Prosodic influences on formant frequencies of Polish vowels

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1 Overview

• The paper analyzes formant frequencies of (Standard) Polish vowels.

• Prosodic effects were studied; in particular, how formant frequencies are affected by stress and the position within the prosodic word.

• The paper follows the standard organization; Introduction is followed by the Method, Results, Discussion and Conclusion sections.

2 Introduction

The Polish vowel system is traditionally described as one consisting of 6 oral and 2 nasal vowels (Jassem 2003). This is shown in (1). Only oral vowels were the subject of the study.

(1) Polish vowels (Jassem 2003)

\[
i \quad i \quad u
\]
\[
e \quad ė \quad o \quad ź
\]
\[
a
\]

Stress typically falls on the penultimate vowel of the word. In (2), we see that the stress shifts right, if a suffix is added.
Polish has no phonological vowel reduction. In other words, the inventory of unstressed vowels is identical to the vowels that can appear in stressed positions (see Crosswhite 2001 for a cross-linguistic typology of phonological reduction).

Similarly, phonetic reduction is generally considered limited, if not completely absent (Jassem 1962, 2003, Sawicka 1995). This is contrary to the generalizations found in most other languages.

- In an early study, Lindblom (1963) shows that vowels’ formant frequencies (in Swedish) are dependent on the duration of the vowel: the shorter the vowel, the more-schwa like it is (i.e., its formant frequencies are closer to that of schwa). This happens because of the influence of the neighboring segments, and is since known as (phonetic) undershoot.

- Gay (1978) shows that undershoot is caused primarily by stress. This is also because stressed vowels are normally longer than unstressed. He shows that speech tempo has significantly less influence on formant frequencies in comparison to word stress. Later studies confirmed that (Tuller et al. 1982, Engestrand 1988, Miller 1989, Fourakis 1991).

- The phonetic reduction depends on duration and stress, while particular consonant environment (i.e. segments preceding and following a particular vowel) has a less significant effect (Lindblom 1963, Moon & Lindblom 1994, Erickson 2002, Sluijter & van Heuven 1996). For individual languages see also Fourakis et al. 1999, Adank et al. 2004, Hirata & Tsukada 2004, inter alia.

In this study we examined the correlation between vowels’ formant frequencies and their position with respect to word stress.

3 Method

3.1 Corpus

- 57 words selected from the online dictionary of Polish (Słownik języka polskiego PWN at http://sjp.pwn.pl/). All of the words were nouns.

- 18 were monosyllables of the type CVC, while 39 were trisyllables, ideally of the type CVCCVCV.

- The words were chosen with a preference for stops and fricatives in the onsets. Segmentation is considerably easier this way.
• In trisyllables, 54 tokens were measured. All the tokens were in open syllables.

• Examined positions were prestressed, stressed and poststressed. There were three words per position per vowel.

• Two tokens were disregarded, due to the differences in expected and actual pronunciations.

3.2 Speakers

• 6 speakers were chosen, 3 male and 3 female.

• They came from different parts of Poland, and all were speakers of standard Polish.

• All the speakers were students aged 20–25.

3.3 Procedure

• Corpus material was randomized using and online data randomizer.

• Two Power Point presentations were prepared: one for monosyllabic and one for trisyllabic words.

• Words were presented in separate slides. All the words were written in black font on a white background; the position of a word in the screen varied. The slides were changing automatically at 3 s and 4 s intervals for monosyllabic words and trisyllabic words respectively. For each presentation there were three words added initially that were not subsequently measured. Each word appeared twice non-consecutively.

• The speakers were given oral instructions by the experimenter and encouraged to correct themselves, if they had any concerns with the pronunciation of any particular word.

• Recordings were made at the University of Tromsø language laboratory (i.e., a sound treated room).

• Sampling frequency was 44.1 kHz, at a 16-bit rate. The recordings were stored on a portable recording device and transferred to computer for analysis.

• The acoustic analysis was performed using the Praat LPC analysis software (version 4.5).

• F1, F2 and F3 values were measured. Whenever possible, the formant steady state was measured. Otherwise, the central point was measured, or the mean value was calculated. Whenever the reading of a formant was not possible (e.g. too low intensity), the results were dismissed.
A total of 2,526 readings out of 2,592 tokens (or 97.5%) were finally acknowledged. The data were then statistically analyzed. Mean formant values for all the vowels in all positions were calculated (together for male and female speakers). Standard deviation and confidence intervals were calculated. Finally, an ANOVA was performed.

4 Results

The average measurements for individual vowels depending on the condition (monosyllables, prestressed, stressed, poststressed) are graphically represented with a standard F1/F2 vowel plot (figure 1).

Figure 1: Average F1 and F2 of Polish vowels depending on the prosodic condition

For each vowel all the possible positions with respect to stress were analysed and compared against each other. The values of particular formants in the four different positions for each vowel were tested for statistical significance with respect to one another. The results of ANOVA analysis are summarized in 1. Only p-values are shown. The results were mostly statistically significant ($p < 0.05$).
Table 1: p-values of ANOVA depending on the condition.

<table>
<thead>
<tr>
<th>Vowel</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>0.56</td>
<td>0.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>i</td>
<td>&lt;0.001</td>
<td>0.025</td>
<td>0.31</td>
</tr>
<tr>
<td>e</td>
<td>&lt;0.001</td>
<td>0.007</td>
<td>0.99</td>
</tr>
<tr>
<td>a</td>
<td>0.002</td>
<td>0.41</td>
<td>0.27</td>
</tr>
<tr>
<td>o</td>
<td>&lt;0.001</td>
<td>0.007</td>
<td>0.06</td>
</tr>
<tr>
<td>u</td>
<td>0.64</td>
<td>&lt;0.001</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Note that standard deviations, and consequently also confidence intervals are considerably high. Mean formant values were calculated for male and female speakers together. This was a source of great variation in values within a sample and the cause for the high standard deviation. These differences, however, are quite consistent across the population, so they are considered to have a limited effect for the relative vowels positions.

5 Discussion

- As expected, monosyllables are the most peripheral, both in F1 and F2, with the exception of /u/, for which the poststressed position has the lowest F2. This is surprising, but consistent with the findings for other languages (see references in section 2).

- Vowels in stressed position are used in the following analysis as reference points for the vowels in unstressed positions, and also as points determining the shape of the Polish vowel space.

- According to the data, /i/ is quite front. The featural description of /i/ is problematic and sources disagree in that respect. Rubach (1984) argues that the vowel is [back]. However, the data here point towards the vowel being front centralised, which is in agreement with the labelling by Sawicka (1995).

- The vowel /e/ is quite low. This agrees with the data from Jassem (2003), where /e/ is mid-low, i.e. [ɛ]. Note that no token was /e/ preceded by a palatalized consonant. Had this been the case, a coarticulatory effect would be expected, with a considerable lowering of the F1 value. In constrast, /o/ is slightly higher. This is consistent with the vowel dispersion theories (see, for example, Boersma & Hamann 2007 for an Optimality Theoretic account).

- The vowels in unstressed positions tend to have a lower F2 value than the corresponding vowels in stressed positions. The tendency is observable for all non-low vowels. The only exception is pre-stressed /e/, which has an F2 higher than the corresponding stressed vowel. The vowels’ relative behaviour with respect to F1 is
rather inconsistent. For the vowel /a/ the unstressed vowels have a lower F1 value than the corresponding stressed vowel, while there is little difference in F2 value.

- The respective positions of pre-stressed and post-stressed vowels are difficult to generalize. Poststressed vowels tend to have a lower F2 (exceptions: /i/ and /i/). The differences with respect to F1 are even more inconsistent, and, in most cases, they are not significant.

- The difference in F1 of [i] and [e] is considerably reduced, but still highly significant (p < 0.001) even in F1. Thus, all vowels are contrastive within each prosodic position.

6 Conclusion

As regards prosody, vowels in monosyllables are distinctly peripheral, while the differences between pre- and post-stressed vowels are mostly not statistically significant.

In short, there is no phonological neutralization within each prosodic condition; Polish data show some tendency for phonetic neutralization, but vowels are contrastive in all examined conditions.

References


