



The effect of primary and rhythmic stress on onset consonant duration in Polish

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Abstract

Polish is known for having two levels of stress – penultimate primary stress and iterative rhythmic stress on odd-numbered syllables, forming a typologically rare binary system with internal lapses. Rhythmic stress has been reported to be cued by increased onset consonant duration relative to unstressed positions, both word-initially and word-medially. Little is known about the potential role of consonant duration as a phonetic correlate of primary stress. Hitherto available acoustic studies, relying mostly on vocalic parameters, often point to a strong dependence of those parameters on the focus position. In this study, we report acoustic results of an experiment designed to measure onset consonant (as well as vocalic) duration across the syllables of segmentally matched three- and four-syllable words, e.g. *telefon* [010] ‘telephone (nom. sg.)’, *telefon+y* [2010] (nom. pl.); 0 = unstressed, 1 = primary stress, 2 = rhythmic stress. In order to disentangle the potential effects of sentence-level prominence, the stimuli appeared in discourse-new, contrastive focus, and no focus contexts. Our results demonstrate significantly increased onset consonant duration in primarily/rhythmically stressed syllables relative to unstressed syllables, occurring to a different degree both in the presence and absence of focus.

Index Terms: primary stress, secondary stress, acoustic correlates of stress, focus, Polish

1. Introduction

In the phonetic literature, word-level metrical prominence is usually associated with heightened values of vowel parameters, such as vowel duration, intensity, and fundamental frequency. Relatively little attention has been given to onset consonant duration. The present paper fills this gap by investigating potential effects of word-level stress and sentence focus on onset consonant duration in Polish.

The metrical system of Polish has two degrees of grammatical (predictable) stress ([1], [2], [3], [4], [5]). As the examples below show, primary stress falls regularly on the penultimate syllable; secondary (rhythmic) stress appears on every odd-numbered syllable, as long as no clash with primary stress would ensue. Those characteristics make Polish a well-known example of a typologically rare binary stress system with internal lapses, i.e. sequences of unstressed syllables occurring in the vicinity of primary stress (e.g. [4], [6]).

- po'midor (‘tomato’ N., nom. sg.)
- ,pomi'dory (‘tomato’ N., nom. pl.)
- ,pomido'rowy (‘tomato’ Adj., nom. sg.)
- ,pomi,doro'wego (‘tomato’ Adj., gen. sg.)

Previous experimental research on Polish, beginning with the 1932 kymographic study by Maria Dłuska ([7]), suggests

that rhythmic (secondary) stress is manifested in terms of increased onset consonant duration, both word-initially and word-medially ([3], [4], [5]). The acoustic results in [3], [4], and [5] were obtained on the basis of citation forms embedded in a frame; the kymographic results in [7] were based mostly on target words in different declarative sentences, which were delivered with a neutral intonation pattern, thus leaving unanswered the question about the role of sentence focus. Also, little is known about the potential effect of primary stress on onset consonant duration in Polish [4]. Moreover, available acoustic studies of primary stress, which rely mostly on vocalic parameters, often suggest a strong dependence of those parameters on the focus position ([8, 9]; cf. [10], [11]). In this study, we report on the results of a pilot experiment designed to investigate temporal effects in consonants and vowels depending on the primary/secondary degree of stress and sentence focus type, i.e. discourse-new, contrastive focus, and no focus contexts.

2. Experiment

2.1. Method

2.1.1. Participants

The experiment is based on standard Polish spoken in Warsaw. Previous research ([3], [4], [5], [7]) points to the relevance of regional variation: rhythmic stress is expected to occur predominantly in the so-called Warsaw and Krakow Polish standards. Eight native speakers of standard Polish (4 M, 4 F; age range 31-54) participated in this pilot study. All of them were life-long residents of Warsaw. None of them had speech or hearing problems based on self-report. As required for research involving human subjects, the protocol of the experiment was approved by the Committee for the Ethics of Research Involving Human Participants at the University of Warsaw (decision no. 132/2022).

2.1.2. Stimuli

The stimuli consisted of 36 paired three- and four-syllable target words, such as *megafon* [mɛ'gafɔn] ‘megaphone (nom. sg.)’ – *megafony* [mɛgafɔni] (nom. pl.). Such words have the metrical structures [010] and [2010], respectively. Thus, they differ systematically in the absence/presence of rhythmic stress in the first syllable as well as in the presence/absence of primary stress in the second and third syllables. This allows us to compare segmentally matched rhythmically/primarily stressed and unstressed syllables occurring in three positions of the word, as schematized in Table 1. Such segmental comparability is important especially from the point of view of onset consonant duration, since intrinsic length differences across consonantal categories can be much bigger than the expected differences in length induced by stress ([4]). The analyses are thus conducted separately for each syllable. This allows us not

only to control for the potentially confounding segmental effect, but also to empirically distinguish between the effects of metrical prominence and potential initial strengthening (for a similar approach, see [12] and [13]).

Table 1: *Stress conditions: an illustration.*

1 st syllable	2 nd syllable	3 rd syllable
unstressed mɛ	primary 'ga	unstressed fɔ(n)
rhythmic ,mɛ	unstressed ga	primary 'fɔ(n)

The target words occurred in three different conditions from the point of view of sentence focus: discourse-new, contrastive focus and no focus. The sentences in which the target items were embedded were part of a short story (the discourse-new context; cf. [14]) and two mini-dialogues (contrastive focus vs. no focus contexts, where the target item was separated from the focused word by two words; [15]), as exemplified in Table 2.

Table 2: *Focus conditions: an illustration.*

Elicited sentences (underlined)	Focus conditions
[1] Poszli na demonstrację antywojenną. Pożyczyci megafony na ponad trzy godziny. Całkiem tam stracili głos. [They went to an anti-war protest. <u>They borrowed megaphones for over three hours.</u> They entirely lost their voices there.]	Discourse-new
[2] Pożyczyci <i>mikrofony</i> na ponad trzy godziny? Pożyczyci megafony na ponad trzy godziny. [They borrowed <i>microphones</i> for over three hours? They borrowed <u>megaphones</u> for over three hours.]	Contrastive focus
[3] Pożyczyci megafony na ponad <i>dwie</i> godziny? Pożyczyci megafony na ponad trzy godziny. [They borrowed megaphones for over <u>two hours</u> ? They borrowed <u>megaphones for over three hours.</u>]	No focus

2.1.3. Procedure

The recordings were conducted in laboratory settings, in a sound-treated room, using a Tascam DR-100 MKII recorder, set to a sampling frequency of 44.1 kHz, and an AT897 microphone. The experiment was presented by means of a PowerPoint presentation on a computer screen. Participants were asked to read aloud underlined sentences, which appeared on the computer screen. As illustrated earlier in Table 2, the

items occurred in triplets pertaining to different focus conditions. The ordering of triplets was randomized across speakers. We also randomized the ordering of contrastive focus and no focus conditions within each triplet. The speakers were encouraged to follow the task at their own pace and, in case of any mispronunciation or hesitation, to repeat the whole phrase before moving on to the next one. To elicit maximally natural responses, the task was described as participating in a conversation with a friend. Each participant produced six sets of paired triplets (as exemplified in section 2.1.2, Table 1 and Table 2).

2.1.4. Measurements

Duration measurements were conducted in 1728 consonants and vowels occurring across the first three syllables in the target words. Segmentation was done using a high-resolution waveform editor (Sound Forge PRO, v.11), on the basis of standard auditory and visual criteria, i.e. inspection of changes in the dynamics of successive glottal pulses as well as the spectrogram in *Praat* (v. 6.2.09; [16]); see Figure 1. The effect of focus was both perceptually and acoustically robust in the data (i.e. F0 peaks consistently aligned with positions of primary stress in focused words, as predicted in [9]). Measurements were automated in terms of *Praat* scripts.

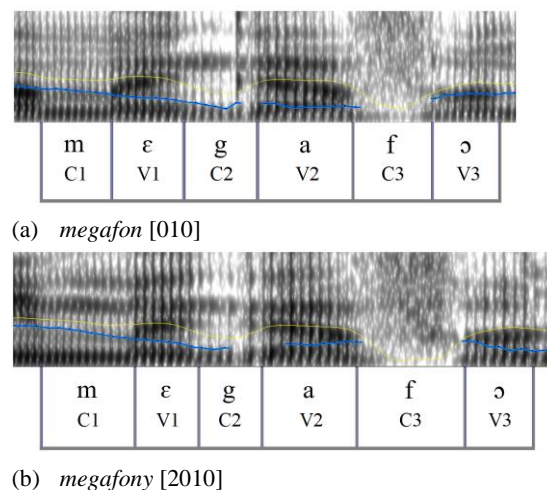


Figure 1: An example of a segmented pair of tokens, representing different stress conditions across the three syllables; uttered in the 'no focus' context; speaker M2. The stressed initial and third consonants in panel (b) are visibly longer than their unstressed counterparts in panel (a).

2.1.5. Statistical analyses

Statistical analyses were conducted in SPSS, v. 29. To test the effect of stress and focus on consonant/vowel duration, we built linear mixed effects (*lme*) models, with 'stress', 'focus' and the interaction term 'stress*focus' as fixed factors. Separate analyses with vowel and onset consonant durations as dependent variables were conducted. The random structure was fully specified in the final models, i.e. it included intercepts for speaker, item, speaker*item, as well as speaker- and item-specific slopes for the 'stress' and 'focus' conditions, except for the analysis of vowel duration in the first syllable, where item-specific slopes for the stress condition were discarded because

of convergence problems. ‘Item’ was understood as a segmentally identical chunk; thus, segmentally paired sequences were coded as a single item ([3], [4], [5], [17]).

2.2. Results

2.2.1. Onset consonant duration

In the *lme* analysis of the first syllable, in which the ‘stress’ condition has two values, ‘rhythmically stressed’ vs. ‘unstressed’, we obtained a significant result for the main effect of ‘focus’ ($F(2, 17.233) = 9.22, p < .005$) and the stress*focus interaction ($F(2, 199.2) = 3.882, p < .05$). As illustrated in Figure 2, ‘contrastive focus’ is associated with a conspicuous increase in onset consonant duration relative to ‘discourse-new’ and ‘no focus’ contexts. Additionally, a statistically significant effect of ‘stress’ was found within the ‘no focus’ condition, where the onset consonant of the rhythmically stressed syllable turned out longer than its unstressed counterpart ($\beta = 5.68, SE = 2.26, t = 2.513, p < .05$).

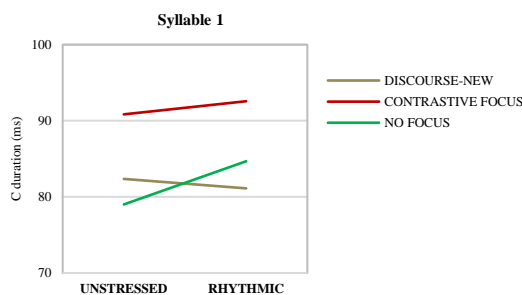


Figure 2: Estimated marginal means of onset consonant duration in the first syllable, depending on stress and focus.

In the second syllable, in which the ‘stress’ condition has two values, ‘primary stress’ vs. ‘unstressed’, all three fixed effects were statistically significant; ‘focus’: $F(2, 9.07) = 15.901, p < .001$; ‘stress’ $F(1, 6.630) = 16.813, p < .01$; ‘stress*focus’ $F(2, 197.099) = 6.627, p < .005$. As can be seen in Figure 3, there is an overall tendency of onset consonants to lengthen in syllables carrying primary stress, however the degree of duration enhancement depends strongly on the focus condition.

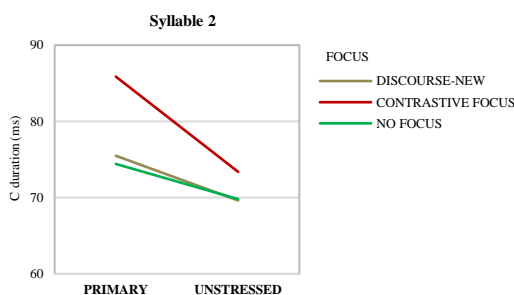


Figure 3: Estimated marginal means of onset consonant duration in the second syllable, depending on stress and focus.

The most conspicuous lengthening of a stressed syllable’s onset relative to the unstressed one occurs under contrastive

focus, where the average difference between the metrically strong and weak positions amounts to 12 ms. A much smaller degree of lengthening occurs in the other two focus conditions. The difference within the ‘no focus’ condition is not statistically significant in the regression analysis: $\beta = 4.617, SE = 2., t = 2.007, p = .063$.

In the *lme* analysis of the third syllable, in which the ‘stress’ condition has two values, ‘primary stress’ vs. ‘unstressed’, ‘focus’ and ‘stress’ are statistically significant factors. ‘Contrastive focus’, but not ‘discourse-new’, is significantly different from the ‘no focus’ condition (the reference level in the analysis); contrastive focus: $\beta = 7.548, SE = 3.342, t = 2.259, p < .05$; discourse-new: $\beta = -0.406, SE = 3.342, t = -0.122, p = .904$. There is no significant interaction between ‘stress’ and ‘focus’. There is a tendency for onset of the primarily stressed syllable to be longer than that of the unstressed syllable across all focus conditions; the difference within the ‘no focus’ condition is statistically significant: $\beta = 4.668, SE = 2.111, t = 2.21, p < .05$; cf. Figure 4.

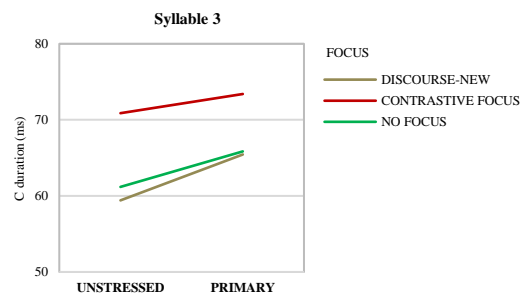


Figure 4: Estimated marginal means of consonant duration in the third syllable, depending on stress and focus.

2.2.2. Vowel duration

The statistical analysis regarding the initial syllable points to an overall subtle vowel contraction effect in that syllable in four-syllable words relative to three-syllable words. No significant interaction between ‘stress’ and ‘focus’ is found. There is no significant increase in vowel duration induced by rhythmic stress or focus; cf. Figure 5.

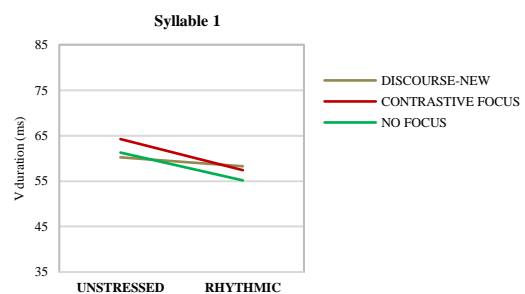


Figure 5: Estimated marginal means of vowel duration in the first syllable, depending on stress and focus.

In contrast, all three fixed effects, ‘stress’, ‘focus’ and the ‘stress*focus’ interaction, turn out significant in the statistical analysis pertaining to the second syllable. The mean difference between primarily stressed and unstressed vowels within

‘contrastive focus’ amounts to 32 ms, and is much bigger than the differences in the ‘discourse-new’ and ‘no focus’ conditions. The difference in the ‘no focus’ condition is statistically significant: $\beta = 9.634$, $SE = 4.484$, $t = 2.148$, $p < .05$. Mean vowel duration values in the second syllable are presented in Figure 6.

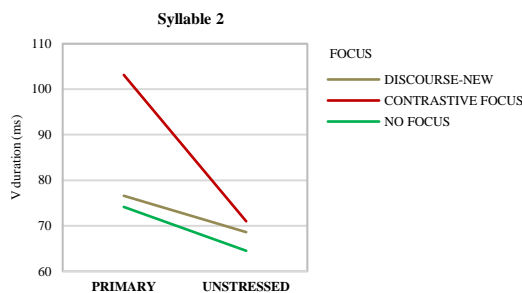


Figure 6: *Estimated marginal means of vowel duration in the second syllable, depending on stress and focus.*

The situation is similar in the third syllable, where all three fixed effects are statistically significant; however, the interaction effect is less pronounced here. The differences between primarily stressed and unstressed vowels are more uniform across the three focus conditions than in the second syllable. The smallest mean difference of 16 ms occurs within the ‘no focus’ condition; it is statistically significant: $\beta = 16.193$, $SE = 4.843$, $t = 3.344$, $p < .01$; see Figure 7.

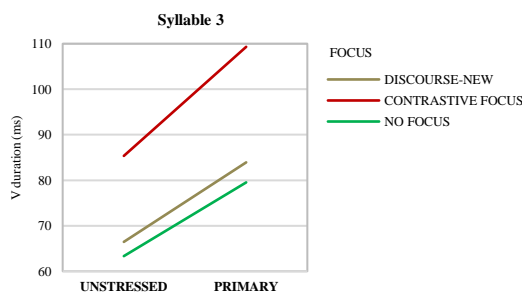


Figure 7: *Estimated marginal means of vowel duration in the third syllable, depending on stress and focus.*

3. Discussion

The results of our study demonstrate that there is a differential effect of primary/rhythmic stress as well as sentence focus on the duration of onset consonants and vocalic nuclei in Polish.

The results of our experiment demonstrate that rhythmic stress has an effect on onset consonant duration, but not on vowel duration. These results corroborate previous findings, suggesting that Polish has ‘consonantal rhythm’ ([3], [4], [5]). This highlights the importance of onset consonant duration as a potential secondary stress parameter. As pointed out e.g. in [4] and [18], secondary stress may be cross-linguistically under-reported because most acoustic studies rely exclusively on vocalic parameters. Moreover, our study shows that the effect of rhythmic stress is statistically significant only within the ‘no focus’ condition, which indicates that rhythmic stress is independent of prominence enhancement occurring on the sentence level. The design of our study also allowed us to

disentangle the rhythmic stress effect from a potential initial strengthening effect (cf. the suggestion in [19] that initial consonant lengthening in Polish might be merely indicative of the latter). We conclude that although the rhythmic stress effect is acoustically subtle, it seems to be a pertinent feature, at least of some varieties of Polish. Its presence is further corroborated by its playing a relevant role in speech perception ([20]).

Another novel finding is a conspicuous duration increase in the onset consonant of the first syllable within the ‘contrastive focus’ condition relative to ‘discourse-new’ and ‘no focus’ conditions. Interestingly, that kind of focus-induced lengthening is a general strengthening effect occurring both in rhythmically stressed and unstressed syllables.

A conspicuous increase in onset duration under contrastive focus is also found in the second and third syllables, which are analogous in terms of stress conditions, i.e. they both host primarily stressed vs. unstressed syllables. An interesting difference in the expression of primary stress is seen in three-([010]) and four-syllable ([2010]) words, investigated in this paper. In the second syllable, a significant onset consonant duration enhancement in [010] words relative to [2010] words occurs only within the ‘contrastive focus’ context. In the third syllable, there is a relatively uniform primary stress effect in [2010] words compared to [010] words across all three focus conditions. Thus, it is only in four-syllable words that an increase in onset consonant duration of a primarily stressed syllable is found independently of sentence-level prominence enhancement. This suggests that a mediating effect of focus on primary stress is inhibited in words, in which both primary and secondary degrees of stress are present.

An analogous situation occurs in the case of vowel duration. Both in the second and third syllables, primarily stressed vowels are significantly longer than their unstressed counterparts. Similarly to onset consonant duration, there is a bigger interaction between ‘stress’ and ‘focus’ in the second syllable than in the third syllable. This seems to point to a systematic difference between the expression of primary stress vis-à-vis various focus types in three-syllable (i.e. [010]) words vs. four-syllable words (i.e. [2010]). The bigger interaction between focus and stress is seen in the former, where only one degree of stress is present. In four-syllable words, which accommodate both primary stress on the third syllable as well as rhythmic stress on the initial syllable, the primary stress effect is more uniform across the three focus conditions.

4. Conclusions

The results of our experiment demonstrate an interesting interplay of onset consonant and vocalic duration as phonetic correlates of primary and rhythmic stress vis-à-vis three sentence-level prominence conditions: discourse-new, contrastive focus, and no focus. Rhythmic stress is manifested in terms of increased onset consonant duration, independently of sentence-level enhancement and domain-initial strengthening effects. Primary stress is expressed in terms of consonant and vowel duration, with a bigger mediating effect of focus in [010] words than in [2010] words.

5. Acknowledgements

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6. References

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