Vowel duration in pre-geminate contexts in Polish.

Zofia Malisz¹,²

¹ School of English, Adam Mickiewicz University, Poznań, Poland
² Centre for Speech and Language Processing, Adam Mickiewicz University, Poznań, Poland
zmalisz@if.a.amu.edu.pl

Abstract
The study presents Polish experimental data on the variability of vowel duration in the context of following singleton and geminate consonants. The aim of the study is to explain the low vocalic variability values obtained from "rhythm metrics" based analyses of speech rhythm. It also aims at contributing to the discussion about current dynamical models of speech rhythm that contain assumptions of the relative temporal stability of the vowel-to-vowel sequence. The results suggest that vowels in Polish co-vary with following consonant length in a roughly proportionate manner. An interpretation of the effect is offered where a fortition process overrides the possibility of temporal compensation.

Index Terms: gemination, vowel duration, speech rhythm, Polish

1. Introduction
Rhythmic type was found to correlate with different patterns of geminate effect on duration of the preceding vowel. [1] observed that syllable-timed languages such as Italian exhibit a shortening effect of geminates on the preceding vowels, resulting in a durational inverse or compensation. Several researchers [2,3] have shown that Japanese, a mora-timed language, lacks the durational inverse in the context of geminates; Japanese vowels are in fact longer in the pre-geminate position and shorter in the post-geminate position.

The patterns mentioned are also correlated with the amount of overlap in the singleton-geminate length: Italian shows a large degree of overlap [4] whereas Japanese tends to have robust durational differences. It is interesting to see what kind of a pattern occurs in Polish: although it lacks vocalic quantity contrasts, there are consonant length distinctions. In addition, Polish happens to be an unclassified language within the space of standard rhythm classes.

The view that phonotactic complexity and segment duration variability are correlated with rhythm classes derives from [5] and [6]. Some of the proposed determinants of language rhythm type described in the earlier work are reanalyzed quantitatively in rhythm metrics proposals in [7, 8, 9]. The general approach entails a parameter space where the choice of parameters is defined by reference languages, such as English and Italian, traditionally classified as canonically stress-timed and syllable-timed.

Languages often described as difficult to classify, such as Polish, fall out of the space at some point because their status may be changed depending on the combination of parameters (at least in the case of [7]). For example, the analyses of Polish in [7] present low vocalic variability values, in fact the lowest in the dataset (ΔV, standard deviation of vocalic intervals = approx. 0.025). The lack of temporal vowel reduction is cited to be behind the low ΔV scores and consequently, to be the main reason why Polish is not a good candidate for a stress-timed language. On the other hand, high consonantal variability values preclude it from being classified as syllable-timed. Indeed, complex onsets and codas found in Polish are uncharacteristic of a syllable-timed language. Other structural features, relevant to Polish, that may change the values of parameters and indices, are: the role of word accent (penultimate fixed accent in this case) and quantity contrasts [5, 10]. The effect of the latter is the subject matter of the present study.

Another motivation for the study of pre-geminate durations in Polish comes from a different perspective on the modeling of rhythm. The perceptual or acoustic evaluation of rhythm metrics, such as [11], often proceeds according to the objective of how neatly the standard rhythm classes are separated out from the data. The question of how well the metrics match some putative criteria necessary for an accurate modeling of rhythm in general is not addressed, very often because a working definition of speech rhythm is not given a priori. A general rhythm model needs to include criteria such as: alternation of prominences, iteration of events, hierarchical structure [12]. Most rhythm metrics capture only the global, linear aspects of prosodic structure.

Nonlinear approaches exemplified by [13, 14, 15] offer a better solution in this regard. E.g. the speech rhythm model in [14] is specified by the coupling of syllable-sized and phrase stress oscillators, where the first provides regularity and the other structure. In general frameworks of this type relate rhythmic tendencies between and within languages to holistic cognitive and motor principles of rhythmicity and use methods and formalisms that are independent of bias of expectations depending on standard rhythm types [16].

Similarly to the metrics described earlier dynamical models based on coupled syllable and stress oscillators [14] or adaptive oscillators [15] underline the importance of vowels in the modeling of rhythm. The syllabic oscillator in [14] is implemented by V-to-V units and assumes a tendency to regularize the recurrence of vowel onsets. Duration compensation phenomena inside the V-to-V unit support the hypothesis of a relatively stable intervocalic onset period.

Longer vs. shorter consonants within a V-to-V frame act as perturbing factors. Compensation phenomena such as “the voicing effect” [17, 18], interpreted in terms of temporal relations between segments only, were studied in Polish by [19]. It was found that Polish again deviates from a major tendency concerning temporal relations: it does not observe the shortening of vowels in front of voiceless consonants (relatively longer than voiced, all other things being equal). In principle, a related case of the inverse effect of geminates on vowel duration mentioned earlier is of similar relevance for nonlinear models as well as linear metrics of speech rhythm. An experiment on Polish geminate effect on preceding vowel
duration was conducted to clarify the problems posed by Polish timing relations to both types of approaches.

2. Method

In the design of the experiment and in the results no claim is made as to the phonological status of vocalic duration variability as a potential additional cue to geminate categorization. We interpret the results only in terms of timing relations between segments. Questions of categorization would require a greater number of speakers and additional perceptual experiments.

2.1. Speech material and speakers

Four speakers of standard Polish (2 male, 2 female, 20-21 years old) from the Great Poland (Wielkopolska) region were asked to repeat stimuli around 10 times (around 1280 tokens were recorded and annotated). Target words of the form /paCa/ and /paCa:/ were used as stimuli (where C was one of the eight fricatives or eight stops under study). The stop stimuli involved the bilabials /p/, /b/, and the dentals /t/, /d/.

The fricative stimuli involved the alveolar voiceless /s/, postalveolar /z/ and /s/ and the alveolo-palatal voiceless /c/ contrasting in length, word medially.

2.2. Procedure

The main stimuli were presented to the subjects on randomized strips of paper in the following form:

"To nie jest papa __________, to papa __________"

"To nie jest pappa __________, to pappa __________"

The words to be filled into the gaps were given on separate strips of paper: dobra, tania ("good", "cheap") for the first condition containing meaningful target words (e.g.: "papa", "passa", "pasia") and losina, dagna (no meaning) for the second condition containing nonsense target words (e.g.: "patta", "paba" etc.). In a few preparatory runs the speakers did not have problems with incorporating the nonsense elements into a meaningful carrier sentence, producing fluent utterances.

The two pairs of additional stimuli functioned as masking words. The main task was constructed so that the target word would not attract prominent focus, assigned to other potential locations in the frame. The "new information" status and position in the phrase attracted phrasal prominence to the masking words rather than to the target word. This way we attempted to control emphasis pragmatically.

The experiment was controlled for the following factors that influence segment duration: vowel identity, syllable shape and count, position in the phrase, lexical stress, emphasis. It was not directly controlled for individual speaker rate. However see 3.2 for the method of handling speaker differences.

2.3. Measurements and annotation

The data were transcribed manually using Praat according to oral constriction criteria for prosodic annotation as defined in [19, 20].

Stop geminates were defined as a consonant with a prolonged closure and a final release burst, fricative geminates as a consonant with a prolonged sustained frication noise. Some speakers occasionally produced two released consonants in the stop geminate trials, e.g.: two doubly articulated stops in papa vs. the expected ambisyllabic geminate stop in pappa. Doubly released stops and affricates are quite common in clear Polish speech [21]. All consonants with a double release and/or vocalic epenthesis were excluded from the analysis. Only medial VC-VC: sequences were considered.

3. Results

3.1. Description of the whole set under study

3.1.1. Consonant length differences

All speakers produced significantly longer geminate consonants than singleton consonants. The mean ratio of geminate to singleton length was 2.6 for stops and 2.3 for fricatives.

3.1.2. Vowel duration differences

Fig. 1 and Fig. 2 present the results of the vowel duration study in pre-geminate and pre-singleton contexts, grouped into stops and fricatives, separately for each speaker.

Figure 1: means and standard deviations of vowel duration in the context of the following geminate (dark bar) and singleton (clear bar) stops.

All vowels turned out to lengthen in the context of a geminate by approx. 14 ms in front of stops and by approx. 21 ms in front of fricatives. All differences returned significant results at p<0.0001. The standard deviations and absolute mean differences suggest that the effect is more robust if a fricative geminate follows.

3.2. Analysis results of a data subset

Because the design of the whole dataset was not balanced, a subset of vowel durations in the context of two pairs of stops and fricatives each (t, d, s, z) was submitted to a repeated measures ANOVA with subject as the error term. The factors under consideration were Length (geminate, singleton) Manner (fricative, stop), Voicing (voiced, voiceless). Place was excluded as in this particular data subset the Manner and Place factors conflate. Manner was included because judging by the mean differences for the whole dataset (Figure 1 and 2) a significant main effect of Manner was expected to be confirmed. The factor of Voicing was entered to compare the results with [19] where a voicing effect in the case of some fricative contexts was found.
In general, factors other than Length served as controls for the main effect of Length.

The number of samples in the analyzed data subset was 576. Table 1 presents the results of the analysis of variance. All factors showed a significant main effect, as well as significant interactions with other factors. Figure 3 groups the mean differences by manner of articulation and voicing.

The most striking result are the mean durations of vowels preceding singleton consonants. As expected in the case of Polish, the difference in length across consonant manners is very small, with a slight preference for the lengthening effect of fricatives. So is the effect of voicing on vowel duration, a result that confirms the experimental findings of [19] who showed that the strongest lengthening effect occurs in front of voiced fricatives such as /z/, /s/, /z/.

Nonetheless, the effect of consonant length is present in both manner and voicing conditions. Cumulatively, as confirmed by the significant Length*Manner*Voicing interaction, vowels lengthened more before geminate fricatives (M=109, SD=17), especially before the voiced geminate fricative /z/ (M=116, SD=17).

Table 1. Results of an ANOVA for vowel duration in the data subset.

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>419.732</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Manner</td>
<td>162.368</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Voicing</td>
<td>52.853</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Length*Manner</td>
<td>48.603</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Length*Voicing</td>
<td>23.998</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Length<em>Manner</em>Voicing</td>
<td>5.957</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Figure 3: means and confidence intervals of vowel duration in the context of the following geminate (dark bar) and singleton (clear bar) fricatives.

4. Discussion

The results show that Polish follows Japanese in the timing pattern of pre-geminate vowel duration. In both languages consonant length differences show no overlap and vowels co-vary with long consonants that follow. Does it mean that Polish is also mora-timed in parts? What does the combination of structural features mean for the rhythm class hypothesis when a language exhibits different characteristics of all standard types? Any conclusions should be approached with caution, bearing in mind that "rhythmic units are independent of higher order linguistic units while still correlating with them", [22] after [23]. In the face of additional evidence in [19] of a mild voicing effect in the context of fricatives, confirmed in the present study, a non-rhythmic interpretation of both cases of lengthening will be offered. It is likely that pre-geminate vowel lengthening is a case of fortition. Aerodynamic constraints come into play: a continuant geminate, a sound with a long, sustained constriction, as well as voiced obstruents in general, require more articulatory effort [24]. Vowels in front of consonants requiring more effort are articulated in a more forceful manner and are therefore, longer. In fact, the effect seems to be cumulative in Polish.

The lengthening of vowels in Japanese entails also post-geminate shortening. The combination is crucial for the considered dynamical rhythm models. If the same effect could be found for Polish, at least some adaptation to achieve relative stability of vowel-to-vowel onsets in words such as “passa”, “pappa” would be found. An interesting possibility presents itself by considering the adaptive oscillator model used for Japanese in [15]. If the temporal “inflexibility” of Polish vowels is further confirmed, especially in the face of adjacent consonantal perturbations to the vocalic pulse train, perhaps an "oscillator that assumes onsets to be noisily isochronous" [15] may be a model to consider for global Polish timing.

The relatively stable length of vowels preceding singleton consonants in different paradigmatic configurations explains part of the low standard deviations calculated for Polish vocalic intervals as well as the results obtained by [23] where a measure closest to global isochrony was found for Polish.

5. Conclusions

The research reinstates the “mixed” status of Polish timing relations. Further study of other relations in similar context is needed.
6. References