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Pretonic Lengthening as the Lexical Stress Domain Extension

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Abstract

This paper reports on an acoustic study of pretonic lengthening in Ukrainian, a language with a hybrid metrical system comprising lexical stress and grammatical secondary (rhythmic) stress, both cued by vowel duration ([1], [2]). The existence of pretonic lengthening has gone unnoticed in the traditional descriptions, and although recent acoustic research ([1], [3], 4]) has pointed to its presence in Ukrainian, this phenomenon has not been systematically investigated. The phenomenon is interesting because by reducing the temporal difference between the pretonic and the tonic syllable, pretonic lengthening weakens the durational cue to lexical stress. It also distorts the otherwise regular iteration of secondary stresses. In this paper, we report on the measurements of the duration and formant (F1/F2) structure of the vowel /a/ in different prosodic positions (lexical stress and three preceding syllables). The analysis of the data collected from 11 native speakers of Ukrainian points to a gradual effect of lengthening and the presence of vowel undershoot across syllables preceding lexical stress. We argue that the existence of pretonic lengthening in Ukrainian is closely related to the domain of lexical stress, and may reflect a more universal anticipatory effect induced by lexical stress.

Index Terms: pretonic lengthening, lexical stress, secondary stress, vowel undershoot, Ukrainian

1. Introduction

Temporal adjustments are common in different loci, the most widely described prosodic positions causing an increase in duration include word boundaries and metrically strong positions (lexical/grammatical stress). Less known is the presence of lengthening in the syllables adjacent to stress. In languages such as Catalan ([5]), Cordoban Spanish ([6], [7]), Russian ([8]), and in some East Slavic dialects ([9], [10]), lengthening affects the syllable immediately preceding lexical stress. A related phenomenon, called "stress – adjacency effect", has been observed in English, where a stressed syllable undergoes lengthening before another stressed syllable, e.g., in *peach light* in comparison to *peach delight* ([11], [12], [13]).

The present paper reports on an acoustic study of pretonic lengthening in Ukrainian. The existence of pretonic lengthening has gone unnoticed in the traditional descriptions of the language, and although recent acoustic research ([1], [3], [4]) has pointed to its presence in Ukrainian, this phenomenon has not been systematically investigated.

Ukrainian has a complex metrical system with lexical stress and predictable grammatical secondary (rhythmic) stress. Lexical stress appears on any syllable of the word; rhythmic stresses are placed at both word edges and on word-medial syllables, iterating from the edges towards lexical stress, e.g. *oso*ˈ*bystyj* 'private' [ˌɔsɔˈbɨstɨj], *molo*ˈ*ko* 'milk' [ˌmɔlɔˈkɔ], ˈ*stvorennja* 'creation' [ˈstvɔrɛˌnnʲa], *kuku'rudzjanyj* 'corn, adj.' [ˌkukuˈrud͡zʲaˌnɨj], *za'pamoročennja* 'dizziness' [zaˈpamɔˌrɔt͡ʃɛˌnnʲa], *kapitali'styčnyj* 'capitalist, adj.' [ˌkaʲpiˌtalʲiˈstɨt͡ʃnɨj]. Both lexical and grammatical stress are expressed acoustically in terms of increased duration ([1], [3], [4], [14]).

In addition to the increased duration in metrically strong positions of primary and secondary stress, recent acoustic research has also detected an increased duration of the syllable immediately preceding the syllable carrying lexical stress ([1], [3], [4]). The studies of [1], [3], based on words with lexical stress on the fourth, fifth, and sixth syllables (e.g. *amery'kanec'* 'an American' [ˌamɛrɨˈkanɛt͡sʲ], *ameryka'nizm* 'americanism' [ˌamɛˌrɨkaˈnʲizm], *municypali'tet* 'municipality' [ˌmunʲiˌt͡sɨpalʲiˈtɛt]), have revealed a difference of 25 ms in syllable duration and a 14 ms difference in vocalic duration between the pretonic syllable and the shortest syllable in the word (i.e. the second syllable, unstressed position). Pretonic lengthening has also been detected in a study based on extrinsic comparisons of segmental (consonantal and vocalic) duration in minimal pairs such as *po*ˈ*padaty* 'fall' (perf.) [pɔˈpadaˌtɨ] - *popa*ˈ*daty* 'get' (imperf.) [ˌpɔpaˈdatɨ] ([4], [15]), which contrasted only in terms of the position of lexical stress. The findings of this study point to a small but statistically significant difference of 8 ms between the pretonic vowel and the same vowel in the secondary (rhythmic) stress position. Cf. the vowel /ɔ/ in the pretonic position in *po*ˈ*padaty* 'fall' (perf.) [pɔˈpadaˌtɨ], and the vowel /o/ in the rhythmic stress position in the segmentally identical word with lexical stress on the third syllable, *popa*ˈ*daty* 'get' (imperf.) [ˌpɔpaˈdatɨ].

Although previous research has presented some preliminary results concerning the presence of pretonic lengthening in Ukrainian, the phenomenon itself was not the main focus in these studies. The present paper expands on the earlier work, reporting on an experiment designed to investigate pretonic lengthening on the basis of duration and formant structure measurements in the same vowel category (/a/), occurring in the same flanking consonantal contexts, and in words having the same length and metrical structure. The parameters of the vowel are measured in four prosodic positions in pentasyllabic words with lexical stress falling on the fourth syllable, which allows for comparing the pretonic vowel with lexical stress-bearing, and other non-lexical stress positions.

2. Experiment

The purpose of the experiment reported here was to test for the presence of pretonic lengthening in Ukrainian. As suggested in recent research ([1], [3], [4]), a subtle but consistent increase in duration is expected in the vowel immediately preceding the

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syllable carrying lexical stress, in comparison with vowels that are farther away from lexical stress. At the same time, despite the hypothesized lengthening effect, the pretonic vowel is expected to be metrically weak. If so, this should manifest itself in terms of reduced quality (formant undershoot); [16]. The experiment is thus designed so that it enables a meaningful comparison of the relevant parameters of the pretonic vowel, i.e. duration and formant structure, with those characterizing vowels in other positions.

2.1. Method

2.1.1. Participants

11 speakers of Ukrainian participated in the recordings. They were all monolingual native speakers of Ukrainian (7F; aged 24-65, *M* = 42), living in Western Ukraine.

2.1.2. Stimuli

To minimize the potential effect of confounding factors on the duration of the pretonic vowel, such as the position of lexical stress, polysyllabic shortening or boundary lengthening (e.g. [17]), the word stimuli all had lexical stress falling on the fourth syllable; they also had similar length and identical metrical structure, as schematized in (1). Most items (8 out of 9) consisted of five syllables, and had lexical stress on the penultimate syllable.

[σσσˈσ(σ)] (1)

In sum, the stimuli in (1) contained the vowel [a] in one of the following three positions preceding the lexically stressed syllable: initial, second or pretonic, as exemplified in Table 1. As we planned to conduct measurements not only of vowel duration but also of formant structure, these test items were also balanced with regard to the place of articulation of the consonants preceding and following the vowel [a].

Table 1: *Examples of stimuli.*

Prosodic position	**Example**
initial	*za̲paku ˈvaty* ‘to pack’ [ˌza̲pakuˈʋatɨ]
second	*neza̲peˈrečnyj* ‘unquestionable’ [ˌnɛza̲pɛˈrɛt͡ʃnɨj]
pretonic	*peresa̲ˈdyty* ‘to transplant’[ˌpɛrɛsa̲ˈdɨtɨ]

The vowel [a] in the tonic (i.e. lexical stress) position was represented by another set of stimuli – simple bisyllabic words, e.g. *baza* ‘base’ [ˈbaza] . Those stimuli and the stimuli in (1) were matched for the places of articulation of the flanking consonants.

2.1.3. Procedure

Participants were asked to read target words embedded in a frame (*Skažete …druhyj raz* ‘You (pl.) will say … for the second time’ [ˈskaʒɛˌtɛ ˈdruɦɨj ˈraz]). Lexical stress was marked orthographically to facilitate the identification of words. (It is customary to mark lexical stress in dictionary entries in Ukrainian.) The words put in a frame were presented on a computer monitor. The list was randomised to avoid order effects. The participants were asked to read the stimuli at their natural pace. The recordings were performed using an H4 Zoom portable recorder, set at a sampling rate of 44.1 kHz, and an AT897 microphone. 9 words in 3 repetitions were recorded for each of the three positions preceding lexical stress. 8 words in 3 repetitions were recorded for the tonic position. Segmentation was done manually by the authors, using Sound Forge and Praat ([18]). In sum, 1136 segments were obtained for acoustic analyses (35 tokens x 3 repetitions x 11 speakers, minus 19 vowels, which had to be excluded due to disfluencies of pronunciation).

2.1.4. Measurements

Measurements of duration and formant frequencies were conducted automatically in Praat, by means of scripts. Formant measurements (F1, F2) were conducted using the Burg LPC algorithm, with the ceiling of the formant search range being 5000 Hz for male speakers, and 5500 Hz for female speakers. Formant values were measured at acoustic midpoints. To control the effect of asymmetrical consonantal contexts, the data were balanced for the places of articulation of the preceding and following consonants. In order to be compatible with human perception, and to ensure across-speaker data comparability, formant frequencies were expressed on the mel scale ([16], [19]) and translated into a normalized acoustic space (cf. [19]), i.e. the data from each speaker were rescaled by the average distance of each data point from the median formant value of the tonic [a] for this speaker.

2.1.5. Statistical analyses

The statistical analyses were conducted in SPSS v. 26. To test the effect of position (initial, second, pretonic) on duration, we built linear mixed effects models with fully specified random structure, speaker- and item-specific intercepts and slopes. The reference category in the regression analyses was the pretonic position. Further, to test for the presence of vowel undershoot, correlation analyses were performed for F1/F2 and vowel duration.

2.2. Results

2.2.1. Duration

The results demonstrate that although pretonic vowels are longer than both the vowels in the initial and the second position (see Figure 1), significant differences were obtained for the pretonic vs. initial positions (β = -10.5, *SE* = 4.203, *t* = -2.499, *p* < 0.05), but not for the pretonic vs. second positions (β = -7.03, *SE* = 4.202, *t* = -1.674, *p* = 0.102). Thus, there is a gradual increase in length across the three syllables that precede lexical stress in words of the [σσσˈσ(σ)] type.

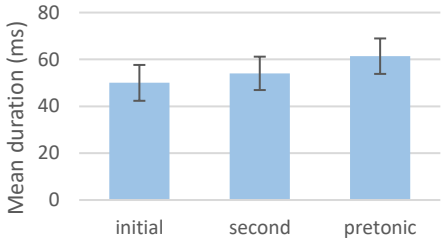

Figure 1: *Mean vowel duration values in the three syllables preceding lexical stress.*

2.2.2. *F1, F2 formants*

The results for F1 and F2 point to reduced quality of the vowel [a] in all positions preceding lexical stress, as illustrated in Figure 2. There is a clear rise in F1 in these vowels in comparison with the [a] in the tonic position.

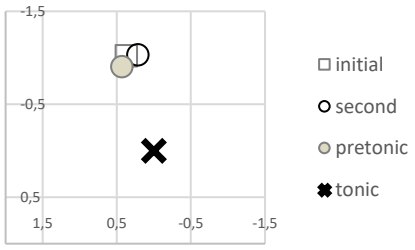

Figure 2: *Mean normalized F1-F2 values depending on position.*

The results for each of the formants are further presented in Figures 3 and 4, divided by speakers. Although the speakers show individual degrees of reduction in the three positions preceding lexical stress, as well as individual subpatterns across the first two vowels (initial and second positions), the difference between the pretonic and tonic positions is conspicuous for all speakers, especially in the case of F1 values. (Note that there is no inter-speaker variability in the tonic position because this vowel's median serves as the reference point in the normalized measurements; hence, it is 0.0 for all speakers.)

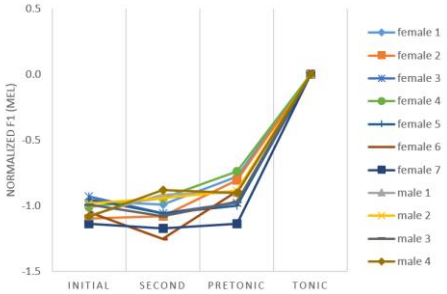

Figure 3: *By-speaker medians of normalized F1 values depending on position.*

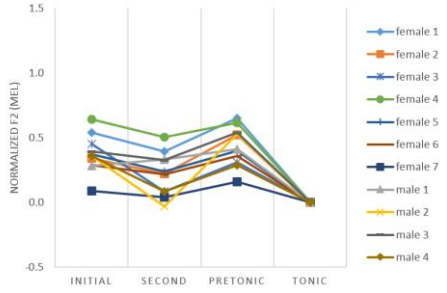

Figure 4: *By-speaker medians of normalized F2 values depending on position.*

Further, there is clearly a non-linear correlation between F1 and raw duration values (cf. the left panel in Figure 5). The vowels in the tonic (lexical stress) position and those occupying the non-tonic positions form heterogenous sets. This is so because, relative to other vowels, lexically stressed vowels occupy the upper ranges of duration and normalized F1 values, and also differ in the relative variability of the two parameters. The bigger range of duration values goes hand in hand with a smaller range of F1 values in these vowels (which shows that F1 targets are stably reached in these vowels, as expected). In order to minimize the effect of non-linearity, and also heteroscedasticity, the Pearson correlation was calculated on the basis of logarithmicized duration values (cf. the right panel in Figure 5). The overall analysis points to a strong correlation between decreasing duration and the undershoot of F1 targets; $r(1134) = 0.78$, $p < 0.001$.

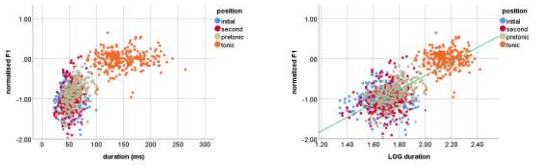

Figure 5: *The relationship between normalized F1 and duration (raw vs. log), divided by position.*

The relationship between F2 and duration shows a considerable degree of heteroscedasticity, which remains visible after duration values are logarithmicized (cf. Figure 6). With this caveat, the overall correlation between the two parameters is very small ($r(1134) = -0.23$, $p < 0.001$).

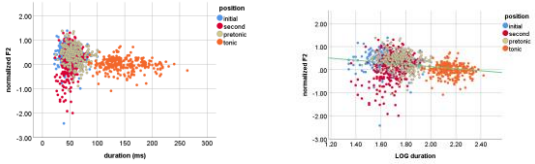

Figure 6: *The relationship between normalized F2 and duration (raw vs. log), divided by position.*

Below, we present more detailed analyses, focusing separately on the initial, second, pretonic and tonic positions (cf. Figure 7). Although initial (rhythmic stress) and second (unstressed) syllables exhibit comparable ranges of vowel duration values, only the latter shows a weak, yet statistically significant, positive correlation between F1 and duration (initial: $r(289) = 0.075$, $p = 0.203$; second: $r(291) = 0.19$, $p < 0.05$). There is no correlation between F1 and duration in the tonic position ($r(262) = 0.061$, $p = 0.325$). The duration-induced undershoot effect consistently appears in the pretonic position ($r(286) = 0.46$, $p < .001$).

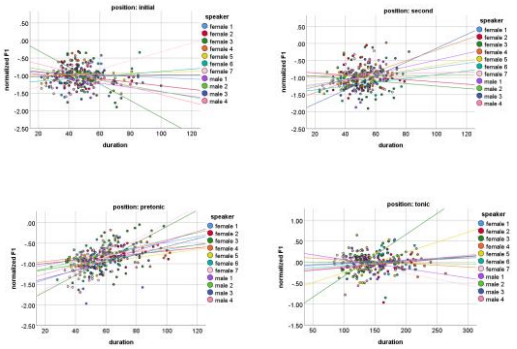

Figure 7: *The relationship between F1 and duration depending on position, divided by speakers.*

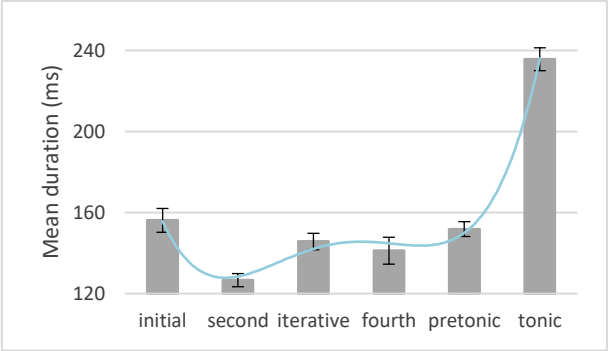

Figure 8: *Mean whole-syllable duration values in [σσσσσˈσ(σ)] words (based on [1].*

3. Discussion

The results of the current experiment point to a gradual effect of lengthening in the prosodically weak positions preceding lexical stress in Ukrainian. As indicated in [4], the functionality of this prominence-related duration adjustment is not fully understood. For English, [11], [12], and [13] suggest that the increased duration of the stressed syllable preceding another stressed syllable results in the equalization of feet duration and, thus, constitutes the timing effect of rhythm. This explanation cannot be applied to languages such as Ukrainian, in which pretonic lengthening affects the unstressed syllable, leading to a weakening of the syntagmatic distinction between the metrically prominent syllable and the preceding prosodically weak position. [9] argues that pretonic lengthening in East Slavic dialects is triggered by phonological tone, which docks on a syllable immediately preceding lexical stress. However, the lengthening effect detected in Ukrainian is very subtle in comparison with that reported for the East Slavic dialects, and available F0 measurements [3] do not reveal any pitch rise associated with the pretonic syllable.

The duration pattern in [σσσˈσ(σ)] words reported here seems to be compatible with the duration pattern reported earlier for longer words, having lexical stress on the sixth syllable, i.e. words of the [σσσσσˈσ(σ)] type [1] (p. 378). Interestingly, in [1], such words were observed to have an alternating strong-weak rhythmic pattern at the beginning of the word: both the initial and third syllables were longer than the second syllable in such words. This alternating pattern was further observed to disappear in the vicinity of lexical stress. As illustrated in Figure 8 (based on data from [1]), there was a relatively flat structure across the third, fourth, and fifth (i.e. pretonic) syllables in these words, with duration subtly increased in the pretonic position.

As the regular alternation of rhythmically strong and weak syllables is distorted in pretonic positions, i.e. in the vicinity of the lexically stressed syllable, it is suggested in [1] that the existence of pretonic lengthening in Ukrainian is unconnected to rhythm, but is closely related to the domain of lexical stress, which appears to extend to the pretonic syllable. This phenomenon may reflect a more universal anticipatory effect induced by lexical stress.

Formant measurements point to a reduced quality of the vowel [a] in all positions preceding lexical stress. The pretonic position stands out among other prosodic positions in that it shows a clear correlation between the undershoot of F1 targets and decreasing duration. Only a weak duration-dependent undershoot has been attested in the second position, and no correlation between duration and F1 targets was detected in the initial (rhythmic stress) position and in the position of lexical stress. These results are in line with the previous findings reported in [16], suggesting that the stability of F1 targets in prosodically strong positions (i.e., the positions of rhythmic and lexical stress) might serve to cue metrical prominence. Thus, despite being lengthened, the pretonic vowel remains metrically weak, which manifests itself in the presence of the formant undershoot.

4. Conclusions

The results of the current study point to the presence of pretonic lengthening in Ukrainian. The analysis has demonstrated that pretonic vowels are significantly longer than the vowels in the initial position, but not in the second position in words with lexical stress located on the fourth syllable. The analysis of formant structure reveals that vowels are subject to undershoot in all positions preceding lexical stress. However, the effect of duration on F1 is not automatic and depends on the prosodic position, in that the correlation between duration and formant undershoot is attested in metrically weak second and pretonic position but not in prosodically strong positions (rhythmically and lexically stressed).

5. Acknowledgements

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6. References

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