into clearly distinct classes, descending from [s] with the highest values, to [ɕ] with mid values, to [ʂ] with lowest values. The three classes show no overlap at all. These measurements attest our expectations in as far as the COG for the [ʃʲ] tokens lies between those of [ɕ] and [ʂ].

The results for the COG measurements for speaker KZ (male) are given in figure 2.

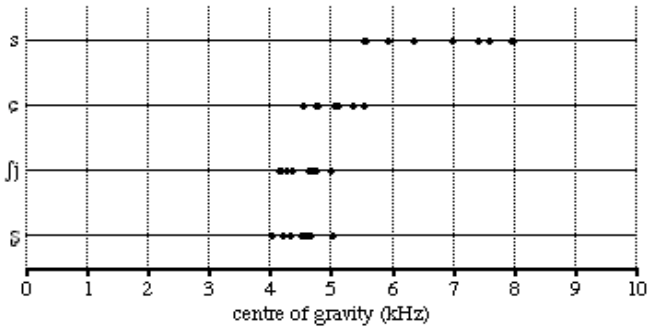

Figure 2: COG values for the Polish sibilants [s, ɕ, ʂ, ʃʲ] in _a context for speaker KZ (male).

The COG measurements for speaker KZ show some overlap between the [ʃʲ] and [ɕ] values, in contrast to the results of speaker MZ, cf. figure 1. Furthermore, KZ's values for [ʃʲ] totally overlap with those of [ʂ]. For speaker KZ the COG thus yields no reliable method to distinguish the three back sibilants in Polish.

The results of the measurements with three COG values for each token are given in figure 3 for speaker MZ in _a context.

Figure 3 shows that the tokens of [ɕa] and [ʃʲa] are distinct categories throughout all three intervals. In contrast, the tokens of [ʂa] and [ʃʲa] display large overlap for the first and second interval, but considerably differ for the third interval. We interpret this difference as the influence of palatalization on the palatalized post-alveolar [ʃʲa], which affects only the final part of this segment. The results of speaker KZ also show this difference in the temporal domain between [ʃʲa] on the one hand and [ʂa], [ɕa], and [sa] on the other.

Our acoustic measurements only partly support the results we obtained in the perception tests. [ɕ] and [ʃʲ] differ in their acoustic properties only for speaker MZ, whereas for speaker KZ an acoustical overlap for these two categories could be observed.

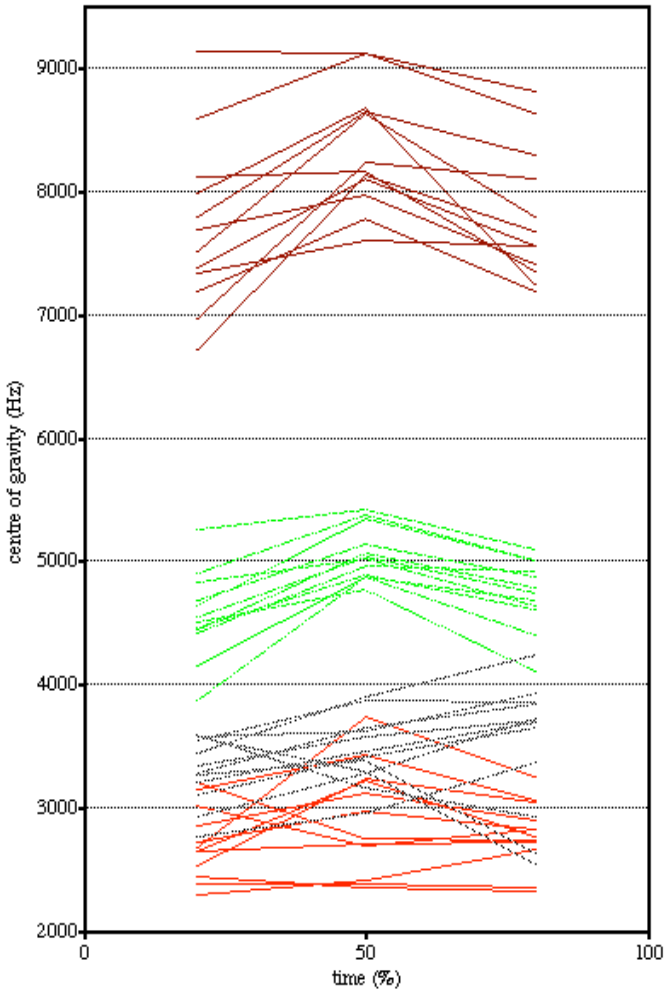

Figure 3: COG measures (in kHz) for three intervals for all 4 sibilants. The red solid line (at the bottom) stands for the retroflex [ʂ], the black dotted one for [ʃʲ], the green dashed line for [ɕ], and the maroon solid line (at the top) for [s].

4. CONCLUSION

The two perceptual experiments proved that the Polish sibilants [ʃʲ] and [ɕ] can be consistently distinguished by both Polish and German native speakers. This is in contrast to [1] and [2], who stated that these two sounds are identical. Since [ʃʲ] starts to be adopted in foreign words (not only before [i]), it should be recognized as a phonemic category.

The perceptual tests showed that the listeners had most problems distinguishing between [ʃʲ] and [ʂ], which was mirrored in the acoustic measurements, where the two sibilant classes displayed largest overlap.

For our acoustic measurements we used only the centre of gravity to describe the difference between the four Polish fricatives. This proved to be sufficient for the description of MZ's sibilants. For the speaker KZ, however, large overlap between all but the alveolar fricative occurred for this method. In order to test whether the COG is a reliable measurement to distinguish all four Polish sibilants across speakers more informants have to be included in future studies.

ACKNOWLEGMENTS

We would like to thank T. Alan Hall, Bernd Pompino-Marschall, and Christine Mooshammer for comments on earlier versions of this paper. Furthermore, we thank Radek Swiecinski for providing us with results of the first perception experiment, and Paul Boersma for advice. This research has been supported by the DFG projects GWZ-4/7-2-P1 and GWZ-4/8-1-P2.

REFERENCES

[1] M. Halle and K.N. Stevens, "The postalveolar fricatives of Polish," in *Speech Production and Language*, S. Kiritani, Hirose, H and H. Fujisaki, eds., pp. 177–193. Berlin: Mouton de Gruyter, 1997.

[2] P. Ladefoged and I. Maddieson, *The Sounds of the World's Languages*, Oxford: Blackwell, 1996.

[3] Dogil, G., "Hissing and Hushing Fricatives: A Comment on non-anterior Spirants in Polish", Manuscript University of Stuttgart, 1990.

[4] Rubach, J., *Cyclic and Lexical Phonology. The Structure of Polish*, Dordrecht: Foris, 1984.

[5] Hamann, S. and M. Rochoń, "Preferences in Sibilant Fricative Systems: Postalveolar Puzzlement in Slavic Languages", Poster presented at LabPhon 8, New Haven: Yale University, 2002.

[6] Hamann, S., "The Phonetics and Phonology of Retroflexes", Dissertation Manuscript, University of Utrecht.

[7] Hume, B., *Front Vowels, Coronal Consonants, and their Interaction in Nonlinear Phonology,* London: Garland, 1994.

[8] Liskier, L., "Hearing the Polish sibilants [s, ś, š]: Phonetic and auditory judgments," in *Travaux du Cercle Linguistique de Copenhague vol. XXXI. To Honour Eli Fischer-Jørgensen*, N. Grønnum and J. Rischel, eds., pp. 226-238. Copenhagen: C.A. Reitzel, 2001.

[9] Gordon, M., P. Barthmaier, and K. Sands, "A cross-linguistic acoustic study of voiceless fricatives," to appear in: *Journal of the International Phonetic Association.*