The Interaction of Animacy with Phonetic and Phonological Factors in Neoštokavian Pitch Accents

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1. Introduction

The Neoštokavian dialect of Croatian belongs to the somewhat obscure category of pitch accent languages,[1] making use of both tone and another type of prominence, usually termed *stress*, in word-level prosody (Babić, 1988; van der Hulst & Smith, 1988; Bethin, 1994; Inkelas & Zec, 1988; Zec, 1992, 1999). The interaction between tone and stress yields four accents, traditionally called long falling (â), short falling (ä), long rising (á) and short rising (à). If tone and stress are distinguished as properties that are partially independent in their realization, meaning that they can but do not have to be realized on the same syllable, falling accents can be described as High tone on the stressed syllable, as in (1a) and (1b) (since the tone falls following the 'stressed' syllable), and rising accents as High tone on the post-stressed syllable, as in (1c) and (1d) (since the tone rises following the 'stressed' syllable). The stressed vowel can be either short or long.

(1) a. ˈpjésma
b. ˈmáajka
c. ˈnogá
d. ˈruuká

The position of stress is completely predictable. If the High tone is located on the first syllable, stress is aligned with it, as is the case in falling accents. Otherwise, stress is found on the syllable immediately preceding the syllable with High tone, which produces rising accents. In other words, all nouns in (1) have initial stress, but differ in the location of High tone. Because stress is predictable, this paper, like most of the research that deals with South Slavic pitch accent systems, focuses only on the location of High tone.

A number of studies have investigated the phonetic (Lehiste & Ivić, 1986; Godjevac, 2000) and phonological (Babić, 1988; Bethin, 1994; Inkelas & Zec, 1988; Zec, 1992, 1999; Jelaska, 2004) properties of Neoštokavian pitch accents. However, there are still many areas that have not been fully elucidated, one of which this paper addresses using a novel technique. In previous analyses, it has been claimed that morphemes in Neoštokavian can underlyingly be toneless, or associated with High tone (Zec, 1988, 1992, 1999; Inkelas & Zec, 1988; Bethin, 1994). The question that has not yet been asked is whether there are factors that influence a word's preference for a certain type of pitch accent – in other words, is there anything about the phonetic, phonological, morphological or semantic properties of a word that would make it more likely for the High tone to occupy one syllable or another, regardless of whether that High tone is underlyingly present or assigned at a later stage in the derivation. This paper addresses that question using regression modeling, and finds that phonetic and phonological factors interact synergistically with animacy to influence the location of High tone in nouns derived from monosyllabic masculine roots.

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[1]In the literature, this dialect is often referred to as Serbo-Croatian, or BCS (Bosnian/Serbian/Croatian), depending on the country in which it is spoken. Although differences exist, the accentual systems do not vary much between Neoštokavian dialects.

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The reason for restricting the analysis to only monosyllabic masculine roots is a purely practical one. Disyllabic nouns derived from monosyllabic roots were chosen because they still preserve the Proto-Slavic accentual paradigms, and because the location of tone is restricted to only two positions, making it easier to model. Only masculine nouns were modeled because feminine and neuter nouns differ in some crucial aspects from masculine nouns, which would make it impossible to include certain predictors in the model. However, this research is part of a bigger project which aims to investigate the influence of phonetic, phonological, and semantic factors in different parts of the lexicon.

The structure of the paper is as follows. In §2 I present the data and give details about how the logistic regression model was used to analyze it. In §3 I discuss the results of the model and their implications for the analysis of Neoštokavian pitch accents. I conclude the paper in §4.

2. Data and Model

2.1. The Data

The database includes 441 masculine disyllabic nouns consisting of monosyllabic roots and inflectional endings, taken out of the Dictionary of Croatian Language (Anić, 1998), and accented according to the intuitions of four native speakers of the dialect in question. The database thus contains all disyllabic nouns derived from monosyllabic roots.[2] These nouns fall into three accentual paradigms, depending on the location of High tone in different inflectional cases throughout the declension. In the so-called *baritone* paradigm, the High tone is located on the root syllable in all inflections, as in (2). In the *oxytone* paradigm, the High tone is always on the affix, as in (3), and in the *mobile* paradigm, it is on the root syllable in some inflections, and on the affix in others, as in (4).[3]

(2)	BARITONE	(3)	OXYTONE	(4)	MOBILE
	G ˈgád-a		G ˈsnop-á		G ˈrát-a
	L ˈgád-u		L ˈsnop-ú		L ˈrat-ú

The data have been coded for the following predictors, based on the factors that have been claimed in the literature to influence High tone placement in Neoštokavian (Zec 1988, 1992, 1999; Inkelas & Zec 1988, Babić et al. 1991) and based on the most obvious phonological, morphological, and semantic factors that could potentially influence the placement of High tone: CASE, ANIMACY, ROOT VOWEL LENGTH, and POSTVOCALIC CONSONANT. I briefly review the predictors in the following paragraphs.

CASE. Two inflections have been included for each root, the genitive case and the locative case, which covers the accentual differences between the three accentual paradigms.[4]

ANIMACY. Animacy is morphologically marked in masculine nouns in Neoštokavian – in the accusative case, animate and inanimate nouns have distinct forms.[5] It is traditionally reported (Babić et al., 1991) that it is the inanimate nouns from the Proto-Slavic accentual paradigm *c* that belong to the mobile paradigm in Neštokavian. This seems to hold true; 98% of the nouns in the mobile paradigm are in fact inanimate. There are inanimate nouns in the other two paradigms as well (84% in the oxytone, and 64% in the baritone), and thus, though animacy is a good predictor of membership in the mobile paradigm, it is neither a necessary nor a sufficient condition. A logistic regression model can readily incorporate these sorts of tendencies and can show which other factors interact with animacy to influence the distribution of nouns between the three accentual paradigms.

[2] Around 10% of nouns have been excluded from the data set due to variation in the location of High tone. Additional eleven nouns have been excluded either because they were archaic, or very rare/regional.

[3] Croatian has seven inflections. Only two, the genitive (G) and the locative (L), are illustrated here.

[4] A potential concern when including multiple forms for each root is inflation of the data. In order to verify that this did not skew the results, separate models were built for the genitive forms and the locative forms (Peter McCullagh, p.c.). The predictors in the two models followed the same trends as the predictors in the model containing both the genitive and the locative forms, suggesting that including two forms for each root did not significantly alter the results.

[5] Animacy is morphologically marked only in masculine nouns. This is why nouns of all three genders could not be included in the same model.

ROOT VOWEL LENGTH. Zec (1999) suggests that vowel length influences the docking site of the High tone, claiming that an underlying tone cannot be associated with a bimoraic syllable, and that underlying tones surface on long vowels only if they have no choice, i.e., in monosyllabic words.[6] This is not true of monosyllabic masculine roots, since there are monosyllabic roots with long vowels that follow both the baritone and the mobile pattern, and nouns in both paradigms could not be underlyingly toneless, since they follow different accentual patters. Zec (1988) analyzes nouns in the baritone paradigm as being underlyingly endowed with tone, and those in the mobile paradigm as underlyingly toneless. The 'mobility' of the accent is due to the underlying High tone of the affixes in particular inflections, which can only surface if the root is toneless. This, however, predicts that the baritone paradigm should not contain roots with long vowels, which is not the case in the variety of Neoštokavian analyzed in this paper. An interesting observation to make here is that historically, all nouns in the baritone paradigm did in fact have a short vowel. However, a number of nouns with long root vowels, that used to pattern with the nouns in the mobile paradigm, have moved to the baritone paradigm. The model reveals which other factors have (at least partially) influenced this migration.

POSTVOCALIC CONSONANT. This predictor refers to the consonant that follows the root vowel, which is either the final consonant of the root, or the first consonant in a sequence, if the root has a complex coda. Although no influence of the intervocalic consonant on tone placement has ever been reported for Neoštokavian, consonants are known to influence surrounding vowels in various ways (e.g. voiced consonants cause the preceding vowel to be longer (Lehiste, 1976), voiceless consonants have a pitch-raising, and voiced consonants a pitch-lowering effect on the following vowel (Haudricourt, 1954; Hombert, 1978), etc.). In this data set, consonants have been coded as *voiced, voiceless*, and *sonorant*, where the first two labels encompass all obstruents.

All predictors have been contrast coded, which centers the predictor values.[7] Table 1 lists all independent variables and their values.

Predictor	**Description**	**Values**
CASE	Inflection of the noun	genitive, locative
ANIMACY	Animacy of the root	inanimate, animate
ROOT VOWEL LENGTH	Length of the root vowel	short, long
POST-VOCALIC CONSONANT	Type of the root post-vocalic consonant	voiced, voiceless, sonorant

Table 1: Independent variables

2.2. The model

Generalized linear models are statistical models that estimate the value of a dependent variable as a function of one or more predictors (or independent variables). Logistic regression is a variety of generalized linear model that estimates the probability of a given outcome for a binary dependent variable.[8] This statistical technique has been used extensively in modeling sociolinguistic variation but

[6] Another possibility is to have initial High tone assigned to an underlyingly toneless morpheme at a later stage in the derivation. Since each word must surface with exactly one High tone, the forms that are analyzed as underlyingly toneless according to Zec receive tone via the Initial Insertion Rule, which associates High tone with the first mora in the word.

[7] This makes the results easier to interpret, since the model is not comparing one value to the other, but to the average (which is changed to be equal to zero). For predictors with two levels, by changing the contrasts we are changing the numeric values associated with each level to be the difference of that level from the mean. What is being tested is whether the difference between the value of the dependent variable for the two levels is significantly different from zero. For the predictor with three levels, two new predictors were created. In the first, two levels were contrast coded with the third (*ab:c*), and in the second, the two levels that were grouped together in the previous predictor (*a:b*).

[8] For a general description of the model, see Agresti (2002) and Baayen (2008), and for an overview of the benefits of using logistic regression over ANOVA for categorical data analysis, see Jaeger (2008). An especially useful presentation of regression models can be found in Gelman & Hill (2007).

has not had wide application in other linguistic subfields.

The formula of the model is shown in (5), where β_0 is the intercept, and $\beta_1 - \beta_n$ are the regression coefficients of the factors $x_1 - x_n$.[9]

(5) $log(\frac{1}{1-p}) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n$

The Neoštokavian accentual database constructed for this study consists only of monosyllabic roots followed by the inflectional affix, and the tone can take one of two positions: it can be located on the root, or on the affix. The dependent variable, TONE, has the value '1' when High tone falls on the root, and '0' when it fall on the affix. The model assesses the likelihood of the outcome being '0' or '1', based on the chosen predictors.

The model was fit using the *glm()* function in the statistical software R. It was built both in a bottom-up and a top-down fashion, namely, both by adding predictors one by one, and by starting with the maximal number of predictors and their two-way and three-way interactions, and removing the insignificant ones one by one. In both procedures, each model was compared to the preceding one with ANOVA, to confirm that keeping a predictor, or leaving it out, makes the model significantly better fit the data.

In a model that contains many predictors, and especially their interactions, collinearity is a concern, since many variables could be partially predicted from each other. The overall collinearity of the model was checked using the *kappa()* function in *R*, which returned a condition number of 7.42, which indicates very mild collinearity.[10]

Another piece of information that we want to have about the model is how well it fits the data, i.e., what proportion of the variability in the outcome is accounted for by the model. In linear models, this is given by the R^2 number. In logistic regression, however, since the dependent variable is the log of the odds ratio, R^2 cannot be straightforwardly calculated. There are several *R*-like measures that have been developed, one of which is the Negelkerke R^2 (the so-called pseudo-R^2), that assesses the quality of a model with respect to a baseline model (a model that contains only the intercept). The Nagelkerke R^2 for this model is .429, which means that the model accounts for about 43% of the variance in the data. This is a reasonable fit, since it is not expected that the predictors investigated here are the only ones that effect the location of High tone in Neoštokavian pitch accents.

Finally, *bootstrapping* was performed on the model using the *validate()* function in the *Design* package in *R*, to verify the robustness of the results. Bootstrapping is a resampling technique that draws samples with replacement from the original data set, creating new data sets of the same size as the original set. As a result of drawing random samples, the new data sets have some data points drawn more than once, and some data points not drawn at all. For each of the subsamples, this method uses the "Aikake information criterion" (AIC; which establishes a trade-off between number of free parameters and goodness of fit) to determine how many predictors to remove from the model for each subsample. If the model is well suited to the data, then most times most of the predictors will be kept. Across 200 bootstrap runs, all predictors were retained 42 times, one predictor was dropped 85 times, two predictors 45 times, three predictors 24 times, and four predictors four times. The Nagelkerke R^2 was reduced from .429 to .397, meaning that the model is overly optimistic, due to over-fitting, by around .03%.

3. Results

Table 2 shows the summary of the results, divided into three parts. All results can be interpreted as supporting the following two claims:

[9] The intercept is the value of the logit when the value of all independent variables is zero, for binary predictors. If a predictor has different values, the model chooses one of its values as the baseline. The regression coefficients describe the size of the contribution of the respective factors. A positive regression coefficient means that the predictor increases the probability of the outcome, while a negative coefficient means that the probability of the outcome is decreased.

[10] According to Baayen (2008), a condition number between 0 and 6 means that there is no collinearity, medium collinearity is indicated by a condition number around 15, and harmful collinearity by a number above 30.

1. syllable weight has a significant influence on the location of High tone in this data set, and
2. animacy interacts with all other predictors, mediating their effects.

All results are discussed in the following sections within these two overarching findings.

	Coeff. β	*SE*	z	*p*	
(Intercept)	-0.4893	0.0943	-5.192	$2.08e{-}07$	***
ANIMACY = *I*	-1.3550	0.2398	-4.913	$8.17e{-}07$	***
CASE = *L*	-1.8453	0.1891	-9.759	$< 2e{-}16$	***
ROOT VOWEL LENGTH = *SH*	-1.0021	0.1867	-5.367	$8.03e{-}08$	***
POSTVOCALIC CONSONANT = *V/S vs. VL*	0.6803	0.1853	3.672	0.000241	***
POSTVOCALIC CONSONANT = *V vs. S*	0.3044	0.2477	1.229	0.219065	
ANIMACY = *I* : CASE = *L*	-1.6125	0.5422	-2.974	0.002939	**
ANIMACY = *I* : ROOT VOWEL LENGTH = *SH*	1.7496	0.5381	3.251	0.001148	**
ANIMACY = *I* : POSTVOC. CONSONANT = *V/S vs. VL*	0.2042	0.5024	0.407	0.684371	
ANIMACY = *I* : POSTVOC. CONSONANT = *V vs. S*	-1.7402	0.7138	-2.438	0.014774	*
CASE = *L* : ROOT VOWEL LENGTH = *SH*	2.6009	0.3726	6.981	$2.93e{-}12$	***
ANIMACY = *I* : CASE = *L* : ROOT VOWEL LENGTH = *SH*	2.6863	1.0563	2.543	0.010985	*

I = inanimate; L = locative; SH = short; V = voiced; VL = voiceless; S = sonorant

Table 2: Result summary

3.1. Syllable weight

Before turning to probabilistic effects predicted by the model, it should be mentioned that statistical exploration of the data also revealed a deterministic effect that has not been reported before. Namely, if the root ends in a consonant cluster, the first member of which is not a sibilant, the tone is **always** located on the root syllable. If we assume that the first member of such a cluster is syllabified as the coda of the root syllable (which is in agreement with native speakers' intuitions), this suggests that syllable weight has a large influence on High tone placement in this group of nouns.

The effect of ROOT VOWEL LENGTH confirms this: having a long root vowel makes it more likely for the noun to have High tone on the root syllable ($p < 0.0001$).

It is not unusual for heavy syllables to attract tone or stress – weight sensitive prominence is a common thing in the worlds' languages (Gordon, 1999). However, the observation of this pattern is at odds with the previously mentioned claims by Zec (1999), that in Neoštokavian High tone avoids being associated with a bimoraic syllable, and that codas are not moraic in Neoštokavian.[11]

Another result that can be interpreted as a weight-related effect is that of POSTVOCALIC CONSONANT. The model predicts that having a voiceless obstruent following the root vowel makes it significantly less likely for the High tone to be located on the root syllable, compared to a voiced obstruent ($p < 0.001$). Since it is known that voiced obstruents cause lengthening of the preceding vowel (Lehiste, 1976), this effect could also be attributed to the tendency of heavy syllables in these nouns to attract High tone.

An alternative account of this effect has also been explored. Namely, an interesting comparison to make is one between the observed effect of the type of consonant on the distribution of High tone in Neoštokavian and the known influence of the type of consonant on tone in the accounts of tonogenesis (eg. Haudricourt (1954); Hombert (1978); Hyman (1978)), which connects the emergence of tones with the type of the prevocalic consonant. It is generally agreed that voiceless consonants have a pitch-raising effect, while voiced consonants have a pitch-lowering effect on the following vowel. The results of the model suggest that such an effect might also be present in tone placement in Neoštokavian. Namely, the predictor POSTVOCALIC CONSONANT refers to the postvocalic root consonant, which becomes the onset of the following syllable in the inflected form of the noun. The model predicts that the tone is

[11] Zec does not deal with nouns discussed in this paper, and my preliminary findings indicate that monosyllabic feminine roots do in fact behave as Zec predicts. This means that we may have to consider the existence of co-phonologies for Neoštokavian pitch accents, and not try to offer an analysis that will account for the entire system.

more likely to be on the suffix if its onset is voiceless, than if it is voiced, which could mean that if the vowel already has intrinsically higher pitch, due to the effect of a preceding voiceless consonant, it is more probable that the tone will be drawn to it.

To test this hypothesis, the onset of the root syllable was also coded for the quality of the consonant, but it had no effect in the model. Since there is no reason to believe that a phonetic effect would be present only in the second syllable, and not in the first, it is more likely that the consonant following the root vowel effects the vowel that precedes it, rather than the vowel that follows it.

The effects of postvocalic consonant quality and root vowel length on the placement of High tone are both mediated by animacy. These interactions are discussed in the next section.

3.2. The effects of animacy

The three-way interaction between CASE, ROOT VOWEL LENGTH, and ANIMACY, illustrated in Figure 1,[12] offers more insight into the interplay of factors that influence the distribution of nouns between the three accentual paradigms.

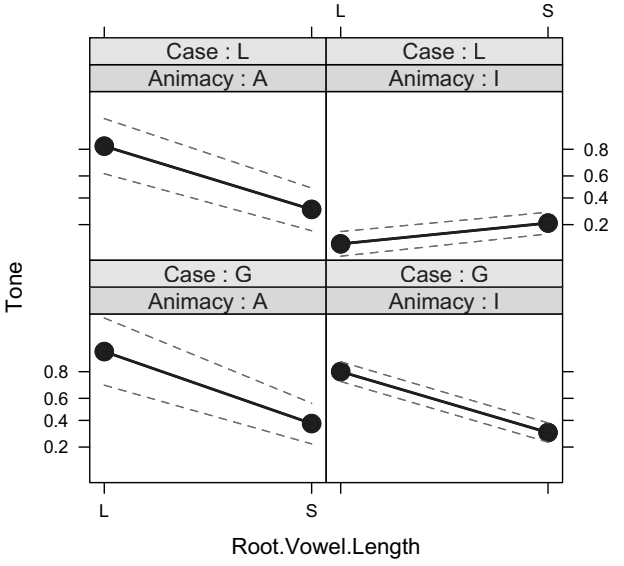

Figure 1: Three-way interaction between ROOT VOWEL LENGTH, ANIMACY and CASE.

The plot shows that animate nouns with long root vowels have greater likelihood of having High tone on the root syllable, compared to animate nouns with short root vowels. In inanimate nouns, however, the effect of syllable weight is not uniform across inflections. Namely, inanimate nouns with a long root vowel have a greater likelihood of having High tone on the root in the genitive case, but not in the locative, compared to the ones with a short root vowel.

This pattern corresponds to the distinction between the first and the third accentual paradigm. The model has revealed that it is nouns with long root vowels that are affected by their animacy status, while nouns with short root vowels show no such effect. Nouns with long root vowels are distributed between the first accentual paradigm (*baritone*), in which the tone is on the root syllable in all inflections, and the third accentual paradigm (*mobile*), where the tone is on the root syllable in some inflections, and on the affix in others, in such a way that animate nouns with long root vowels are more probable to fall into the former, and inanimate nouns with long root vowels into the latter group. The question of which factors influenced the historical migration of nouns with long vowels from the mobile to the baritone paradigm can now be answered – it is the interaction of syllable weight and animacy.

[12]The numbers on the y-axes are expressing the probability of TONE equaling 1 (i.e., being on the root). They are represented on a logarithmic scale, which is why the distances between two numbers that are linearly equally apart are not the same.

Another mediating effect of animacy is observed in its interaction with POSTVOCALIC CONSONANT. As it was already noted, the model predicts that having a voiced obstruent following the root vowel significantly increases the probability of the tone being located on the root syllable, compared to when the postvocalic consonant is a voiceless obstruent or a sonorant.

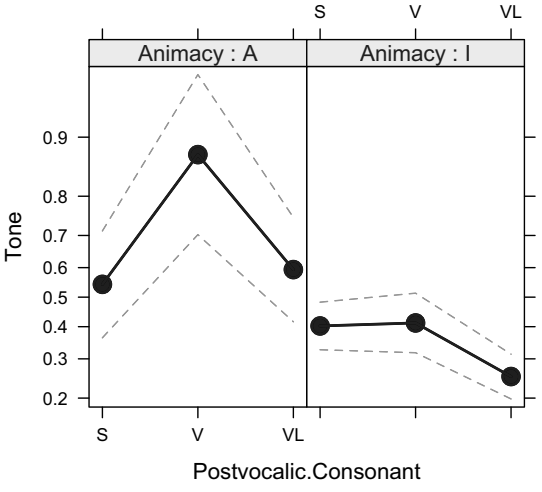

Figure 2: Interaction between ANIMACY and POSTVOCALIC CONSONANT.

The effect of the quality of the root postvocalic consonant has been attributed to the lengthening effect of the voiced obstruent on the preceding vowel, resulting in higher probability for the tone to be associated with that vowel. However, this appears to influence only animate nouns (regardless of the length of the vowel), as Figure 2 illustrates.

At the moment, only a speculative explanation can be offered. Namely, it seems that there is a tendency to associate heavy syllables with animate nouns. On the other hand, we have seen that there are many inanimate nouns with long vowels, residing in the mobile paradigm. The mobile paradigm, however, does not have consistent accent throughout the inflections, which in turn restricts the lengthening effect of voiced obstruents to nouns in the baritone paradigm, where the location of High tone does not change. This interaction shows that even purely phonetic phenomena are not necessarily equally influential across the board, and moreover, that they can be mediated by non-phonetic or non-phonological factors.

4. Conclusions and further research

There are several important results of the logistic regression model presented in this paper. First of all, it shows that syllable weight plays a big role in determining the location of High tone in monosyllabic masculine nouns. Contrary to Zec's claims, having a long vowel makes the root generally more likely to have tone, and having a coda always causes the tone to be located on the root. The voicing of the postvocalic consonant can also be interpreted to influence syllable weight, since having a voiced obstruent following the root vowel significantly increases the probability that the High tone will be located on the root.

Another strong effect is that of ANIMACY, which provides information about the distribution of roots between the three accentual paradigms. Inanimate nouns are generally less likely to have tone on the root, or, in other words, they are less likely to belong to the baritone paradigm. This is, however, also dependent on the length of the root vowel – animate nouns with long vowels tend to exhibit the baritone pattern, while inanimate nouns with long vowels tend to have the mobile pattern (they are more likely to have High tone on the root than nouns with short vowels in the genitive, but less likely to do so in the locative). What is interesting about animacy, is that its effect of dividing the nouns between the baritone and the mobile paradigm is restricted to roots with long vowels; inanimate nouns with short vowels

are overall more likely to have tone on the root. And finally, the interaction of ANIMACY and FINAL CONSONANT suggests that even purely phonetic phenomena, like phonetic length, are not necessarily equally influential across the board, and can be restricted to specific categories.

The model presented here shows that the location of High tone (and thus the type of pitch accent) is greatly influenced by various factors of phonetic, phonological, and semantic provenance. Such effects are difficult to capture and describe in traditional frameworks. Statistical models offer tools that can handle these types of data, and give valuable insight into gradient and synergistic effects of factors. The results presented in this paper are interesting not only synchronically, but also from a diachronic point of view, as they reveal the driving force behind the migration of nouns from one paradigm to another (as is the case with animate nouns that have a long root vowel).

Further research will focus on extending the analysis to more forms, in order to establish whether the factors that significantly influence the location of High tone in monosyllabic masculine roots also do so in other parts of the lexicon. Preliminary results from feminine and neuter nouns (also derived from monosyllabic roots) suggest that not all of the same factors are (equally) significant. This implies that looking for a unified analysis of Neoštokavian pitch accents might not be the optimal approach, and that the existence of sub-phonologies may be an area worth investigating.

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