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Word-final rhythmic prominence in Ukrainian

Beata Łukaszewicz [1], *Janina Mołczanow*[1]

[1]University of Warsaw
b.lukaszewicz@uw.edu.pl, jmolczanow@uw.edu.pl

Abstract

As is well known, metrical prominence may coincide with boundary effects in word-final position. In this study, we report the results of an acoustic study of the metrical system of Ukrainian, designed to disentangle the potential domain-final lengthening from lexical and rhythmic stress in that language. The experiment is based on three-syllable words, differing in the position of lexical stress and rhythmic structure. We compare segmentally matched final syllables in triplets of words exhibiting three different metrical patters: [102], [010], [201]. The results point to statistically significant differences in vocalic duration, which depend on the stress level (rhythmic = 2, unstressed = 0, lexical = 1), and thus indicate that Ukrainian has word-final rhythmic prominence independent of boundary effects. We supplement those results with data from another acoustic study based on intrinsic (within-word) comparisons of vowel durations in the penultimate vs. final syllables. The comparison is based on three-syllable words lexically stressed on the first syllable, with penultimate and final vowels belonging to the same segmental category. The vowel in the final syllable (the rhythmic stress position) is significantly longer than the preceding vowel (the unstressed position). Our results corroborate the existence of word-final rhythmic stress in Ukrainian.

Index Terms: rhythmic stress, lexical stress, word boundary effects, domain-final lengthening, Ukrainian

1. Introduction

Ukrainian has weight-insensitive lexical stress, which is expressed phonetically by prolonged vowel duration ([1], [2], [3], [4], [5]). Lexical stress can appear in any syllable of the word, as illustrated by the minimal pairs in (1).

[ˈsɛstrɨ] ‘sister, nom. pl.’ - [sɛˈstrɨ] ‘id., gen. sg.’ (1)
[dɔˈrɔɦa] ‘way, nom. sg.’ - [ˌdɔrɔˈɦa] ‘dear, fem. sg.’
[ˈmɔlɔˌdʲi] ‘youth, dat. sg.’ - [ˌmɔlɔˈdʲi] ‘young, nom. pl.’
[pɔˈvɔdiˌtɨ] ‘behave’ - [ˌpɔvɔˈdɨtɨ] ‘lead, perf.’

Previous research has also detected increased syllabic and vocalic length in lexically unstressed word-initial, word medial, and word-final positions ([3], [4], [5]):

[ˌʊɛlɔˌsipɛˈdɨst] ‘cyclist’ (2)
[ˈʊɨzɔˌlɔtɨˌtɨ] ‘to gild’

This temporal enhancement has been interpreted to manifest rhythmic (grammatical) stress in this language ([3], [4], [5]), in line with previous traditional descriptions ([2], [6]). However, it is well established that variations in the temporal patterns of prosodic structure can be modulated by a variety of mechanisms, which, besides metrical prominence, include domain boundary effects, word length, segmental structure, and many others (see e.g. [7], [8], [9], [10], [11]). Given that increased duration is a multi-purpose prosodic cue, it is not obvious whether the temporal pattern observed in Ukrainian reflects metrical structure or whether it has a demarcative function, i.e., it signals word boundaries. The present study aims to decouple the mechanism of the potential word-boundary strengthening from lexical and rhythmic stress by zooming in on the domain-final position in trisyllabic words.

The confounding factor of word boundaries on the expression of rhythmic stress has been addressed in previous research on Ukrainian in a study of segmentally identical quadrisyllabic word pairs differing only in the position of lexical stress and rhythmic structure, e.g. [pɔˈpadaˌtɨ] ‘fall’ (perf.) - [ˌpɔpaˈdatɨ] ‘get’ (imperf.) ([12], [13]). This design made it possible to empirically distinguish between the effects of metrical prominence and lengthening at the word edges, simultaneously controlling for the potential confounding influence of polysyllabic shortening and intrinsic segmental length. The results point to the existence of edge-based prominence independent of boundary strengthening. However, this study had a limitation in that all the analysed items were verbs in the infinitive form, ending in the suffix *-ty* [tɨ]. It is unclear then whether the same prosodic pattern is present in words with (1) a different number of syllables, (2) a different morphological structure, and (3) a different segmental structure. In the current study, we circumvent these limitations by investigating words of varying segmental and morphological structure, providing acoustic measurements based both on extrinsic and intrinsic comparisons of vowel duration in lexically stressed, rhythmically (grammatically) stressed, and unstressed positions in trisyllabic words.

2. Method

2.1. Stimuli

Experiment 1 is based on extrinsic comparisons of vowel duration in the final syllable of three-syllable words, differing in the position of lexical stress and, hence, also in the presence/absence of rhythmic stress in the final syllable: [ˈσσˌσ], [σˈσσ], [ˌσσˈσ]. In three-syllable words, rhythmic stress can appear only at word edges, thus, it is important to distinguish carefully between potential domain-strengthening effects and rhythmic stress effects. We compare final syllables which are segmentally the same but metrically different, as shown in Table 1 below. In this way, we control not only for potential boundary effects, but also segmental effects. If the final enhanced duration reported in previous studies is a boundary effect, we expect identical temporal adjustments in

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the final syllables in [ˈσσˌσ] and [σˈσσ]. If rhythmic stress is located on the final syllable in Ukrainian, we expect duration of this syllable to be bigger in [ˈσσˌσ] than in [σˈσσ].

Experiment 2 is based on intrinsic comparison of vowels in the final and penultimate syllables of the same word. The vowels are categorically the same. The test items are three-syllable words having the metrical structure [ˈσσˌσ]. Comparing vowels occurring in the same word token allows us to control for the variation in the tempo of speech. Examples of stimuli are provided in Table 2.

Table 1: *Experiment 1 (stimuli)*

Position of the target syllable	**Stimuli**	**Gloss**
lexical stress ˌσσˈ**σ**	[ˌlɨstɔˈpad] [ˌnɛbɛˈsa] [ˌbʲirʲuˈza] [ˌmɔlɔˈka]	November**,** nom. sg. heaven, nom. pl. turquoise, nom. sg. milk, gen. sg.
rhythmic stress ˈσσˌ**σ**	[ˈt͡ʃɛrɛˌpa] [ˈɦlɔbuˌsa] [ˈzalɔˌza] [ˈmuzɨˌka]	skull, gen. sg. globe, gen. sg. gland, nom. sg. music, nom. sg.
unstressed σˈσ**σ**	[kaˈnapa] [tɛˈrasa] [bɛˈrɛza] [sɔˈbaka]	couch, nom. sg. terrace, nom. sg. birch, nom. sg. dog, nom. sg.

Table 2: *Experiment 2 (stimuli)*

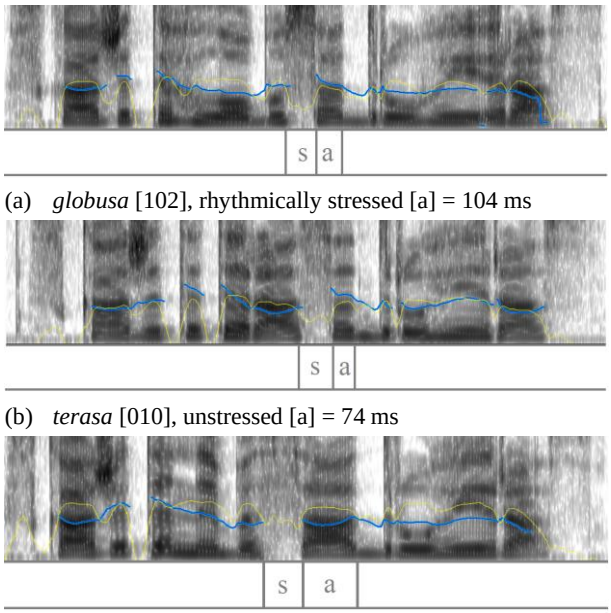
Vowels in σ_2 and σ_3 in [ˈ$\sigma_1\sigma_2$ˌσ_3]	**Stimuli**	**Gloss**
a - a	[ˈʊɨpaˌla]	fall out, past. fem. sg.
ɛ - ɔ	[ˈʊɛsɛlˌɔ]	merrily
u - u	[ˈʊɨbuˌdu]	check out, fut.1st pers. sg.
ɨ - ɨ	[ˈbat͡ʃɨˌtɨ]	see, inf.
	[ˈʊɨsɨˌpɨ]	spill out, inf.

2.2. Participants

14 native speakers of Ukrainian took part in the two experiments (Experiment 1: 10 speakers (9F, 1M; aged *M* = 48), Experiment 2: 14 speakers (10F, 4M; aged *M* = 45). All participants came from Western Ukraine (Lviv, Lutsk, Ivano-Frankivsk, and Rivne regions).

2.3. Procedure

The recordings were performed using a Tascam Dr-100mkIII portable recorder, set at a sampling rate of 44.1 kHz, and an AT897 microphone. Participants were audio-recorded reading sentences containing target words in three repetitions. The words put in a frame were presented on a computer monitor; the list was randomised to avoid order effects. Apart from target items, filler words were used. Target words all appeared in the same frame: [ˈskaʒɛˌtɛ … ˈdruɦij ˈraz] ‘You (pl.) will say … for the second time’. Lexical stress was marked orthographically to facilitate the identification of words. In the first experiment, we obtained 1080 tokens in total (10 participants * 3 stress conditions * 3 positions * 4 segmental types * 3 repetitions). 21 tokens (1.9 % of data) were rejected during analysis because of speech dysfluencies. Only the data from the final position (360 tokens) are analysed in this paper. In the second experiment, we obtained 420 tokens in total (14 participants * 2 stress conditions * 5 words * 3 repetitions). 4 tokens (less than 1% of data) were rejected because of speech dysfluencies.



(a) *globusa* [102], rhythmically stressed [a] = 104 ms

(b) *terasa* [010], unstressed [a] = 74 ms

(c) *nebesa* [201], lexically stressed [a] = 198 ms

Figure 1: *An example of segmented vowels in the final syllables in different metrical contexts: rhythmically stressed (a), unstressed (b), and lexically stressed (c).*

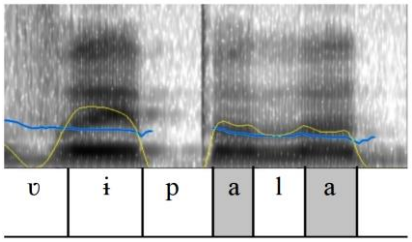


Figure 2: *An example of segmented penultimate (unstressed) and (final) rhythmically stressed vowels, belonging to the same phonological category.*

Segmentation was done manually using a high-resolution waveform editor (Sound Forge Pro v. 11.0); vowel boundaries were marked based on the dynamics of changes in the shape of the waveform, the visual inspection of the spectrogram in Praat, and auditory perception. Measurements were conducted in Praat (v. 6.2.09; [14]); duration values were obtained using a script. In Experiment 1, raw duration values, expressed in [s], were used to calculate by speaker z-scores in order to make the data more comparable. Illustratory examples are presented in Figure 1 (Experiment 1) and Figure 2 (Experiment 2) above.

2.4. Statistical analyses

To test the effect of stress on vowel duration, linear mixed effects models were built with duration as the dependent variable and stress as the fixed effect. In Experiment 1, the fixed effect had three values: 'lexical', 'unstressed', 'rhythmic'; in Experiment 2 it had two values: 'unstressed' and 'rhythmic'. In both analyses the random structure was fully specified in initial models, i.e. both speaker- and item-specific intercepts and slopes for the fixed effect of stress were used. In Experiment 1, item-specific slopes turned out non-significant and, as such, were discarded; in Experiment 2, the fully specified random structure was retained in the final model. The models converged.

3. Results

3.1. Experiment 1 (Extrinsic comparisons)

The linear mixed effects analysis, testing a potential effect of stress in the third syllable of [102], [010], and [201] words yielded significant results. The final rhythmic condition, which is the reference category, turns out significantly different from both the lexical stress condition (β = 1.941, *SE* = 0.060, t = 32.585, $p < .001$) as well as from the unstressed condition (β = -0.154, *SE* = 0.059, t = -2.588, $p < .05$. The estimated mean values of vowel duration in the three conditions are graphed in Figure 3.

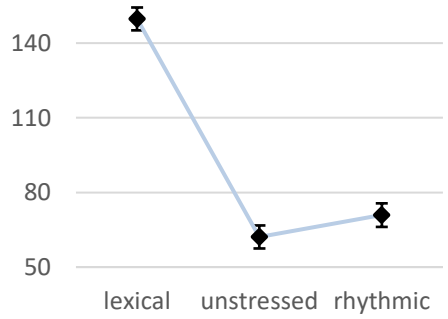


Figure 3: *Estimated duration means (in ms) of lexically stressed, unstressed, and rhythmically stressed vowels based on extrinsic comparisons in three-syllable words.*

3.2. Experiment 2 (Intrinsic comparisons)

A preliminary analysis in terms of a paired t test point to a statistically significant difference of 36 ms between the unstressed penultimate vowel and the vowel of the same category occurring in the rhythmically stressed final syllable in the same word token; t (206) = -17.652, $p < .001$. The statistical relevance of the difference was further confirmed by the linear mixed effects analysis of the same data, with 'stress' as the fixed effects, and 'speaker' and 'item' as random effects. The random structure was fully specified, i.e. both speaker- and item-specific intercepts and slopes for the fixed effect 'stress' were included. The average stress-induced difference in duration amounts to around 37 ms; β = 0.037, *SE* = 0.007, t = 5.355, $p < .001$. The estimated means of the unstressed and rhythmically stressed vowels are shown in Figure 4.

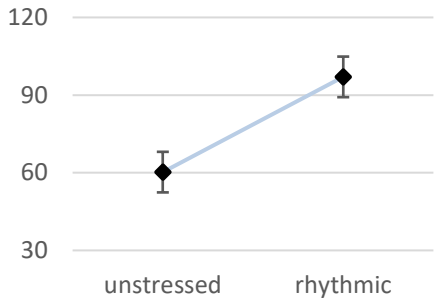


Figure 4: *Estimated duration means (in ms) of unstressed, and rhythmically stressed vowels based on intrinsic (within-word) comparisons.*

4. Discussion

The current study aimed to set apart domain-final lengthening from the effects of lexical and rhythmic stress in Ukrainian. We have conducted two experiments, involving between- and within-word comparisons of vocalic duration patterns. In the first experiment, the measured segment was the vowel [a], which appeared in segmentally identical sequences, [pa], [ka], [sa], [za] in word-final position across different stress conditions. We hypothesized that if word-final enhanced duration detected in previous research cues rhythmic stress in Ukrainian, then there should be differences in temporal adjustments between the corresponding syllables σ_3 in (3):

i. [ˌσ1σ2ˈ**σ3**] (3)
ii. [ˈσ1σ2ˌ**σ3**]
iii. [σ1ˈσ2**σ3**]

The acoustic measurements reveal a longer duration of the vowel in the final syllable σ_3 in both (3i) and (3ii) compared to (3iii). The difference in the duration between lexically stressed and unstressed vowel amounted to 88 ms, whereas the difference between rhythmically stressed and unstressed vowel was 9 ms, both reaching statistical significance.

To further control for the differences in speech tempo, the second experiment was designed to compare duration of the same vowel categories within the same word in unstressed (σ_2) and rhythmically stressed (σ_3) syllables in words with prosodic structure [ˈσ1σ2ˌσ3]. The measurements revealed a statistically robust difference of 36 ms between prosodically weak and prosodically strong vowel.

These results point to the presence of the effects of word-final rhythmic stress which is independent of boundary strengthening, thus confirming the findings of earlier research which investigated timing patterns in longer (quadri- and pentasyllabic) words ([5], [12], [13]). The current study complements previous research by providing both intrinsic and extrinsic comparisons of vowel duration in trisyllabic words of varied morphological and segmental structure.

Let us note that the present findings are consistent with earlier descriptions of Ukrainian ([15], p. 172), which schematically represent the relative vowel durations in three-syllable words as 2 – 1 – 1.75, 1 – 2 – 1.5, and 0.75 – 1 – 2

(vowel length has been represented on a scale from 0.75 to 2, where 2 stands for maximal duration of stressed vowels). Similarly to the results obtained in the current study, this description points to an increased duration (2 – 1 – 1.75) of the final rhythmically stressed syllable.

From the theoretical perspective, word-edge rhythmic stress detected in this and previous research makes Ukrainian a bidirectional system, in which predictable secondary stresses apply at the edges towards the syllable carrying primary stress. This proves the empirical adequacy of the theoretical mechanisms devised to account for such systems (see [16] for further discussion).

5. Conclusions

The present study has investigated vocalic duration in word final position in Ukrainian in two experiments designed to disentangle the potential confounding factor of word-final strengthening from the effect of rhythmic stress. Extrinsic comparisons of vowels were performed based on segmentally identical syllables in three prosodically different positions (lexically stressed, rhythmically stressed, unstressed). These measurements were supplemented by the intrinsic comparisons of duration of different vowel categories in the unstressed and rhythmically stressed positions within the same word. The results indicate that vowels lengthen in syllables carrying both lexical and rhythmic stress, The comparison of the word-initial and word-final syllables in rhythmically stressed and unstressed positions revealed statistically significant temporal differences. This finding indicates that increased duration at word edges does not constitute a boundary effect but serves to cue rhythmic prominence.

6. Acknowledgements

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7. References

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