FORMANT FREQUENCIES OF POLISH RAISED /ɛ/ AND /a/ IN PALATAL CONTEXTS

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ABSTRACT

There is general agreement in the literature that the Polish vowels /ɛ/ and /a/ have raised allophones in the context of palatal consonants. However, extant descriptions are predominantly articulatory in nature, with formant values given by Wierzchowska [13] and Gonet [4], and a formant chart given by Nimz [7]. Also, there is some disagreement as to whether the palatals have an effect on one or both sides of the vowel. The present study explores these issues. Ten female speakers of Poznań Polish were recorded reading phonotactically well-formed nonwords disguised as surnames and embedded in carrier sentences. A balanced set of flanking consonants was used, with palatals and dento-alveolars in symmetric and asymmetric configurations. The effect of the palatals was stronger for /ɛ/. Importantly, following palatals seem to have a weaker effect than preceding ones. Thus, existing descriptions are only partially vindicated.

Keywords: vowels; Polish; allophony; raised; palatal.

1. INTRODUCTION

Polish has a relatively unremarkable six-part oral vowel system comprising /i/, /ɨ/, /ɛ/, /a/, /ɔ/ and /u/. Authorities agree that there is little allophonic variation. For example, Wierzchowska [14, pp. 128–129] devotes about one-third of a page to a section titled "Vowel variants", and mentions positional variants of /a/, /ɛ/ and /ɔ/, most usually in an environment of 'soft' (i.e. palatal) consonants on both sides. Jassem [6, p. 106] is more specific, but also more terse, in saying "[t]here is little contextual allophony, but /e/ [our /ɛ/] is half-close between palatals, as in [pjeɕɲ] *pieśń* 'song' and /a/ is Cardinal 4 in this position, e.g. [ˈdʑiɕaj] *dzisiaj* 'today'". There is some disagreement on the details of the palatal effect. Benni [1] claims that palatal consonants on both sides of a vowel raise it more than just one neighbouring palatal consonant. Wierzchowska [13, 14] claims that palatal context following a vowel raises the vowel more than a preceding palatal consonant. Other sources (Steffen-Batogowa [11], Ostaszewska and Tambor [10], Dukiewicz [2], Wiśniewski [15]) maintain that raised allophones occur only if palatal consonants or [i̯] surround/follow a vowel; in other words, a preceding palatal does not trigger raising.

Importantly, while acoustic studies of the entire vowel system do exist (e.g. [4], [8]), there is little acoustic data for the raised allophones. Wierzchowska [14] claims that the raised /a/ has an F1 of "about 700 Hz" and an F2 of "about 1600 Hz", while the F1 of the raised /ɛ/ is "about 400 Hz", with an F2 of "about 2000 Hz"; but she does not offer any details of the sources of the data. Gonet [4] explores the effect of palatals, but only on the left-hand side, concluding that only one of his four male speakers shows a statistically significant difference between the raised and plain allophones. Nimz [8] gives an F1–F2 vowel chart showing the allophones; numerical data are averages for each vowel phoneme. From the chart, it can be gleaned that the raised [e] has an F1 of about 450 Hz, and an F2 of about 1850 Hz, as opposed to averages of 548 Hz and 1559 Hz for /ɛ/. The palatal-context allophone of /a/ differs in F2 only: F1 is about 650 Hz (the mean for /a/ is 637 Hz), while F2 is about 1550 Hz (mean for /a/ 1251 Hz). All of these data come from male speakers.

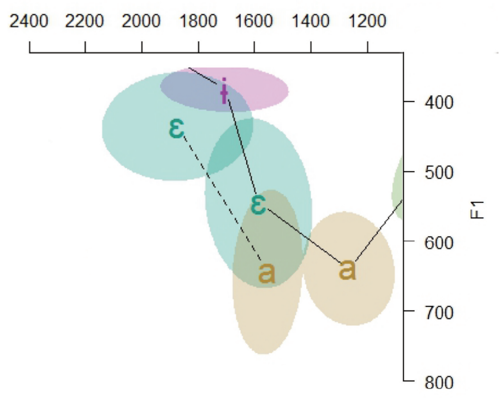

Figure 1: The relevant portion of the formant chart from Nimz [8, p. 101]. The solid line is the perimeter of the vowel space; the dashed one connects the palatal-context allophones.

The present study aims to address this descriptive gap. In addition to providing acoustic data for the two vowels in palatal contexts, it will also attempt to establish if there are differences between contexts that are symmetrically palatal or not.

2. METHOD

2.1. Informants

The data for the present study comes from a larger project investigating the basic acoustics of Polish vowels and palatal consonants. In order to minimize inter-speaker variability, ten female speakers of Poznań Polish were selected from the total pool of speakers. They were all natives of Poznań (a major urban centre of the Greater Poland region in the western part of the country, pop. 550,000) or the immediate vicinity. Since the chief differences between Poznań Polish and the national standard pertain to details of sandhi consonant voicing, data on vowels data can be argued to be broadly representative of Standard Polish. All the speakers were aged 21–38 at the time of recording. They were administration staff or students of a local institution of tertiary education.

2.2. Material

The material consisted of read speech. For the larger project, each informant read 150 carrier sentences in which target words were embedded. The target words contained all Polish vowels in two consonantal frames, the two vowels under investigation here in four consonantal frames, and some additional material. The order within each block was randomized.

The carrier sentence for the present study was *Ta pani nazywa się Anna X* 'This woman's name is Anna X' where *X* was a phonotactically legal non-word disguised as a surname. This was done because obtaining a minimal quadruple of the required structure is impossible with real Polish words. For both vowels, the minimal quadruple placed the vowel in a stressed syllable, in a symmetric or asymmetric consonantal context, with a palatal or dento-alveolar sound on one or both sides. The dento-alveolars were chosen to be non-palatal but only minimally different in terms of place of articulation. The procedure resulted in four repetitions of each context per speaker. This is summarized in Table 1.

Table 1: The target words.

V	Word	Transcription	Context
/ɛ/	Ciesiak	/ˈtɕɛɕak/	palatal–palatal
	Ciesak	/ˈtɕɛsak/	palatal–dento-alv.
	Cesiak	/ˈtsɛɕak/	dento-alv.–palatal
	Cesak	/ˈtsɛsak/	dento-alv.–dento-alv.
/a/	Ciasiak	/ˈtɕaɕak/	palatal–palatal
	Ciasak	/ˈtɕasak/	palatal–dento-alv.
	Casiak	/ˈtsaɕak/	dento-alv.–palatal
	Casak	/ˈtsasak/	dento-alv.–dento-alv.

2.3. Procedure

The recordings were made in a sound-treated booth. The informants read the sentences, presented on a computer screen, at a self-controlled pace. Sound was captured using an MXL-770 condenser microphone, placed about 30 cm in front of the speaker's mouth and slightly to the side, connected to a PC via an Edirol UA-25 USB audio interface. The recordings were digitized at 44,100 Hz, 16 bits, and saved to the computer's hard disk.

The resulting recordings were force-aligned using the speech services offered by the CLARIN-PL consortium (http://mowa.clarin-pl.eu/). The boundaries for each target vowel were manually corrected to include the voiced portion between the voiceless fricatives/affricates on both sides, to within one glottal cycle.

A Praat script was used to make automated measurements of the first three formants and durations of all target vowels, along with reference charts used to visually assess the immediate results. The formant measurements were taken as averages in a window from 20% to 70% of the vowel's duration. Outliers were identified visually and either measured manually or discarded as invalid due to speaker errors or factors such as breathy voice.

To further minimize inter-speaker variability, the measurements were normalized using the Watt–Fabricius method [3], as offered by the NORM suite, which is an online frontend to the *vowels* R package (Thomas and Kendall [12]).

3. RESULTS

Figure 2 offers a graphical summary of aggregate results for all the consonantal frames in the present study, plus all Polish vowels from one of the consonantal frames in the larger project, i.e. *b–ty* (*bity*, *byty* /bɨtɨ/, *bety*, *baty*, *boty*, *buty*).

As can be seen, the normalization procedure improved the overlap between the individual speaker vowel spaces on the vertical (F1) axis. As the 1 SD ellipses suggest, the spread of /ɛ/ was as expected, along a diagonal line from higher F1 and lower F2 values at one end towards lower F1 and higher F2 at the other. The measurements for /a/ did not show such a clear pattern; in particular, it was not apparent if there was a raising effect (as suggested by Wierzchowska), or a fronting pattern (as suggested by Jassem and Nimz).

The distributions for /ɛ/ and /a/ were inspected in more detail. A two-dimensional density plot for the two vowels after normalization, limited to measurements from the palatal and dento-alveolar consonantal frames, is presented in Figure 3.

Figure 2: F1 and F2 of Polish vowels. Top: Raw Hz. Bottom: Normalized according to Fabricius et al. [3]. Colours for vowel categories; ellipses for 1 SD confidence intervals for each speaker; symbols for speaker means.

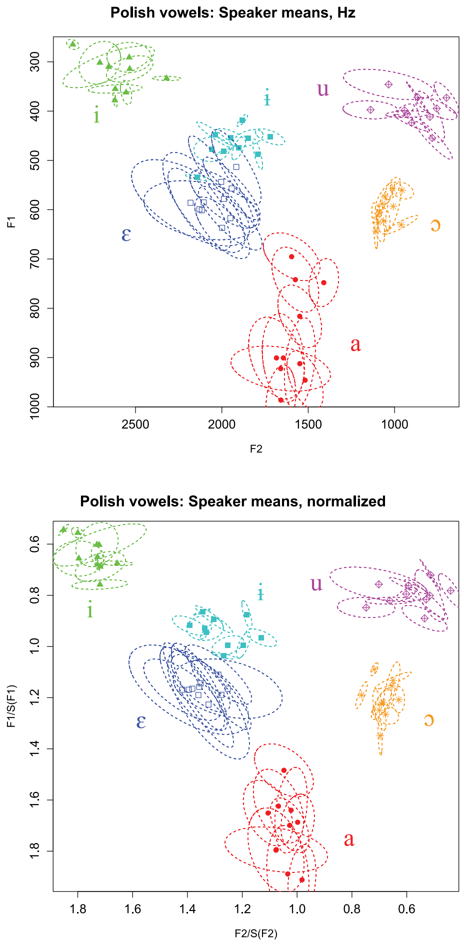

Figure 3: A 2D density plot for /ɛ/ and /a/. F1 and F2 stand for the Fabricius et al. [3] measures, i.e. Fx/S(Fx).

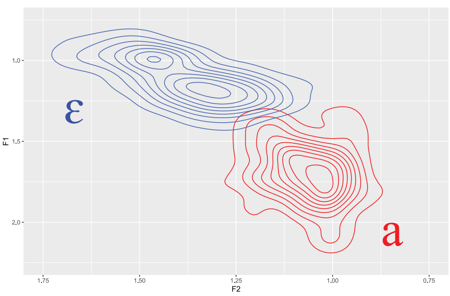

Fig. 3 shows two clear maxima for /ɛ/ but arguably only one for /a/. This may reflect the accepted views on the allophony of /ɛ/ but not necessarily of /a/.

To investigate further, data from the palatal and dento-alveolar contexts were analysed statistically.

From the descriptives in Table 2, it seems that the symmetrical and left-side palatal contexts have very clear effects, in particular for F1 in /ɛ/, and F2 in both vowels. The role of the right-hand palatal context is less well-defined.

Table 2: Descriptive statistics for the first two formants of /ɛ/ and /a/, by context on both sides. Pal = palatal; d-a = dento-alveolar.

V	Context	F1	SD	F2	SD
ɛ	pal–pal	0.98	0.08	1.50	0.10
	pal–d-a	1.11	0.08	1.37	0.13
	d-a–pal	1.22	0.10	1.32	0.11
	d-a–d-a	1.23	0.06	1.22	0.07
a	pal–pal	1.62	0.20	1.13	0.11
	pal–d-a	1.69	0.13	1.07	0.07
	d-a–pal	1.76	0.18	1.05	0.08
	d-a–d-a	1.71	0.17	1.01	0.07

Mixed-effect linear regression using the *rbrul* R package [6], ver. 3.1.1, was employed to explore the effects in more depth. Models were fitted separately on the normalized F1 and F2 data, with Speaker as a random factor, and Left and Right context as fixed factors. The best models included all the factors in all but one cases. However, the effect sizes differed considerably. The models are summarized below in a slightly abbreviated format.

```
F1 in /ɛ/
     AIC      BIC   logLik deviance df.resid
  -349.7   -331.1    180.9   -361.7      158

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.5903 -0.7304 -0.0232  0.6172  3.7571

Random effects:
 Groups   Name        Variance  Std.Dev.
 Speaker  (Intercept) 0.0001086 0.01042
 Residual             0.0063550 0.07972

Fixed effects:
            Est.   S.Error  df      t value   Pr(>|t|)
(Intercept) 1.232  0.013    83.360  94.596    <2e-16***
LeftP      -0.117  0.018   155.057  -6.407 1.69e-09***
RightP     -0.002  0.018   156.659  -0.110     0.913
LefP:RigP  -0.133  0.025   159.197  -5.267 4.45e-07***

F2 in /ɛ/
     AIC      BIC   logLik deviance df.resid
  -281.5   -266.0    145.7   -291.5      159

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.2547 -0.3989  0.0946  0.5586  2.1588

Random effects:
 Groups   Name        Variance Std.Dev.
 Speaker  (Intercept) 0.002146 0.04632
 Residual             0.008985 0.09479

Fixed effects:
            Est.  S.Error  df      t value   Pr(>|t|)
(Intercept) 1.211 0.020    19.868  61.818    <2e-16***
LeftP       0.171 0.015   155.522  11.333    <2e-16***
RightP      0.118 0.015   154.491   7.836 7.01e-13***
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F1 in /a/
     AIC      BIC   logLik deviance df.resid
  -197.8   -179.1    104.9   -209.8      160

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.66651 -0.62438 -0.00845  0.53615  2.50680

Random effects:
 Groups   Name        Variance Std.Dev.
 Speaker  (Intercept) 0.01578  0.1256
 Residual             0.01381  0.1175

Fixed effects:
            Est.  S.Error  df     t value   Pr(>|t|)
(Intercept) 1.709  0.044  13.506  38.882  2.94e-15***
LeftP      -0.019  0.026 156.157  -0.748  0.455784
RightP      0.054  0.026 156.033   2.072  0.039882*
LefP:RigP  -0.127  0.037 156.206  -3.456  0.000706***

F2 in /a/
     AIC      BIC   logLik deviance df.resid
  -368.5   -352.9    189.2   -378.5      161

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.7248 -0.4359  0.0729  0.5451  3.3910

Random effects:
 Groups   Name        Variance Std.Dev.
 Speaker  (Intercept) 0.001591 0.03989
 Residual             0.005382 0.07336

Fixed effects:
            Est.  S.Error  df     t value   Pr(>|t|)
(Intercept) 1.009  0.016  18.280  62.485    <2e-16***
LeftP       0.066  0.011 156.294   5.761  4.31e-08***
RightP      0.051  0.011 156.171   4.505  1.29e-05***

Significance codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
'.' 0.1 ' ' 1
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As can be seen, the left-side palatal context has an effect of decreasing F1 and increasing F2, as expected. From the estimates, the larger *t*-values and the *p* values above, the effect seems to be more pronounced for /ɛ/. Palatals on the right side of the vowel have a less clear effect. In particular, the effect of the right-side context was not statistically significant for F1 in /ɛ/, and was borderline for F1 in /a/ (a *t* of |3| is usually considered a cut-off value). There was also an effect of the interaction between the left and right context for F1 in both vowels, but not for F2. (Note that this interaction, due to the structure of the target words, was tantamount to an effect of Word, since each combination of left and right context was represented by one word only.) The contribution of Speaker as a random factor was limited, as could be expected after normalization (cf. [5] for an approach where normalization is not performed prior to a mixed effects analysis).

4. DISCUSSION

The raising and fronting effect of palatal consonantal contexts on Polish /ɛ/ and /a/ is confirmed in general. This is to be expected, since palatal consonants involve a raising of the front of the tongue towards the hard palate (cf. Ćavar et al. [16]). This articulatory posture is evidently similar to high front vowels, and it is unsurprising that the acoustic result is also similar.

However, some details do differ from earlier articulatory accounts. For both vowels, the effect is stronger for a preceding palatal than for a following one, contra [2], [10], [11], [13] and [15]. This may suggest that the perseverative influence from a consonant to a following vowel is stronger here than the anticipatory influence of a consonant on a preceding vowel.

This makes the differences from Gonet [4] a little unexpected. In his study, Gonet found the allophonic effect in only one of four speakers, despite the fact that most of the words he used included palatals in the left-hand context only. Perhaps an explanation could be sought in syllable structure. In some of Gonet's words, the CV pairing occurred in a final unstressed syllable (e.g. *wodzie*, *bracie*). Here, the left-hand palatal was always the onset of a stressed syllable. The fact that the right-hand palatal was across the syllable boundary in the onset of the second syllable may explain the weaker effect.

Also in contrast to [4], we speculate that, in our study, the contextual effect is present in all speakers, as suggested by Figure 2, even though individual intra-speaker statistical analyses were not performed due to the relatively low number of tokens per speaker.

More data will be needed to investigate the issue more thoroughly in future research. In particular, a larger dataset is necessary to study the effect of the interaction between the two contexts independently from word identity, and in structures where the right-hand palatal is in the coda of the same syllable. Using male speakers will allow a more direct comparison with [4] and [8]. Finally, a spontaneous corpus will enable a structured comparison between stressed and unstressed positions.

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