# F0 and duration changes in unstressed vs. stressed syllables connected to postlexical stress and sentence type in Standard Lithuanian

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**Abstract**

This paper presents an analysis of F0 and duration changes in unstressed vs. stressed syllables connected to the postlexical stress and sentence type in Lithuanian. The aim of this analysis is to provide a systematic investigation on Lithuanian lexical stress by examining the F0 and duration differences between stressed and unstressed syllables in different sentence types and postlexical stress positions. The material consists of 540 audio-recorded phrases read by two Standard Lithuanian speakers – a male and a female. The results show that F0 does not consistently mark lexical stress in these two speakers' data and it rather serves postlexical purposes. Significant differences between lexically stressed and unstressed syllables were found only in exclamations and questions when the target word was postlexically stressed. Duration was found to be the marker of both lexical and postlexical stress. However, with regard to syllable duration, exclamations behave differently from both questions and statements.

Keywords: focus, lengthening, intonation, experimental phonetics, mixed-effect linear regression

## 1. Introduction

The aim of this study is to provide a systematic investigation on Lithuanian lexical stress by examining the F0 and duration differences between stressed and unstressed syllables in different sentence types and postlexical stress[1] positions. Most of the previous research on similar topics investigating Lithuanian language was conducted a relatively long time ago, using the means of that time, and some of it provides quite contradictory results. Therefore, it is important to analyse this issue in more detail, and this paper is meant to be a pilot study of such analysis.

Concerning the research on F0 changes in relation to lexical stress, some authors (Vaitkevičiūtė 1965, Mikalauskaitė 1975) mention that stressed syllables have higher F0, while others (Laigonaitė 1958) claim that F0 is not a very important attribute of stressed syllables in Lithuanian. The most explicit analysis of F0 changes in relation to lexical stress, postlexical stress, and sentence type in Lithuanian was conducted by Pakerys (1982) and showed that in many positions F0 of stressed vowels and diphthongs is higher than of the unstressed ones. This fact would go along with the data of other languages which show that sentence focus is marked with a pitch rise (Féry and Kügler 2008, Breen et al. 2010, Ots 2017). However, one quite recent study showed that some differences between different generation speakers are possible too (Kazlauskienė and Sabonytė 2018); thus, the contemporary Standard Lithuanian language requires a more detailed analysis on this issue.

F0 changes due to different sentence type and F0 declination (i.e., the decrease of pitch range towards the end of statements) can affect the F0 changes in stressed vs. unstressed syllables depending on their position. Additionally, free word order in Lithuanian could also have an effect on prosodic focus

[1] The term 'postlexical stress' used in this paper roughly corresponds to the term 'nuclear stress' used in autosegmental-metrical phonology. The reason is that the authors see the term *postlexical stress* as more fitting to the peculiarities of the Lithuanian language.

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marking – most of the time the semantic load is naturally transferred to the last part of a phrase which might interact with the regularities of F0 declination, as it is, e.g., in Estonian (Ots 2017).

Concerning the Lithuanian phonology of lexical stress, a few things relevant for this analysis should be mentioned. Lithuanian is a free-stress language, i.e., lexical stress can occur anywhere in a word, and there is variation of stress position even within the paradigms. The occurrence of secondary stress has not been analysed in Lithuanian so far, thus it is not known whether and, if so, where to expect the occurrence of secondary stress. There are no phonotactic constraints for the unstressed syllables, i.e., the position of lexical stress cannot be predicted based on the non-acoustic features of words, and stress clashes can occur, e.g., *gerų metų* ([gʲɛ²ˈruː ²ˈmʲæːtuː], 'good year (pl. gen.)'; stressed syllables are underlined in the example). Lithuanian has three types of lexical stress: one for short stressed syllables and two types of long stressed syllables. Short stressed syllables have a short vowel as syllable nucleus, and long stressed syllables have either (mixed) diphthongs or long vowels as syllable nuclei. If the first part of such nucleus is stressed, the lexical stress is called *acute*, and stressing on the second part is called *circumflex*. There is still not enough data to clarify whether or not the differences between acute and circumflex in Standard Lithuanian are encoded in F0 and/or other acoustic features, even though there are some works analysing this issue – starting with Pakerys (1982) and continuing with some relatively new research on the lexical stress types of Lithuanian dialects (e.g., Bakšienė 2012, Švageris 2016). However, this information may serve the reader as a broader context since the analysis of different lexical stress types is beyond the scope of this paper. This study aims to investigate the effects of lexical stress on F0 and duration independently of lexical stress type; therefore, words with all three types of lexical stress are included in the experimental material.

Considering the phenomenon of lengthening, the influence of lexical and postlexical stress on duration is recognized analysing the intonational patterns of various languages (Sluijter and van Heuven 1996, Baumann 2006, Breen et al. 2010). In the literature on lengthening in Lithuanian, there seems to be no analysis carried out so far on the pre-boundary lengthening, and the lengthening due to postlexical stress is analysed relatively poorly as well. The analysis of Pakerys (1982) showed that lexically stressed syllable nuclei have a longer duration than the unstressed ones, as well as the ones that are postlexically stressed. However, due to the means used at that time, this analysis has to be repeated in order to provide comparable results.

To sum up, in Lithuanian phonology, there is a traditional predisposition that both lexically and postlexically stressed syllables have higher F0 (Vaitkevičiūtė 1965, Mikalauskaitė 1975, Pakerys 1982) and are longer (Pakerys 1982). However, as mentioned earlier, this predisposition is not supported by enough data and analysis conducted using the contemporary means for the results to be comparable nowadays. Therefore, it is necessary to conduct such analysis to confirm or deny the existing predisposition.

## 2. Methodology

### *2.1 Participants*

The material of the research consists of the recordings of two Standard Lithuanian speakers – one male and one female, aged 27 and 29 respectively. Both speakers are college educated, living in Central Lithuania (Kaunas) either all of their lives or more than 15 years; so, despite the fact that they can speak the dialects used in their broad families, both of them use Standard Lithuanian daily.

### *2.2 Material*

As mentioned in the introduction, the most explicit analysis for Lithuanian that focused on F0 and duration changes in relation to lexical, postlexical stress, and sentence type, was conducted by Pakerys (1982). Given that this research was conducted relatively long ago and the technological means of that time were used, we decided to choose a very similar methodology and to analyse the F0 and duration

changes in unstressed vs. stressed syllables connected to the mentioned phenomena in current Standard Lithuanian. This decision is also based on the recent findings of Kazlauskienė and Sabonytė (2018), whose pilot study shows that there may be some differences in F0 changes related to the age of speakers of elder and younger generations. The age of the speakers of our study corresponds to the age of younger speakers of Kazlauskienė and Sabonytė (2018).

For this analysis, five minimal pairs of words (quasi-homonyms) that differ only in the position of lexical stress were chosen, as listed in (1). Here and henceforth in the transcription, sign ˈ marks acute, ˆ circumflex, while a lexical stress diacritic ˈ without any number marks short stressed vowel.

(1) *The minimal pairs used for the analysis*
   a. *siū́lė* ([ˈsʲuːlʲeː],'(they) offered') and *siūlẽ* ([sʲuːˆlʲeː],'a stitch');
   b. *bvė́liau* ([ˈvʲeːlʲɛʊ], 'I felted') and *vėliaũ* ([vʲeːˆlʲɛuˑ], 'later');
   c. *láimės* ([ˈlɑˑɪmʲeːs], 'happiness (sg. gen.)') and *laimẽs* ([lɐɪˆmʲeːs], '(they) will win');
   d. *saũsas* ([ˆsɐuˑsɐs], 'dry (sg. nom. masc.)') and *sausàs* ([sɐʊˈsɐs], 'dry (pl. acc. fem.)');
   e. *vìsas* ([ˈvʲɪsɐs], 'whole (sg. nom. masc.)') and *visàs* ([vʲɪˈsɐs], 'whole (pl. acc. fem.)').

Using these minimal pairs, three-word phrases with each of 10 quasi-homonyms were created. At first, before creating the set of phrases with different positions of the postlexical stress, the phrases with the target words being in the most neutral position were created; these are presented in (2). Target words of the minimal pairs belong to different parts of speech (and therefore in (2) the target words of the same minimal pair can be in different positions). Thus, it was necessary, first of all, to create the most natural way of saying every phrase without the postlexical stress or any additional semantic load (due to the word order) added to the target words. This enabled us to easily manipulate the word order creating the set of phrases with the postlexical stress later. In (2), under the 'Phrase' section, the target words are written in bold, and in addition to the IPA transcription, the stressed syllables are shown by underlining them as well.

(2) *The phrases of the most neutral position*

| Phrase | IPA | Translation |
|---|---|---|
| 1. Skaičiau **visas** knygas. | 1. [skɐɪˆt͡ʃʲɛuˑ vʲɪˈsɐs knʲiːˈgɐs‖] | 1. I have read all of the books. |
| 2. Jonas **siūlė** duonos. | 2. [ˆjǫːnɐs ˈsʲuːlʲeː ˈdʊɔnoːs‖] | 2. John offered the bread. |
| 3. Vakar **vėliau** vilną. | 3. [ˆvɑːkɐr ˈvʲeːlʲɛʊ ˈvʲɪlnɑː‖] | 3. Yesterday I felted wool. |
| 4. Linkim Jonui **laimės**. | 4. [ˆlʲɪŋˑʲkʲɪm ˆjǫːnʊɪ ˈlɑˑɪmʲeːs‖] | 4. We wish John happiness. |
| 5. Iširo viena **siūlė**. | 5. [ɪʃʲˈɪroː vʲɪɛˈnɐ sʲuːˆlʲeː‖] | 5. One stitch ripped off. |
| 6. Rasa ateis **vėliau**. | 6. [rɐˈsɐ aˆtɛɪˑs vʲeːˆlʲɛuˑ‖] | 6. Rasa will come later. |
| 7. Smėlis yra **sausas** ant kranto. | 7. [ˆsʲmʲeːlʲɪs iːˈrɐ ˆsɐuˑsɐs ɐnt‿ˆkrɐnˑtoː‖] | 7. The sand is dry on the shore. |
| 8. Lina **laimės** rytoj. | 8. [lʲɪˈnɐ lɐɪˆmʲeːs rʲiːˆtoːɪ‖] | 8. Lina will win tomorrow. |
| 9. Tilpo **visas** tortas. | 9. [ˆtʲɪlˑpoː ˈvʲɪsɐs ˈtɔrtɐs‖] | 9. The whole cake fitted in. |
| 10. Degino **sausas** šakas. | 10. [ˆdʲægʲɪnoː sɐʊˈsɐs ʃɐˈkɐs‖] | 10. (They) fired dry branches. |

After creating the phrases with the target words in the most neutral position, a set of phrases with post-lexical stress were created. As mentioned in the introduction, the word order in Lithuanian is free (though a most neutral word order, *subject + verb + object*, does exist) so the position of the target words was easily manipulated without making the phrases sound unnatural. To create the phrases, two variables that are named in (3) were taken into the account.

(3) *Variables used to create the three-word phrases*
   a. the position of the postlexical stress in a phrase (beginning, middle, end);
   b. phrase (or sentence) type (statement, exclamation, question).

There were 9 different position groups created based on the two variables: 21, 21!, 21?, 22, 22!, 22?, 23, 23!, 23?. The first number indicates the position of the target word in the phrase, the second one the position of the postlexical stress. The question mark indicates a question, and the exclamation mark exclamation. According to these positions, the words of interest were analysed as listed in (4).

(4) *Target words in relation to the postlexical stress position*
   a. if postlexical stress is in the beginning (positions 21, 21!, 21?), the word of interest follows the postlexically stressed word;
   b. if postlexical stress is in the middle (positions 22, 22!, 22?), the word of interest is postlexically stressed;
   c. if postlexical stress is in the end (positions 23, 23!, 23?), the word of interest precedes the postlexically stressed word.

The phrases were created in such a way that next to the lexically stressed syllable of the target word, the syllables of other words are unstressed.

### *2.3 Procedure*

The phrases were given to the speakers to read in groups according to the 9 positions. In each group, the phrases were mixed so that the ones with the words of the same minimal pair do not directly follow one another. The statement-type phrases were written together with a question: the interviewer asks the question (in such a way that the word that needs to be focused on the answer is also focused in the context of questions) and the speaker answers reading the phrase with the target word as an answer.

The phrases were created in such a way that the syllable stress of the quasi-homonyms can be clearly judged by the context. However, in order to diminish the amount of the reading mistakes that might occur, the stressed syllables of all words were underlined and the postlexically stressed words written in bold so that the speakers can clearly see the parts needed to be emphasised.

Every group of phrases was read by two speakers three times, so the overall quantity of the recordings analysed is 540 phrases. The samples were segmented (boundaries of the syllables' nuclei belonging to the target words were determined), and data of mean F0 and duration were extracted using PRAAT (Boersma, Weenink 2019, version 6.0.56) and scripts created by Kroos et al. (2010) and DiCanio (2018), that were adapted by one of the authors of this paper. The segmentation process is illustrated in Figure 1 and Figure 2. Figure 1 shows one of the phrases in position 11 – *Lina laimės rytoj.* ('Lina will win tomorrow.'), segmented by three levels – word, syllable, and sound. Numbers 4, 9, and 3 indicate different lexical stress types: 4 marks short stressed syllables, 9 marks acute, and 3 marks circumflex (such marking was necessary for the annotation process to avoid special characters). Figure 2 shows the same phrase with only analysed syllable nuclei marked and prepared for the data extraction.

After the extraction, if needed, some inconsistencies within the data (which occurred, e.g., due to the fracturing male F0 or creaky voice) were corrected manually using PRAAT commands.

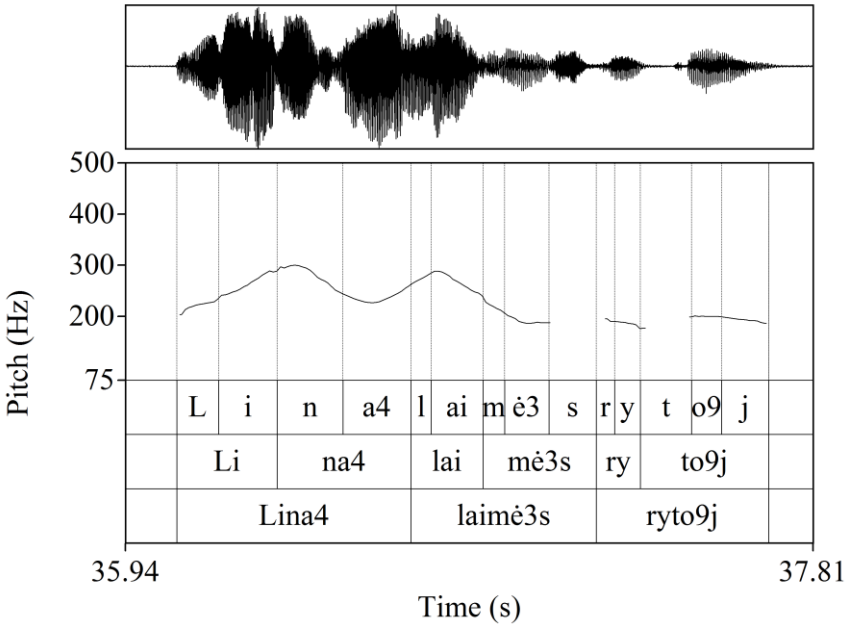


Figure 1. Phrase: Lina laimės rytoj. (‘Lina will win tomorrow.’) in position 21, segmented by three levels – word, syllable, and sound.

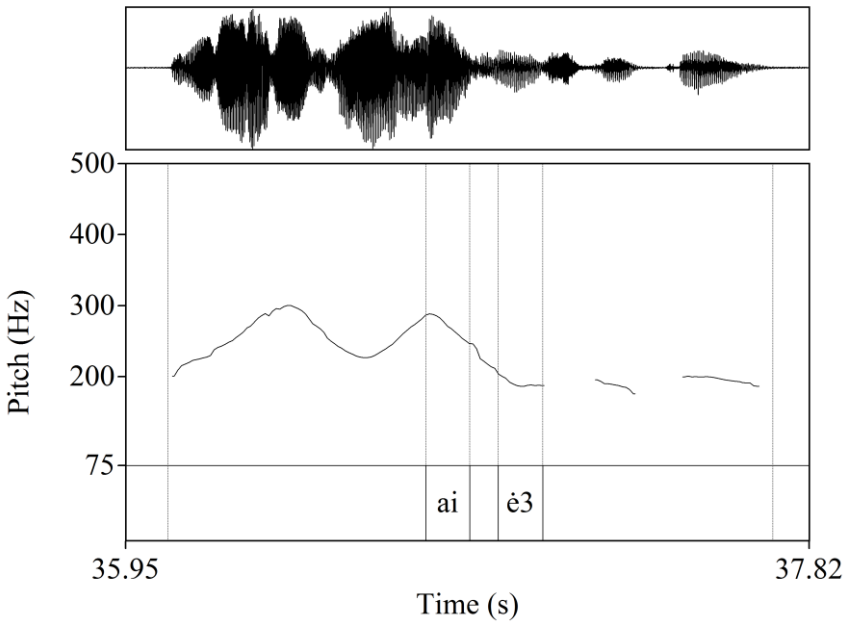


Figure 2. Phrase: Lina laimės rytoj. (‘Lina will win tomorrow.’) in position 21, only with analysed syllable nuclei segmented.

### *2.4 Analysis*

In pre-processing, the measured F0 values (in Hz) and syllable durations (in milliseconds) were centred and ORQ normalized in order to achieve a normal distribution (Peterson and Cavanaugh 2020). Linear mixed-effects models were fitted to each of these parameters using the *lmer* function from the **lme4** package (Bates et al. 2015) in R (R Core Team 2020). Predictors used in the model were lexical stress level (stressed vs. unstressed), postlexical stress position (1 vs. 2 vs. 3) and sentence type (statement vs. question vs. exclamation) as well as interactions between the predictors.[2] For the model of syllable duration, random intercepts were included for target word and speaker. Following the recommendations of Bates et al. (2015), principle component analyses of the random effects structure were conducted. The principle component analysis suggested overfitting in the case of the model of F0 and this model, and therefore only included random intercepts for speaker. P-values were obtained using the *mixed* function in the **afex** package (Singmann et al. 2020) using the Kenward-Roger approximation for degrees-of-freedom as recommended for linear mixed models. Post-hoc tests were performed using **emmeans** (Lenth 2020).

## 3. Results

### *3.1 F0*

Figure 3 shows the measured F0 values in the syllables of interest. Visual inspection of the boxplots indicates that there is little difference between the mean F0 in stressed and unstressed syllables in statements regardless of postlexical stress position. In questions and exclamations, the same picture emerges except when postlexical stress is on word 1 or 3, i.e., when the word of interest is not postlexically stressed. However, when postlexical stress is on word 2, i.e., when the word of interest is postlexically stressed, we see a difference between the lexically stressed and lexically unstressed syllables.

Statistical testing found that F0 was significantly affected by the position of postlexical stress ($F(2, 1052)=50.06$, $p<0.001$) and sentence type ($F(2, 1052)=172.46$, $p<0.001$). Interestingly for our hypothesis, there was no main effect for lexical stress level. However, interaction effects were observed between lexical stress level and sentence type ($F(2, 1052)=16.00$, $p<0.001$) and between postlexical stress position and sentence type ($F(4, 1052)=168.07$, $p<0.001$), and finally a three-way interaction between lexical stress level, postlexical stress position and sentence type ($F(4, 1052)=20.92$, $p=0.001$). This would indicate that F0 does not consistently mark lexical stress in Lithuanian, but rather that it serves postlexical purposes, which may coalesce with lexical stress under specific conditions.

Most interesting for the present investigation is the three-way interaction between lexical stress level, postlexical stress position and sentence type. Within groups, significant differences between lexically stressed and unstressed syllables are only observed when postlexical stress is in position 2 in exclamations ($p<0.001$) and questions ($p<0.001$). In the other groups, there is no statistically significant difference between stressed and unstressed words. Rather than being a marker of lexical stress, this seems to indicate that the stressed syllable serves as an anchoring point for tones associated with particular intonation contours.

If we look at the questions with postlexical stress in position 2, we see that lexically stressed syllables are relatively low. Both lexically stressed and unstressed syllables in words following the postlexically stressed word, i.e., when postlexical stress is in position 1, have a mean F0 that is higher than in all other groups (in all instances $p<0.001$) except for exclamations with lexical stress and postlexical stress position 2, where no significant difference is found. This can be explained assuming a L*H accent in questions, where the L* associates the lexically stressed syllable of the word with postlexical stress and the H aligns with the following syllables regardless of lexical stress level. Likewise, assuming

[2] Since the model includes rather complex interactions, addressing all findings of the model is beyond the scope of the present paper. The data and R code can be obtained by contacting the authors.

an H* accent for exclamations would explain the rather high F0 on the lexically stressed syllable in words with postlexical stress in exclamations. These matters, of course, demand further investigation.

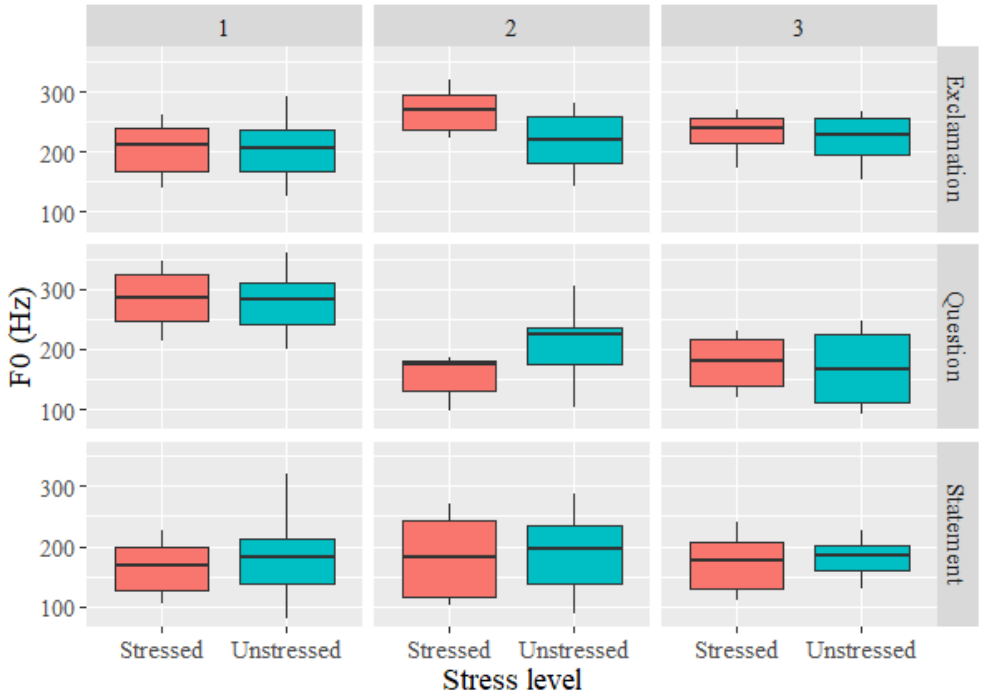


Figure 3. Measured F0 values in Hz for stressed and unstressed syllables by sentence type and postlexical stress position (1 – the postlexical stress is in the beginning, 2 – in the middle, 3 – in the end).

### *3.2 Duration*

Figure 4 shows a boxplot of the measured syllables duration in milliseconds. Visual inspection seems to suggest that lexically stressed syllables have longer duration than lexically unstressed syllables in all conditions, and that this effect is increased under postlexical stress.

Statistical testing found that the duration of syllables was significantly affected by lexical stress level ($F(1, 1052)=603.07$, $p<0.001$), postlexical stress position ($F(2, 1052)=330.88$, $p<0.001$), and sentence type ($F(2, 1052)=27.94$, $p<0.001$). Further, interaction effects were found between lexical stress level and postlexical stress position ($F(2, 1052)=83.49$, $p<0.001$), between postlexical stress position and sentence type ($F(4, 1052)=18.08$, $p<0.001$) and a three-way interaction between lexical stress level, postlexical stress position, and sentence type ($F(5, 1052)=2.83$, $p=0.024$).

The main effect for lexical stress seems to indicate that duration serves as a cue to lexical stress, but that its manifestation is affected by many other things. If we focus on the main effect of postlexical stress, we see that postlexical stress position 2 differs significantly from both postlexical stress position 1 ($p<0.001$) and position 3 ($p<0.001$). However, there is no significant difference between postlexical stress position 1 and 3. This would indicate that duration does serve as a cue to postlexical stress as well. The main effect for sentence type shows that exclamations behave differently from both questions ($p<0.001$) and statements ($p<0.001$), but no difference between statements and questions can be observed on the basis of our data.

If we examine the interaction effect between postlexical stress position and lexical stress level, we see that the difference between stressed and unstressed syllables is significant under all postlexical stress positions (in all instances $p<0.001$). Lexical stressed syllables with postlexical stress in position 2 differ significantly from lexically stressed syllables with postlexical stress in position 1 ($p<0.001$) and 3 ($p<0.001$). No significant difference was found, however, between lexically stressed syllables with post-lexical stress in position 1 and 3 ($p<0.001$). The same pattern is observed for the unstressed syllables, where postlexical stress position 2 differs significantly from 1 ($p<0.001$) and 3 ($p<0.001$), but no difference is found between 1 and 3. In sum, duration consistently serves as a cue to lexical stress regardless of postlexical stress position. The magnitude of the difference between lexically stressed and unstressed syllables, however, is significantly larger when the words have post-lexical stress. This would, therefore, seem to corroborate the impression that duration has a function in marking both lexical and postlexical stress.

The three-way interaction between lexical stress level, postlexical stress position and sentence type shows that within-group differences in the duration between stressed and unstressed syllables can be observed almost across the board. No significant difference was found between stressed and unstressed syllables in questions with postlexical stress position 1, but otherwise the difference is significant ($p<0.001$ in all instances except $p=0.005$ in the case of questions with postlexical stress position 3). The lack of a difference in questions with stress position 1 may be due to some durational reduction in syllables following the postlexically stressed syllable as observed in other languages (Barnes 2006). Otherwise, this corroborates that duration is used for both lexical and postlexical purposes.

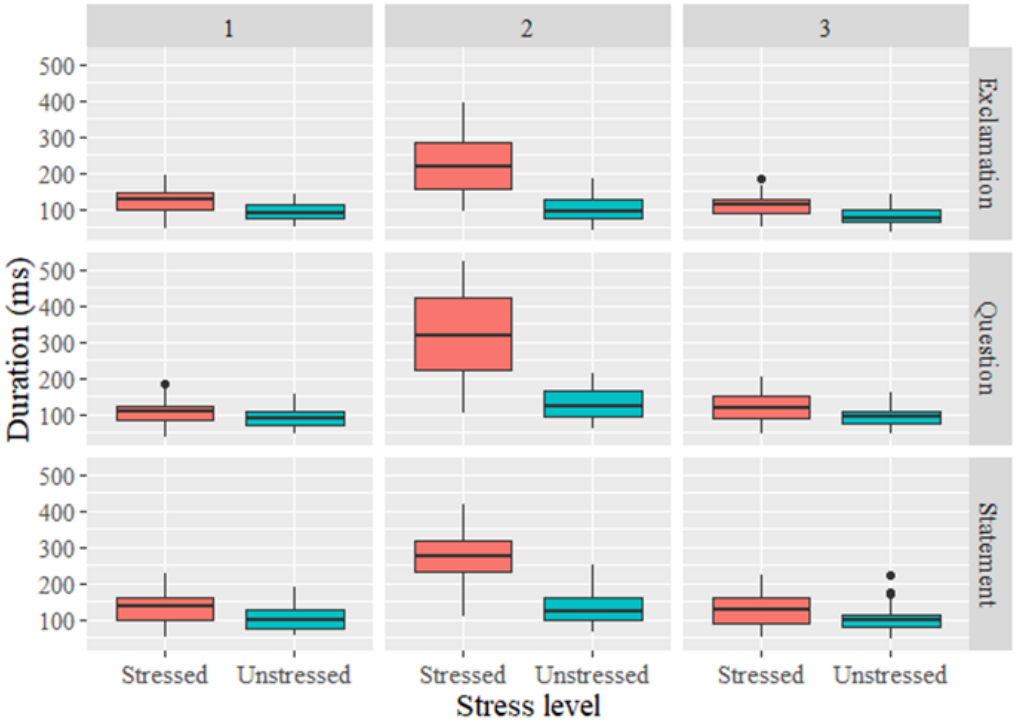


Figure 4. Measured duration values in milliseconds for stressed and unstressed syllables by sentence type and post lexical stress position (1 – the postlexical stress is in the beginning, 2 – in the middle, 3 – in the end).

## 4. Discussion and conclusions

The pilot study of F0 and duration changes in unstressed and stressed syllables connected to the postlexical stress and sentence type revealed that the existing predisposition in Lithuanian phonology to analyse both lexically and postlexically stressed syllables as having higher F0 and being longer is not fully correct.

Concerning F0, the analysis showed that F0 does not consistently mark lexical stress in Lithuanian; rather, it serves for postlexical stress marking, which in some circumstances may co-occur with lexical stress. This finding aligns best with the previous reports for Finnish (Suomi et al. 2003) and Lithuanian research that were conducted by Pakerys (1982) and (Laigonaitė 1958). Suomi et al. (2003) found that the word stress in Finnish is not realized tonally. Pakerys' (1982) analysis showed that in Lithuanian, F0 difference between lexically stressed and unstressed syllables was related to the postlexical stress position, and Laigonaitė (1958) argued that F0 was not a very significant attribute of lexical stress. No main effect for lexical stress level in our study was observed, though F0 was significantly affected by the position of postlexical stress and sentence type. On the other hand, interaction effects were found between lexical stress level and sentence type, postlexical stress position and sentence type, and a three-way interaction between lexical stress level, postlexical stress position, and sentence type was observed. The three-way interaction showed that lexically stressed and unstressed syllables differ significantly only in postlexical stress position 2 in exclamations and questions. It also indicates that lexically stressed syllables may serve as anchoring points for tones related to particular intonation contours.

Duration was found to be a marker of both lexical and postlexical stress (aligning with the previous findings of Pakerys 1982). This was shown by the main effects for both, as well as the interaction effect between postlexical stress position and lexical stress level and the three-way interaction between lexical stress level, postlexical stress position and sentence type. The main effect for sentence type revealed that with regard to syllable duration, exclamations behave differently from both questions and statements.

The future analysis of lexical and postlexical stress effects on F0 will be extended by including more Standard Lithuanian speakers. The phenomenon of lexically stressed syllables serving as anchoring points for tones will be analysed in more detail. With regard to lexical and postlexical stress effects on both F0 and duration, future research should include Lithuanian speakers from different dialects. This would determine whether the effects are the same in different dialects or they are rather observed only in Standard Lithuanian.

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